An Offshore Renewable Energy Environmental Research & Innovation Strategy for the UK

FINAL REPORT

CONTENTS

Acronyms

DBEIS – Department of Business, Economy Innovation and Skills

CASE – Collaborative Awards in Science and Engineering

CfD – Contracts for Difference

COAST – Coastal Ocean and Sediment Transport labs

COP – Conference of the Parties

EIA - Environmental Impact Assessment

EPSRC – Engineering and Physical Sciences Research Council

ERDF – European Regional Development Fund

GHG – Green House Gas

INSITE – INfluence of man-made Structures on the Ecosystem

JIP – Joint Industry Programme

MASTS – Marine Alliance of Science and Technology for Scotland

MEW – Marine Energy Wales

MMO – Marine Management Organisation

MMS – Marine Science Scotland

NERC – Natural Environment Research Council

NER – New Entrants Reserve

O&G – Oil and Gas

OEE - Ocean Energy Europe

ORE – Offshore Renewable Energy

ORJIP – Offshore Renewables Joint Industry Programme

OWIC – Offshore Wind Industry Council

PRIMaRE – Peninsular Research Institute for Marine Renewable Energy RC – Research Council

R&I – Research and Innovation

SCOTMER – Scottish Marine Environmental Research

SEA – Strategic Environmental Research

SEACAMS – ERDF programme for renewables research in Wales

SNH – Scottish Natural Heritage

SPoRRAN – Scottish Offshore Renewables Research Network

TCE – The Crown Estate

UKERC – UK Energy Research Centre

1.0 Executive Summary

The momentum for developing this Offshore Renewable Energy (ORE) environmental research and innovation (R&I) strategy emerged from a workshop in February 2017, when leading representatives of the environmental research community had effectively reached an impasse regarding their attempts to motivate for significant and adequate levels of funding to de-risk environmental consenting for ORE. The failure of the R3 site Navitus Bay to obtain consent and consequent loss of ~£3.5bn investment to the UK economy, brought politicisation of consenting risk sharply into focus. Even without the knowledge (February 2017) of the outcome of the Judicial Reviews of the Tay and Forth Windfarm Consents, it was apparent to those attending the workshop that there was a need to characterise, quantify and communicate environmental risks more effectively to government, industry and research funders, to ensure stakeholders developed a better understanding informed by independent and robust research. Consequently a decision was made at the workshop to develop a strategic plan to enable us to motivate for renewed focus on ORE environmental R&I across all technology sectors.

However, unexpected developments over the summer of 2017, resulted in two offshore wind schemes winning contracts at unprecedented low prices of £57.50 per megawatt hour (MWh), which put them among the cheapest new sources of electricity generation in the UK, joining onshore wind and solar, with all three cheaper than new and nuclear fuelled power generation. Government and the Offshore Wind Industry Council (OWIC) are now predicting very substantial growth in offshore wind in future to 30GW by 2030. From an environmental perspective this highlights the potential for cumulative and regional scale issues for mammals and birds especially, and raises significant questions in relation to environmental carrying capacity, including cumulative effects on receptors and interactions with other maritime sectors including transboundary issues . The prospects for wave and tidal (including tidal lagoons) are currently less positive in the UK, and certainly until a credible route to market is possible for the UK developers. Nevertheless, de-risking environmental interactions with wave and tidal technologies for consenting remains a key priority for industry and academic stakeholders in facilitating progress across all these sub sectors.

This ORE environmental R&I strategy therefore provides a stock-take of existing UK scientific expertise and capabilities to support environmental R&I, documents recent deliverables and outputs from a range of research programmes and projects, and then provides a synthesis of R&I priorities from recent scoping studies and workshops. The report covers all the offshore renewable sub-sectors, with the goal of highlighting different initiatives across the UK ORE R&I landscape, providing up to date information on their forward plans, and then suggests a way forward via recommendations in the strategy action plan.

2.0 Acknowledgements

Thanks are especially due to the Marine Alliance of Science and Technology for Scotland (MASTS), Mark James and Emma Defew particularly, who have kindly acted to bring small amounts of funding together from Scottish Natural Heritage (SNH) and Marine Scotland Science (MSS) in order to allow this project to be progressed and completed. Thanks are also due to all those who have contributed to this report by providing updates and useful perspectives and intelligence. However, their

continuing input to development of a future new collaborative environmental R&I programme with multiple organisations across industry, academia and government will be even more appreciated.

3.0 Background and context for strategy development

3.1 Introduction

The principal aim of developing this environmental R&I strategy for UK ORE, is to set out the high level environmental R&I priorities for the next five to ten years, together with measures for coordinating activity across the various funding organisations and key stakeholder interests, to ensure that the general direction of travel is towards developing a sustainable ORE industry. The strategy will make recommendations for improving communications with new funding programmes and between stakeholder groups, and for pro-actively developing a new strategic collaborative environmental R&I programme involving multiple partners, in order to support maintenance of targets for renewable electricity generation out to 2020 and beyond.

The strategy covers offshore wind (fixed and floating), wave and tidal (stream and range) energy and is focussed on drawing together all the recent and existing initiatives into a comprehensive strategy, and will illustrate how different initiatives complement one another. It is predicated on maximising the use of existing structures and processes (ie. Ocean Energy ORJIP (Offshore Renewables Joint Industry Programme), the Offshore Wind ORJIP, MEW (Marine Energy Wales), SPORRAN (Scottish Offshore Renewables Research Framework, now ScotMER – Scottish Marine Environmental Research), PRIMaRE (Peninsular Research Institute for Marine Renewable Energy) and using information sources such as outputs from recent workshops (eg. The ORE Supergen Hub workshops, Oct/Nov 2017). Recommendations for finalising and implementing the strategy are set out in the final section of this document.

3.2 Policy context

International

It is only recently that the policies for international, European and UK action to transform the energy system whist addressing climate change have become more closely aligned. **The World Energy Council** has recently published (Nov 2017) an *updated version of **'The Energy Trilemma'*** series based on worldwide consultation with policy makers and industry. The global energy sector is undergoing very rapid transformation facilitated by three trends impacting supply and demand – namely decarbonisation, digitalisation and decentralisation. This is against a background of likely doubling of demand for energy by 2060, and thus presents unprecedented challenges and opportunities for policy makers. The key findings of the 2017 report indicate that distributed energy resources are becoming more important in the global system, with improved efficiency and reduced technology costs accelerating this trend. In many countries, regulatory frameworks are struggling to catch up with new technology options and shifting energy users' demands. Energy storage, including batteries, is becoming a key element of supporting grid efficiency, stability and flexibility. Utility scale deployments are expected to increase significantly over the next 5 to 10 years, but without dynamic policy, this growth could stall. Increasing energy access (equity) through distributed energy is the current main driver, but energy security and environmental sustainability at local to global scales are growing in importance.

Meanwhile, international efforts within the ***United Nations Framework Convention on Climate Change (UNFCCC)*** to address climate change through greenhouse gas emissions (GHG) mitigation, adaptation and finance culminated in ***'The Paris Climate Agreement (2015)*** starting in the year 2020. The language of the agreement was negotiated by representatives of 196 parties at the 21st

Conference of the Parties (COP) of the UNFCCC in Paris and adopted by consensus on 12 December 2015. As of November 2017, 195 UNFCCC members have signed the agreement, and 170 have become party to it. The Paris Agreement aims to respond to the global climate change threat by keeping global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. In the Paris Agreement, each country determines action plans and regularly reports its own contribution to mitigate global warming. There is no mechanism to force a country to set a specific target by a specific date, but each target should go beyond previously set targets. However, the **recent IPCC report issued from the Korea summit** (Oct 8th, 2018) is unequivocal (see https://www.ipcc.ch/pdf/session48 /pr_181008_ P48_ spm_ en.pdf) – and concludes that limiting global warming to 1.5ºC would require rapid, far reaching and unprecedented changes in all aspects of society and within 12 years. To what extent this report will impact existing policy measures in the UK and internationally is not yet clear, but the EU continues to scale up investment in the low-carbon economy, to help ensure that the EU will meet its ambitious climate targets whilst creating jobs and modernising the European economy. A number of EU-level funding programmes such as Horizon 2020, NER 300 and INTERREG, as well as national funding schemes, will continue to be used to this effect. The EU also dedicates significant funding to the development of low-carbon innovation. The European Parliament and Council have also just agreed on the creation of a new Innovation Fund to support low-carbon innovation (http://ner400.com/) in areas such as energy-intensive industry, renewable energy and energy storage over the period 2021 to 2030. The EU and Member States also provide significant financial assistance to developing countries, and together provided climate finance of €20.2 bn in 2016, an increase of more than 10% from 2015. However, it has proved difficult to track exactly how these funds have been awarded and whether they are currently delivering the anticipated benefits.

The UK has played a key role in demonstrating the need for action to address climate change through its international leadership, climate diplomacy and domestic action. The passing of the **Climate Change Act** in 2008 and establishment of the independent advisory body the **Climate Change Committee,** set the UK on the path to reduce emissions by 80% of 1990 levels together with the plan to implement that goal. Five carbon budgets have been set to date covering the period 2008 to 2032 – the 4th carbon budget set in 2011 covers 2023 – 2027, and the 5th in 2016 covering the period 2028 to 2032. The UK has so far outperformed other G7 nations in de-coupling emissions from economic growth – having reduced emissions by 42% since 1990 whilst increasing GDP by two – thirds, mainly as a result of closing coal fired power stations.

UK including devolved administrations

Further action is now needed as we approach the 4th Carbon budget period and the recent publication of ***'The Clean Growth Strategy : leading the way to a low carbon future'*** published by the **Dept for Business Energy and Industrial Strategy (DBEIS)** (Oct 2017) sets out the UK government strategy across all sectors of business. Clean growth means growing the UK national income whilst cutting greenhouse emissions and providing an affordable energy supply for businesses and consumers. New technology development is essential to enable us to meet our UK and global climate change objectives, but is also a major contributor towards the innovation, jobs and growth agenda. The UK has the know-how, ability and the ambition to lead the world in developing the technologies required to tackle climate change, and consequently is now progressing low carbon technologies along R&I development pathways to identify the technologies which are the most cost effective, have minimal or no environmental impact and as little risk and uncertainty associated with deployment as possible.

The UK strategy sets out a comprehensive set of proposals and policies that aim to accelerate the pace of 'clean growth' in finance, buildings, transport and energy efficiency. The main elements relevant to offshore renewable energy, however, are covered by the need for 'clean smart flexible power' and are as follows :

- Improving the route to market for renewable technologies such as offshore wind (CfD auctions – pot 2 planned for March 2019, Sector deal – 10GW of new capacity to be developed), and
- Innovation investment of £900m - to include smart systems for grid control, energy storage, advanced demand response technologies, blade technology and advanced foundations.

There is no mention of the potential of tidal (stream or range) or wave energy to contribute to the current strategy and the linkages between the different sectors are not adequately explored with major gaps / missed opportunities apparent in the strategy (see UKERC Review of Energy Policy, Nov 2017). For example, demand for electricity from electric vehicles is expected to increase exponentially in the next five years – and the knock on effects for electricity demand and ORE development have not been considered. Similarly, since we are concerned with the marine system, there is no reference to the O&G decommissioning and policy measures to align this to ORE development. Nevertheless, it is apparent that businesses are actively seeking synergies between offshore renewable and O&G decommissioning (eg. EEEGR (East of England Energy Group) synergies working group) and have already adapted to optimising vessel movements for servicing offshore renewables where O&G is decommissioning. The research community is also attempting to adapt and expand research conducted under the INSITE (Impact of maN made Structures In The Ecosystem) programme to offshore renewable structures.

Devolved administrations

The devolved administrations have additional provisions which potentially impact development of ORE and illustrate their different approaches. In Scotland the **Scottish Energy Strategy**, published in December 2017, and the first of its kind, sets out the Scottish Government's vision for the future energy system in Scotland. The Strategy describes the ways in which the Scottish Government will strengthen the development of local energy, protect and empower consumers, and support Scotland's climate change ambitions while tackling poor energy provision.

The vision is guided by three core principles:

- **A whole-system view** – broadening the focus of the Scottish Government's energy policy to include heat and transport, alongside electricity and energy efficiency – creating an integrated approach which recognises the effect that each element of the energy system has on the others.
- **An inclusive energy transition** – recognising that the transition to a low carbon economy over the coming decades must happen in a way that tackles inequality and poverty, and promotes a fair and inclusive jobs market.
- **A smarter local energy model** – enabling a smarter, more coordinated, approach to planning and meeting distinct local energy needs that will link with developments at the national scale.

Scotland's renewable energy targets at present are as follows :

- 100% electricity demand equivalent from renewables by 2020
- 11% heat demand from renewables by 2020
- At least 30% overall energy demand from renewables by 2020
- 500 MW community and locally-owned renewable energy by 2020

It is recognised that these targets are very ambitious – but probably achievable, especially now that aspects such as energy efficiency have been devolved.

In Wales, a rather different approach has been adopted with **The Well-being of Future Generations (Wales) Act 2015** requiring public bodies in Wales to think about the long-term impact of their decisions, to work better with people, communities and each other, and to prevent persistent problems such as poverty, health inequalities and climate change. The Act is unique to Wales and attracts interest from countries across the world as it offers a huge opportunity to make a long-

lasting, positive change to current and future generations. In order to make sure all are working towards the same purpose, the Act puts in place seven well-being goals : a prosperous Wales, a resilient Wales, a healthier Wales, a Wales of cohesive communities, a more equal Wales, a globally responsible Wales and a Wales of vibrant culture and Welsh language. The Act makes it clear that all public bodies must work to achieve all of the goals, not just one or two, and it is clear that the Welsh assembly regards renewable energy development as a major force for realizing these goals. Nevertheless, it is unlikely that the Welsh Government will settle on a final energy policy position until the outcome of the BREXIT negotiations is known.

Environmental policy and regulations

The main drivers for environmental R&I in the past have arisen from the environmental policy and legal landscape – and the need for all parties involved, but especially regulators and their advisors to understand the impact of new technologies and ensure compliance with current measures.

UK environmental policy has been significantly impacted by membership of the EU, with both the Natura 2000 network and Habitats Directive having now been in place for nearly 20 years, and thus the period during which deployment of offshore renewable energy projects has occurred in UK waters. Much of the R&I commissioned over this period has been directed at development of new technologies and tools for evidence gathering, and has frequently focussed on the need to provide better predictive models for EIA and improved methods for data capture, analysis and curation.

However, the UK policy landscape is at present characterised by significant uncertainty and the concern that leaving the EU will result in weakening of current measures. Recent changes include the European Parliament adopting a revised version of the EIA (Environmental Impact Assessment) directive (2014/52/EU) in 2014, which was transposed by the UK into legislation on 16 May 2017. The UK has taken the view that changes should be kept to a minimum, as the existing approach to EIA is understood by developers, local planning authorities and others involved in the procedures. In the event, this revision appears to have failed to bring about some of the changes needed in offshore EIA practice.

The Conservation of Offshore Marine Habitats and Species Regulations 2017 fulfil the UK's duty to comply with European law beyond inshore waters and ensure that activities regulated by the UK that have an effect on important species and habitats in the offshore marine environment can be managed. These regulations transpose into national law Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (Habitats Directive), and elements of Council Directive 2009/147/EC on the conservation of wild birds (Wild Birds Directive) in the UK offshore area. The 2017 Regulations introduce amendments which transfer responsibility for European nature conservation in the Welsh offshore region to Welsh Ministers, thus giving them similar powers to those currently exercised by Scottish Ministers in Scottish offshore waters. They came into force on 30th November, 2017.

The main relatively new policy development underway in the UK is the development of marine plans – with consultation on the Draft Welsh National Marine Plan expected to deliver a statement this Autumn (2018) with some (but not all) adopted in English waters, and development well advanced in Scottish waters. In the case of Scotland a sectoral (offshore renewable energy) interactive plan also exists to assist development and decision making (http://www.gov.scot/ Topics/ marine/ seamanagement/national) alongside other measures noted above.

3.3 Current status of ORE sub sectors

The ORE sub sectors are all at very different stages of development with fixed offshore wind expanding fast having achieved the challenge of cost reduction three years earlier than expected (see Cost Reduction Monitoring programme (CRMP), ORE Catapult 2017) and very significant expansion is now being planned. Although UK currently has 7GW of offshore wind deployed, a similar amount already in planning, the Offshore Wind Industry Council (OWIC) is now predicting 30

GW of offshore wind for the UK by 2030 , to provide the electricity needed at scale to meet UK low carbon electricity demand. This scale of expansion for offshore wind raises a new set of questions for policy makers and regulators which need to be addressed in parallel with outstanding environmental R&I priorities.

Tidal (stream) energy on the other hand, has stalled through lack of viable CfD and despite important technical and environmental advances over the past couple of years, now desperately needs government to support a route to market for the leading developers. A task force from Renewable UK, Welsh and Scots governments, industry representatives and others is currently working with government to identify new mechanisms which will facilitate progress. Several wave devices are currently being tested at scale in the COAST labs, whereas single device demos continuing in Hawaii and Wales with Wavebob and Wello likely to be the first devices to be deployed at array scale.

With several scale demonstration projects underway and the first array deployed by Hywind off the East coast of Scotland, floating wind is moving ahead steadily in the UK. The Carbon Trust - managed Joint Industry Programme (JIP) (with Orsted, EDF, Innogy, Equinor, E-on and the Scottish Government) is progressing in two stages and due to complete in 2018. There are demo projects underway in Japan and Taiwan (with France / Spain cooperating). The main benefit of these different stages of development for the ORE sector is that there is the opportunity to transfer knowledge and understanding of environmental issues between sectors, whilst advancing the general levels of understanding across all stakeholder groups.

4.0 Stocktake of current and historical UK R&I capability and outputs

An interim report for this project was presented to the funders group on March 31st 2017, and consisted of information collated into a series of appendices to provide the basis of developing the new strategy. These appendices summarised the principal UK academic R&I providers supporting offshore renewable development (Appendices 1&2), the main large collaborative projects funded (Appendix 3), a summary of R&I projects funded by UK organisations in progress and recently updated (see Appendix 4), R&I outputs and deliverables (Appendices 5 & 6) and finally Appendix 7, showing a summary of the R&I priorities identified in successive workshops/ scoping reports right up to and including the new ORE Supergen Hub workshops Oct / Nov 2017.

Essentially, the UK science capability in academic organisations available to support R&I in offshore renewable energy research amounts to about 110 individuals– many of whom have been involved from the inception of NERC interest in the sector in 2008. Collectively they have been involved in delivering highly significant R&I to support industry and regulatory / consenting organisations, often in collaboration with specialist consultancies, and many are now looking to the period ahead to contribute further, and actively facilitate expansion in new science capabilities which may be needed in future R&I to support industry and regulators.

5.0 Strategic Priorities and Recommendations

5.1 Future funding for R&I

There is no doubt that the most pressing issue and highest strategic priority for all parties involved in environmental R&I in all sub-sectors of ORE, has been the lack of funding to support the environmental and socio-economic R&I recognised as necessary to understand the consequences of new technology deployment in the marine system. Without this investment it has been impossible to de-risk offshore wind, wave and tidal energy deployment at the optimal rate and allow industry to progress, and many fundamental questions remain unanswered (see Appendix 7).

The current R&I funding landscape is however, characterised by significant uncertainty created by both BREXIT and the consolidation of the research councils into one umbrella body - UKRI (UK Research and Innovation). The practical reality of BREXIT is that despite government rhetoric regarding environmental legislation, and likely maintenance (even strengthening of EU regulations in UK law), the current policy and regulatory context for ORE and the understanding of R&I which is still needed to meet UK and EU legislation is unlikely to change significantly in the next five years. The development of roadmaps at UK and EU level for ocean energy (ORJIP OE (http://www .orjip.org. uk/ oceanenergy/about) and Ocean Energy Europe (OEE) strategy roadmap (https://webgate .ec. europa.eu/maritimeforum/sites/maritimeforum/files/OceanEnergyForum_RoadmapOnline_Version 08Nov2016.pdf) provide clear indications of the needs and priorities going forward. However, many academics are reporting their exclusion from EU projects in development through the EU main funding routes and this despite the UK government guarantee to honour funded projects until the Article 50 deadline. Consequently we have to assume that the opportunities for R&I to continue in ORE with European funds have mostly closed down, unless the UK succeeds in brokering a new agreement for continuing collaboration. It is ironic that the UK has consistently drawn down research funds from the EU (about 16% of budget annually) which in large measure have contributed to the UK's current leading position globally in ORE R&I.

From April 1st 2018, UKRI has operated, with Sir Mark Walport as CEO, across the whole of the UK with a combined budget of more than £6 billion, and will bring together the seven Research Councils, Innovate UK and a new organisation, Research England, which will work closely with its partner organisations in the devolved administrations. The current message from EPSRC, NERC and others is that for the time being, research providers will see very little change whilst business processes are integrated across the Research Councils (RCs), but exactly how the vision of the new CEO will translate into action on the ground against the background of BREXIT, has yet to be fully revealed.

A wide variety of organisations have contributed to funding ORE environmental R&I as well as the RCs including DBEIS (formerly DECC, BIS) via the SEA programme (currently managed by Hartley Anderson, ORE Catapult, TCE, MSS, MMO, SEACAMS, FP7 / FP6 / Horizon 2020, Industry (ORJIP - Vattenfall / ORSTED / EDF and others). Other programmes directly relevant to this analysis include projects funded by Vattenfall (possibly one off) (https://corporate.vattenfall.co.uk /projects/wind-energy-projects/european-offshore-wind-deployment-centre/scientific-research/).

Consequently Table 1. below is based on 2018 updates from the relevant funding managers and characterises the current R&I funding landscape.

	TYPE OF FUNDING	STATUS
UKRI	• Newton Fund	Advance notice of calls

	• Global Challenge Research Fund (GCRF)	
EPSRC	• ORE Supergen Hub (Core & Flexi funding – environmental & cross disciplinary) • Standard grants • CDT's – EPSRC / NERC funded priority Renewable energy	Confirmed starting July 1st 2018. £9m over four years Open all year Awaiting outcome
NERC	• Follow on fund / KE calls / internships • Joint Strategic Response Contact : Lizzie Garratt (Head of Earth & Energy RP) • NERC Discovery science • Innovation programmes Contact : Lizzie Hinchcliffe	Awaiting results Open all year July 2018 / Jan 2019 closing dates Further calls planned
Innovate UK	• Open programme* • KTN workshops / engagement events • KTPs all year (*See Innovate UK Delivery plan 2017 – 2018) • Contact : David Hytch/Chris Bagley(KTN)	Due to open Feb 2018 Watching brief for appropriate themes Open all year (but being reviewed)
Offshore energy SEA	• Contact John Hartley	Rolling programme on needs basis
SEACAMS	• Collaborative R&D with industry • Contact : Nicole Esteban	Open all year
ORE Catapult	• Secondments, etc. on ad hoc basis • Themed innovation challenges • Open to approach all year • Contact : Paul Ellsmore	Check website for opportunities (eg. Black backed gull tagging technology, May 2017)
The Crown estate	• New programme in development associated with the sector deal • Contact: Ed Salter	Offshore wind research coordinating framework published July 2018
Marine Scotland Science	• New programme (ScotMER) in development based on SPoRRAN evidence maps • Contact : Janelle Braithwaite	Workshop with developers (July 2018) final versions imminent
MMO	• See Evidence Strategy 2015 – 2020 and supporting docs • Contact : Adam Cook	New projects commissioned Jan 2018

UKERC	• Whole Systems Networking Fund ~ £1.5m – awarded autumn 2017 • Workshops to scope topics for Flexifund – first call sept 2018 • Contacts: Jim Watson / William Burns (WSNF)	WSNF - Final call outcomes known July 2018
ORJIP	• Current projects close to completion – new programme in development • Contact : Eloise Burnett	Update due autumn 2018
INSITE	• Foundation phase complete – new programme in development potentially with NERC input • Contacts: Richard Heard / Lizzie Hinchcliff	Awaiting update from NERC / announcement

With fixed offshore wind now commercialised to the point that the most recent auctions have achieved £57.50/MWh, it is unacceptable that consenting risk remains very high for developers in relation to some well known key issues. The costly judicial reviews at Forth and Tay windfarms, with potential lost investment to the UK economy being a recent example of the further impact of underfunded environmental R&I. This situation was entirely avoidable and despite the fact that these research priorities were first identified in 2008, and are well known in the UK environmental science community. Given the aspiration for 30GW of offshore wind ultimately, new momentum is now urgently needed going forward. Consequently the recommendations below are focussed on how to address this strategic priority as well as provide information to influence government policy with respect to tidal and wave energy development.

Recommendation 1 : Develop a business case with potential R&I partners for a strategic collaborative programme of R&I suitable for NERC investment via the Joint Strategic Response route. Discussions are already underway with Scottish Government and the Carbon Trust to move this forward based on R&I needed to underpin understanding of high risk consenting issues at the scale of regional seas. This investment is urgently needed to avoid the economic consequences of lack of understanding of environmental issues against background of projected offshore wind expansion in UK waters.

Recommendation 2 : Develop projects to target the Flexi fund in the ORE Supergen programme which address the wider environmental and socio-economic benefits of ORE beyond delivery of jobs and low carbon electricity. Co funding from NERC should be sought for these projects, which are urgently needed to influence government policy at a time when the consequences of mass expansion of offshore wind are not well understood and tidal energy developers have no route to market with international competitors moving to lead this sector.

5.2 Research leadership and coordination

Given the challenge of transforming the UK energy system, and the ambition of UK government and the Offshore Wind Industry Council (OWIC), it is essential that there is a clear vision of R&I priorities and that a collaborative approach to securing strategic focus across all key stakeholder groups is maintained over the next five years at least. With respect to wave and tidal energy, the role of the ORJIP OE– (funded jointly by WG / NRW / CES / MSS / SNH and TCE with the secretariat function

provided jointly by Aquatera, MarineSpace Ltd and EMEC) has been central since 2015 in reflecting the consensus regarding priorities, and consequently the ORE Supergen Hub will need to maintain a close relationship with the OE ORJIP team. Regular updates of the 'Forward look' by the OE ORJIP to take account of R&I priorities to facilitate consenting and any new R&I commissioned, remain a key element of reducing gaps and overlaps in the UK R&I landscape. The OE ORJIP has also collaborated with the IEA OES Annex IV team at Pacific North-west National Labs (PNNL) and the deployment of US DoE funds for key workshops / meetings and updating via position papers – have all contributed to ensuring that the key stakeholders are on the same wave length with regard to consenting issues and actually getting devices in the water. Similarly the Offshore Wind, Offshore Renewable Joint Industry Project (ORJIP OW) was set up in 2012 by the UK Department for Business, Energy & Industrial Strategy, BEIS (then DECC), The Crown Estate, Marine Scotland and 16 offshore wind developers. The objective of ORJIP OW is to reduce the consenting risk for offshore wind farm developments by funding research projects to better inform consenting authorities on the true environmental risk of offshore wind. The first tranche of ORJIP OW projects are close to reporting and following a workshop with developers, SNCAs and regulators a new programme is now in development.

MASTS – MREF – (Scotland), MEW – (strategy and working group meetings – Wales) and PRIMaRE – SW universities and other key stakeholders have all also performed important coordinating functions – despite very limited funds as in the case of MASTS. MEW is funded (via Wales Government) for a further 18 months but there is no guarantee of further funding after that. PRiMaRE however, has recently been awarded networking funds, which will improve the level of coordination in the SW and more widely in the UK (including South Wales and the East coast of the UK via the East of England Energy Group - EEEGR) and interaction with potential international partners. Although Marine Science Scotland has performed the role of UK hub for knowledge of R&I needs (Ian Davies) there has been noticeable drift in strategic focus elsewhere in the last two years as Wales and the SW have become less well integrated into – (with Northern Ireland almost entirely excluded from) the UK ORE landscape. The consequences are that some of the R&I funded outside Scotland has replicated unnecessarily work in progress and / or completed in Scotland. This is particularly unfortunate given the sparse funds available for R&I and points to the need for better communication and joining up of the regional communities.

The new ORE Supergen Hub potentially provides a highly significant vehicle for centralising research leadership and coordination across the UK landscape. With Beth Scott as Co director and an advisory board encompassing multiple stakeholder interests, the ORE Hub will potentially provide important research leadership, coordination, communication and enabling services for the UK ORE community as a whole.

Recommendation 1: encourage academics and other research providers to sign up, engage then communicate with the ORE Supergen Hub either directly or via the regional academia – industry coordinating groups (MEW, MASTS, PRIMaRE), especially regarding recently funded R&I, publications and PhD appointments, to avoid gaps and overlaps in the UK R&I landscape. Facilitation of relationship building and information exchange between the regional hubs will also promote understanding of developing successful approaches to targeting funding and more streamlined / effective processes for delivering impact.

Recommendation 2: ORE Supergen Hub coordination role would be facilitated by maintaining an active R&I project development pipeline report so that all parties are able to see what R&I needs to be funded and what funding calls should be targeted. This is already underway through ScotMER – but needs to be UK wide.

Recommendation 3 : Present this environmental R&I strategy to ORE Hub Co-director group to facilitate building of understanding across the key hub disciplines and development of the cross disciplinary R&I.

5.3 Strategic relationships with funding bodies

The UK has been at the epicentre of developing European and international relationships with funding bodies, to advance ORE from every R&I perspective, and as a result of representation on the appropriate councils / industry associations and advisory groups (UK, EU and international) has ensured that there have been measures in place to input directly into scoping / activities upstream of designing funding calls. In some instances however, these advisory messages do not appear to be reaching their intended destination and more effort needs to be targeted at this 'upstream' activity.

The new ORE Supergen Hub will provide important intelligence from across the R&I funding landscape with inbuilt measures for regular meetings with key strategically important organisations such as DBEIS, The Crown Estate, The Carbon Trust, the RC's, OWIC and the OREC to ensure funding initiatives are appropriately aligned and targeted. Given the past uncertainty about the OREC role / interest in environmental R&I specifically, it is appropriate to provide further detail regarding the OREC interests and role in facilitating environmental R&I alongside other potential routes to delivering R&I.

Although the ORE Catapult (OREC) does not have an environment-specific strategy, it currently aligns its activities around six 'Knowledge Areas' – Blades, Drivetrains, Electrical Infrastructure, Operations & Maintenance, Foundations & Substructures, and Wave & Tidal, with activities focused around its Test and Demonstration Assets relevant to each 'Knowledge Area'. From an environment point of view, the OREC is less concerned with Environmental Data per se, and more with the technologies used to gather them, and with the processes used to turn such data into useable information. Since the offshore wind industry now has a fairly detailed understanding of its cost base over the full lifecycle from planning through to decommissioning, innovators (supply chain and academic) can have a clear view of where new technologies, and developments of existing technologies, can reduce costs. Crucially, it is also possible to put *value* on these cost reductions, so that the investment required to develop these technologies has a credible path to a return. In addition, the industry itself generates significant cash flow, and can divert some of this into funding for projects that can make quick improvements to future cash flow.

The OREC works both proactively and reactively, and in both cases, uses its assets to commission strategic consultancy reports and networking capabilities to convene consortia to bring together funding to develop innovations, and can use its test and demonstration assets to both verify and validate innovative technologies and approaches (see for eg https://ore.catapult.org.uk/app/uploads/2017/12/An-Introduction-to-Risk-in-Floating-Wind-_-Roberts-Proskovics-_-AP-0014.pdf)

The environment is perceived as a key issue for wave and tidal energy deployment - however, to date, the technological, grid and financial barriers are proving much more challenging than the needs of consenting and licensing. The OREC is therefore interested in technology developments that help to reduce these barriers. In particular, it has a strong focus on technologies that remove or reduce human intervention. These would include autonomous and remotely-operated vessels, both for surface and underwater operation, and the sensors and application packages that they carry.

Since the wave & tidal industry has almost no current ability to generate cashflow, funding to support these innovations must be sought from elsewhere. OREC can again use its networks to convene the right consortia to bid for the necessary funding. The OREC and ORE Supergen Hub plan

to work closely together and to maintain reciprocal membership on their respective research advisory groups to ensure joined up working.

The new team of Co -directors in the ORE Supergen Hub between them sit on many influential advisory and steering groups across the UK and internationally, with Henry Jeffry as chair of the IEA - OES as well as the European Energy Research Alliance, and Feargal Brennan sitting on both the Wind and Marine Supergen boards as well as the ORE Catapult and European Offshore Wind Association board. It is clear that there are some essential lines of communication which must be maintained in the years ahead to ensure that the industry associations and Europe and UK continue to influence government and the research councils.

Recommendation 1: Given the uncertainty and consequences of BREXIT it is essential that even if the UK is not able to draw down EU R&I funds in future, that understanding of the current R&I priorities enable the UK to actively influence decisions in Brussels regarding funding opportunities.

Recommendation 2: The membership of key strategic UK boards and advisory groups needs to be mapped and a watching brief maintained regarding continuation of UK influence through international coordinating bodies – particularly IEA - OES, Ocean Energy Europe, ICES etc. Development of joint R&I programmes should be facilitated where possible. Cf. China (EPSRC), Canada (Innovate UK).

Recommendation 3 : Encourage re instatement of cross RC offshore renewable energy liaison group – NERC / Innovate / EPSRC – to discuss the range of funding mechanisms and future plans for calls – this helps to ensure funding managers are up to date with R&I landscape.

Recommendation 4 : Ensure that RC review panels are briefed on newly awarded R&I funds / projects in development – this avoids duplication and omissions, and helps to ensure maintenance of strategic focus across the ORE landscape.

Recommendation 5 : Maintain close liaison with government depts., (esp BEIS / FCO / DEFRA) industry, regulators, The Crown Estate, NC advisors, Marine Science Scotland, etc. to understand forward plans regarding research priorities and potential for collaborative funding.

5.4 Collaborative R&I between industry, academia and government

It is generally agreed that collaborative R&I between academia, industry and government is the most efficient model for developing understanding of common problems, especially those which affect all sector stakeholders in the early development phases of a new industry. The environmental R&I community has been proactively lobbying for a government (RC) funded R&I programme to complement MSS / MMO and NRW investments for several years to focus on 'bottoming out' the next generation of key priority ORE consenting issues. Such a programme would deliver objective and trusted science and would do a great deal to de risk ORE deployment as well as deliver very substantial benefit in avoided costs, resources and effort (compare the approaches of Denmark (https://ens.dk/en/our-responsibilities/wind-power/offshore-procedures-permits) with significant de risking of sites ahead of leasing, and the Netherlands and Belgium with well founded post deployment monitoring programmes). Collaborating on one large programme with agreed objectives is significantly more cost effective and efficient than multiple small projects and avoids internal competition in specialised science areas, where there is only very rarely more than one academic capable of delivering the science. Such a programme is still needed – quite apart from the consenting issues, it is inappropriate and unacceptable for UK stakeholders to have to consult long term programmes funded in Denmark, Belgium and the Netherlands to facilitate our understanding.

In the past coordinating fora such as ORELG (with joint MS / MMO chairs) have maintained focus on the high priority issues and acted as a means to share information. MASTS / MEW and PRIMaRE have all facilitated communication of progress and dissemination of up to date understanding in industry, academic and government sectors and have facilitated networking, relationship development, intelligence sharing, and data exchange which has formed the basis of collaborative R&I proposals involving academics, industry and regulators. Feedback from ORE Supergen workshops left us in no doubt that industry wanted some simple measures put in place to help them identify potential collaborators – such as an on line directory detailing key capabilities / specialisms of academics and their contact details.

Although the current cohort of academics, industry and regulators involved in environmental R&I across the UK know one another very well, there is a need to bring in new talent and capabilities from other sectors to the existing pool to deliver the next phase of ORE R&I. This requires careful thought, as many of the challenges ahead are cross disciplinary and although some attempts have been made to facilitate relationship building across disciplines this has not always been altogether successful. However, the experience of UKERC should be utilised and integrated where possible into the ORE industry, academic and stakeholder community, http://www.ukerc.ac.uk/ publications/ ukerc-interdisciplinary-review-research-report.html as the evidence suggests that scientists rise to the challenge when faced with a new cross disciplinary call – providing they are appropriately scoped. However, all parties can benefit from time to discuss and get to know potential partners and really understand their background and specialisms.

Successful outcomes from collaboration depend critically on all being party to the most up to date knowledge – and the added value which flows from engaging with bodies such as the OE ORJIP and its collaboration with the US DoE Annex IV team at PNNL. The live 'rolling' programme of knowledge collation and rapid dissemination through the Annex IV team, assisted by international webinars and their enduring profile at international meetings, has facilitated consensus building in relation to the most challenging issues for tidal energy particularly. Increasingly it is accepted that there is a need to 'retire' risks relating to consenting and planning, as adequate understanding is achieved and so the dynamic nature of the knowledge pipeline is useful at both ends ! However it is clear that this intelligence is not always reaching some industry and academics, and for this reason alone we need to encourage them all to interact with the ORE Hub, and to avoid proposals being developed which use outdated information / understanding.

Recommendation 1: Identify possible route to funding an academia / industry / government collaborative programme of both 'blue skies' and applied R&I to address the key environmental issues for ORE going forward, against the background of substantial projected increase in deployed capacity, upscaling of new technology to 10-15MW / unit and associated spatial implications. This could be the NERC JSR mentioned above.

Recommendation 2 : Improve networking / relationship development opportunities in MASTS/ MEW and PRIMaRE (eg. small round table discussions on specific issues)/ quarterly meetings to connect key science capabilities with industry – ie. SMEs + supply chain companies – and set up R&I directory (this was a direct plea from industry).

Recommendation 3 : Utilise annual conferences / assemblies / steering group and any other ORE SUPERGEN / MASTS/ MEW/ PRIMaRE meetings to facilitate cross disciplinary / cross sectoral interactions and discussions to identify new talent / capability /science needed from other sectors..

5.5 Communications within and beyond the UK ORE community

Despite past efforts to create a one stop shop for communication across the UK ORE stakeholder communities, the landscape has remained fragmented along national lines resulting in gaps and overlaps in R&I. For several years, the ORELG (Offshore Renewable Energy Consents and Licensing Group) jointly chaired by MMO and Marine Scotland ensured that progress north and south of the border was more or less aligned, with Wales linking into the forum when possible. ORELG regularly included invited talks from Denmark, Belgium, Netherlands etc. to share experience, which also provided feedback from regulators using models developed in the UK. The future of ORELG is under discussion as the current chairmen are retiring (Jim McKie) or have changed roles (Shaun Nicholson).

In terms of other groups focussed on sharing information and communications representing key relevant stakeholder interests, the FLOWW (Fisheries Liaison with Offshore Wind and Wet Renewables) group managed by The Crown Estate, continues to have regular meetings, with activities focussed on optimising the interactions between fisheries and offshore renewable energy. (see FLOWW Jan 2014 http://www.thecrownestate.co.uk/media/5693/ floww-best-practice-guidance-for-offshore-renewables-developments-recommendations-for-fisheries-liaison.pdf). The main value of FLOWW is in sharing experience / best practice and improving communications between the sectors - however, this group has in the past regularly flagged up gaps and overlaps in the research landscape.

Although matters have improved in Wales since the Welsh Government opted to invest in MEW and individuals with responsibility for representing 'key knowledge' centres across the Welsh landscape, this remains essentially separate from what is happening in Scotland and England. Marine Scotland Science (and Ian Davies especially) has been the epicentre of R&I for about a decade, and the proactive approach of MSS to working collaboratively across the stakeholder landscape, has meant that finding the 'coal face' of knowledge in relation to almost any particular environmental issue has been only a phone call away.

Given the simplicity now of communicating on line, there is no excuse for not being joined up – it is more a question of filtering the large volumes of information which most individuals have to process in order to function and making sure the really important messages are communicated.

As mentioned above, the situation with the main regional coordinating groups appears to have stabilised around MASTS, MEW and PRIMaRE. However, the new ORE Supergen Hub offers an opportunity to enhance this regional offer by providing a UK wide communication and engagement function. The ORE Supergen Hub proposal submitted includes an outline of the proposed communication and engagement plan which will be finalised during the first 6 months of the start of the programme. In addition to the vital task of communicating the mission and scope of the new Hub, the plan will include : mechanisms to connect external groups, mechanisms to secure buy in and steer from external industry and government, means to identify and mobilise leverage via parallel and complementary work globally, measures to facilitate uptake of research and further investment by industry and government, processes to promote achievements of the Hub and wider research network and activities to support the work of other organisations which inform the public and school children. Feedback from the ORE Supergen workshops indicated that both industry and government policy representatives wanted communication from the research community regarding research outputs to be much more accessible, and written in a form which would enable them to immediately apply the knowledge in their businesses and / or directly in the development of new collaborative research proposals. Suggestions included reviving the 'position paper' format and / or approaching RC's to include an impact summary as a formal and quite specific requirement for all funded projects when they have been completed. The research community needs to be encouraged to stop allowing this aspect of a project to fail, because all the effort in delivering a project is pointless if the outcomes are not communicated !

The ORE Hub plans to use the whole range of media – including for eg. video abstracts, to communicate its messages, and will tailor these to address the requirements of different stakeholder groups. It is envisaged that membership of the Hub advisory board will constitute an important networking / updating opportunity for the core Hub team as well as industry / government board members, and every opportunity should be used at these meetings to communicate significant project outcomes and new knowledge / information.

Recommendation 1 : The communication functions of ORE Supergen Hub need to include timely dissemination of research outputs using agreed formats such as video abstracts etc. and position papers on outcomes of key research / KE projects, providing up to date intelligence for key stakeholders whilst avoiding proposals based on out of date information.

Recommendation 2 : Environmental scientists need to be encouraged to interact more with other disciplines making the connections for others at ORE conferences, workshops and meetings. Renewable UK and other conference providers need to be approached to include a special fee for academics and especially post graduates – who invariably do not have the budget for attendance. This is a significant barrier to relationship building and dissemination of research to industry and other non academic stakeholders.

Recommendation 3 : Case studies – with good and bad outcomes - need to be written up and disseminated through both the popular media, short films, trade magazines etc. to share experience of developers / first movers / crowd funders / investors / insurers more widely, to showcase UK capability, problem solving and skills in the sector.

5.6 Summary of strategic R&I priorities

The summary of R&I priorities shown in the following table is based on appendix 7, the consolidated list of needs and priorities extracted from 12 different scoping reports over the past 3 years. The current status of each of these areas is discussed briefly below. Existing roadmaps have not been broken down into issues – but have been dropped into the summary intact **so as to emphasise where an agreed synthesis already exists.** The table below summarises the highest priority issues identified in workshops in the main categories of regulation and consenting, cost and risk reduction and whole systems R&I.

Overview of Priority R&I need / issue/ opportunity	
REGULATION and CONSENTING	
Barriers to development	Lack of understanding and robust models for predicting potential collision risk at sub sea turbines (for all receptors), and avian and bat collision risk at offshore windfarms – including floating structures at array scale
	Understanding of the scale and consequences of potential displacement of essential activities of mammals, sea birds and fish (including basking sharks, migratory fish) from large scale arrays
	Understanding impacts of tidal lagoon development* on migratory fish – including risk of collisions, multiple turbine passes, entrainment, sub lethal damage etc
Modelling and validation	Development and validation of existing IBM / PCoD models to deliver credible / agreed predictive outcomes for birds, mammals and fish
	Further development of Collision Risk Models for mammals and birds including worked and validated case studies
TECHNOLOGY DEVELOPMENT - COST AND RISK REDUCTION	
Autonomy /	Advances in application of drones, AUV / ROV / radar, tagging and remote

remote sensing and digitalisation	sensing for baseline characterisation / monitoring all receptors
	Autonomous multi sensor platforms for monitoring during / post deployment for impact monitoring / model validation integrated into energy capture devices
	Novel methods/ algorithms for rapid data capture /analysis/ curation, and storage of large data sets from remote autonomous technologies
	Marinisation / miniaturisation / dematerialisation all technologies to secure long term and sustainable systems for data capture
WHOLE SYSTEMS AND LONG TERM SUSTAINABILITY	
Whole systems – cross disciplinary integration, environmental mitigation /restoration to build resilience, valuation methods (C and £)	Future proofing electricity generation from offshore renewables whilst considering all sub sectors and potential trans-boundary interactions
	Environmental carrying capacity given long term goal to deploy 30GW by 2030 offshore wind in UK marine system – cumulative impacts at regional seas scale.
	Impact of multiple offshore renewable structures in the UK marine system – integrate understanding with O&G decommissioning, fisheries, MPAs and shipping to inform planning / management
	Investigate potential for 'designing in' benefits / resilience to wind, wave and tidal farms for ecosystem services, conservation and societal benefit
	Investigate potential for hybrid energy / flood / habitat protection schemes for restoration of threatened species / habitats and recovery of ecosystem services
	Devise methods for carbon accounting across engineering and environmental aspects of project life cycle eg. composites, recycling / re-use
	Integration of natural capital / ecosystem services valuation into whole life cycle analysis and business processes
	Stakeholder engagement with offshore energy as investors / owners / 'prosumers' to deliver benefits beyond GVA and low carbon electricity

The current state of play in MSS is that the ScotMER - (Scottish Marine Energy Research programme evidence maps have recently been finalised and these are now available on line at: https://www.gov.scot/Topics/marine/marineenergy/mre/research/maps. The ScotMER Coordination group will continue to discuss priorities across the sub groups and will hold regular workshops with developers, nature conservation advisors to obtain their views, consider priority research projects and identify suitable funding streams then re prioritise issues as research progresses.

The MMO published its Evidence strategy in 2015 for five years and has recently commissioned new R&D projects in line with this strategy (see https://www.gov.uk/government/organisations/marine-management-organisation). The current status of on - going and recently completed projects can be found at https://www.gov.uk/government/publications/evidence-and-the-marine-management-organisation-mmo/evidence-projects-register.

The Offshore Wind ORJIP managed by the Carbon Trust, is in the process of developing the next stage of the programme, including identifying likely themes and management structure for the new programme going forward.. Although the work programme is in the process of being defined and appointments of staff to undertake the research are underway, the inclusion of an environmental work stream in the ORE Supergen programme has the potential to make a significant contribution to advancing our understanding of environmental issues.

Recommendation 1 : In order to facilitate UK wide consistency and coordination of research and innovation going forward it would be helpful if a UK wide coordinating / information dissemination function could be maintained (such as former ORELG). This needs to be discussed

further within the ORE Hub, given the potential for replication and omissions to appear in the R&I landscape.

Recommendation 2 : the most significant future research challenges for offshore renewables together with the shortlist of highest priority consenting risk issues could form the basis of developing a business case for a strategic collaborative R&I programme suitable for joint funding by industry, regulators and NERC (via the Joint Strategic Response route)

Recommendation 3 : the opportunity to address issues of cost and risk reduction should ideally build on the technology development needs mapping undertaken by previous NERC KE fellows. This would assist in identifying opportunities for improved success in Innovate UK Open and Energy catalyst calls as well as potential KTPs and joint projects with the ORE Catapult.

Recommendation 4 : NERC and industry funders are currently developing the next phase of the INSITE programme (INfluence of man-made Structures In The Ecosystem : 2, focussed on oil and gas), via the NERC Joint Strategic Response route. The ORE Supergen programme workshops identified key issues relevant to this programme and so need to remain closely in touch with NERC regarding possible integration of ORE into the INSITE programme..

Recommendation 5 : The ORE Supergen programme needs to maximise the opportunity to learn from UKERC regarding implementation of whole systems thinking. This has the potential to underpin a significant shift in the narrative from mitigating negative environmental impacts of ORE to 'designing in' the positive benefits such as allowing recovery / enhancing resilience of the marine system as a whole and especially protected species / habitats, integrating co located economic activity eg. recreational fishing etc.

6.0 Recommended Strategy Action plan

The following table summarises the principal recommendations with suggestions for how these should be taken forward.

TOPIC	Strategy Action Plan : Recommendations	How/Who to do it?
(1) Future funding for R&I	**1.1:** Develop a business case with potential R&I partners for a strategic collaborative programme of R&I suitable for **NERC investment via the Joint Strategic Response** route. (eg. high risk consenting issues at the scale of regional seas)	Engage and co develop a programme initially with MSS + CT (ORJIP) +TCE + Offshore Energy SEA, NERC, SNH, NRW, MMO
	1.2: Develop a series of projects to target the **Flexi fund in the ORE Supergen programme** which address the wider environmental and socio-economic benefits of ORE beyond delivery of jobs and low carbon electricity.	ORE Supergen to set up meeting with NERC and also maintain interaction with OE ORJIP, ORJIP and other key stakeholders
2) Research leadership and coordination	**2.1**: Encourage academics and other research providers to sign up, engage then communicate with the ORE Supergen Hub, ensure gaps and overlaps do not appear in the UK R&I landscape	ORE Supergen – Communications Team
	2.2: ORE Supergen Hub coordination role would be facilitated by maintaining an active R&I development pipeline report. (to complement	Discuss ORE Hub director and environment Co-director

	ScotMER, MMO, NRW evidence mapping)	
	2.3: Present environmental strategy to ORE Hub Co-director group to facilitate building of understanding of the cross disciplinary R&I	BS to ORE Co-director group
(3) Strategic relationships with funding bodies	**3.1:** Ensure where possible / enable the UK to actively influence decisions (current R&I priorities) in Brussels regarding funding.	Devolved administrations SG / WG are active – what about Westminster ?
	3.2: Map membership of key strategic UK and international boards and advisory groups and maintain a watching brief regarding continuation of UK influence	ORE Hub team to develop international engagement strategy building on existing relationships
	3.3: Encourage reinstatement of cross RC offshore renewable energy liaison group – to discuss range of funding mechanisms and future plans for calls – integrate environmental / socio economic agenda where poss at this early stage	Discuss RC managers - watching brief re new UKRI; possible agenda at Energy programme SAC.
	3.4: Maintain close liaison with government depts., industry, regulators, Crown estate, SNCAs, MSS to understand their plans for funding and specific R&I priorities	ORE Supergen Hub – communications / include key organisations in advisory board membership
	3.5: Ensure that RC review panels are briefed on newly awarded R&I funds / projects in development –avoids duplication, and ensures strategic focus is maintained.	Suggest that ORE Hub leader (or appropriate Co-director) sits on Cross RC liaison group (see 3.3)
(4) Collaborative R&I between industry, academia and government	**4.1:** Identify possible route to funding an academia / industry / government collaborative programme of R&I to address the key issues for ORE going forward, against the background of substantial projected increase in capacity and other sectoral expansion in UK footprint .	NERC JSR (or European scale) project needs to include consideration of development plans for Germany, Denmark, Netherlands, Belgium etc.
	4.2: Improve networking / relationship development opportunities in MASTS/ MEW and PRIMaRE (eg. small round table discussions on specific issues)/ quarterly meetings to connect key science capabilities with industry.	. ORE Supergen Hub – could initiate a voluntary on line directory . MASTS – can lead with funding
	4.3: Utilise annual conferences / assemblies / steering groups of ORE Supergen / MASTS/ MEW/ PRIMaRE to facilitate cross disciplinary / sectoral interactions, identify new talent /science from other sectors.	ORE Hub communications strategy to be developed in first six months
(5)Communications within and beyond the UK ORE community	**5.1** : The communication functions of ORE Supergen Hub need to include timely dissemination of research outputs using agreed formats such as video abstracts and position papers to update on key research areas	ORE Supergen – Communications team
	5.2 : Environmental scientists need to be encouraged to interact more with other disciplines making the connections for others at ORE conferences, workshops and meetings.(Esp when there is prior notice of funding call)	ORE Supergen – Communications team via MASTS/MEW/Primary, to facilitate introductions etc.

	5.3: Case studies based on PhD / PDRA / KE / IDCORE projects – good and bad - written up / disseminated through popular media, short films, trade magazines etc. to showcase UK research capability, problem solving and skills.	ORE Supergen – Communications team – lead by example - (NB : there is funding for MASTS to do this regionally)
(6) Summary of strategic R&I priorities	**6.1** : ScotMER evidence maps prioritise R&I issues in terms of high priority consenting risk – to be regularly updated and disseminated on line	Request ScotMER workshops open to other UK regulatory bodies and their advisors
	6.2 : the shortlist of highest priority consenting risk issues to form the basis of developing a business case for a strategic collaborative R&I programme suitable for joint funding by industry, regulators and NERC (via JSR route)	JSR – again – can be in 1.1 – discuss Carbon Trust possible inclusion industry and TCE in an initial meeting with NERC
	6.3 : the opportunity to address issues of cost and risk reduction should ideally build on the technology development needs mapping undertaken by previous NERC KE fellows.	Ensure environmental dimension included in all future roadmaps
	6.4 : NERC and industry currently developing a proposal for the next phase of the INSITE programme (***INfluence of man-made Structures In The Ecosystem : 2***), via NERC JSR route	Remain closely in touch with NERC re INSITE 2 – could be extended to include ORE structures
	6.5 : The ORE Supergen programme needs to maximise the opportunity to learn from UKERC regarding whole systems thinking.	Include 'Whole systems' speakers at ORE Supergen assemblies / events

ORE Environmental R&D strategy – Appendices

Appendix 1 : Centres with multi-disciplinary capabilities and five or more staff research active

ABERDEEN UNIVERSITY

Key staff directly involved in ORE R&D to date :

Prof. David Lusseau – Reader in Mammal Biology and Ecology
Dr. Tavis Potts - Senior lecturer Dept of Geography
Dr. Beth Scott - Reader - Institute of Biological and Environmental Sciences
Prof Ann-Michelle Slater – Head of Law School and Member of the Centre for Energy Law
Prof Paul Thompson – Prof. School of Biological Sciences and Director of Lighthouse Field Station, Cromarty

Prof. David Lusseau - Decision theory, conservation behaviour, environmental decision support systems, population consequences of disturbances, socio-ecology, cognitive ecology

Using qualitative models to define sustainable management for the commons in data poor conditions F Mancini, GM Coghill, D Lusseau 2017 Environmental Science & Policy 67, 52-60

Food provisioning increases the risk of injury in a long-lived marine top predator F Christiansen, KA McHugh, L Bejder, EM Siegal, D Lusseau, EB McCabe, ...2017

Royal Society Open Science 3 (12), 160560

Meta-analyses of whale-watching impact studies: comparisons of cetacean responses to disturbance V Senigaglia, F Christiansen, L Bejder, D Gendron, D Lundquist, 2016...Marine Ecology Progress Series 542, 251-263

Managing whale-watching as a non-lethal consumptive activity JES Higham, L Bejder, SJ Allen, PJ Corkeron, D Lusseau 2016 Journal of Sustainable Tourism 24 (1), 73-90

Full list of publications : http://scholar.google.co.uk/citations?sortby=pubdate&hl=en&user=_qaO7zwAAAAJ&pagesize=100&view_op=list_works

Dr. Tavis Potts - social and political dimensions of environmental governance, including marine spatial planning and coastal governance; the political economy of ecosystem services and the ecosystem approach

Burdon, D., Potts, T., Barbone, C. & Mander, L. 'The matrix revisited: A bird's-eye view of marine ecosystem service provision'. *Marine Policy*, vol 77, pp. 78-89. DOI: **[ONLINE]** DOI: 10.1016/J.MARPOL.2016.12.015

Potts, T., Pita, C., O'Higgins, T. & Mee, LD. (2016). 'Who cares? European attitudes towards marine and coastal environments'. *Marine Policy*, vol 72, 72, pp. 59-66. DOI: **[ONLINE]** DOI: 10.1016/J.MARPOL.2016.06.012

Stojanovic, T., McNae, HM., Tett, P., Potts, TW., Reis, J., Smith, HD. & Dillingham, I. (2016). 'The "social" aspect of social-ecological systems: A critique of analytical frameworks and findings from a multisite study of coastal sustainability'. *Ecology and Society*, vol 21, no. 3, 15. DOI: **[ONLINE]** DOI: 10.5751/ES-08633-210315

Potts, T., O'Higgins, T., Brennan, R., Cinnirella, S., Brandt, US., Suarez De Vivero, JL., Troost, T., Paltriguera, L. & Gunduz Hosgor, A. (2015). 'Detecting critical choke points for achieving Good Environmental Status in European seas'. *Ecology and Society*, vol 20, no. 1, 29. DOI: **[ONLINE]** DOI: 10.5751/ES-07280-200129 **[ONLINE]** AURA: POTTS_CHOKE_POINTS_2015.PDF

Full list of publications **: http://www.abdn.ac.uk/geosciences/people/profiles/tavis.potts**

Dr. Beth Scott - multi-disciplinary research using expertise in marine ecology, oceanography and fisheries sciences as well as understanding and integration of monetary and non monetary approaches to valuing ecosystem services.
Current research projects http://www.abdn.ac.uk/ibes/people/profiles/b.e.scott:

Fraser, S., Nikora, V., Williamson, BJ. & Scott, BE.(2017) 'Automatic active acoustic target detection in turbulent aquatic environments'. *Limnology and Oceanography*. DOI: **[ONLINE]** DOI: 10.1002/LOM3.10155

Wiesebron, LE., Horne, JK., Scott, BE. & Williamson, BJ. (2016). 'Comparing nekton distributions at two tidal energy sites suggests potential for generic environmental monitoring'. *International Journal of Marine Energy*, vol 16, pp. 235-249. DOI:
[ONLINE] DOI: 10.1016/J.IJOME.2016.07.004

Williamson, LD., Brookes, KL., Scott, BE., Graham, IM., Bradbury, G., Hammond, PS. & Thompson, PM. (2016). 'Echolocation detections and digital video surveys provide reliable estimates of the relative density of harbour porpoises'. *Methods in Ecology and Evolution*, vol 7, no. 7, pp. 762-769. DOI: **[ONLINE]** DOI: 10.1111/2041-210X.12538 **[ONLINE]** AURA: WILLIAMSON_ET_AL_2016_METHODS_IN_ECOLOGY_AND_EVOLUTION.PDF

Scott, BE., Webb, A., Palmer, MR., Embling, CB. & Sharples, J. (2013). 'Fine scale bio-physical oceanographic characteristics predict the foraging occurrence of contrasting seabird species; Gannet (Morus bassanus) and storm petrel (Hydrobates pelagicus)'. *Progress in Oceanography*, vol 117, pp. 118-129. DOI: **[ONLINE]** DOI: 10.1016/J.POCEAN.2013.06.011

Full list of publications : http://www.abdn.ac.uk/staffnet/profiles/b.e.scott/?publications

Ms. Ann-Michelle Slater – Head of Law School, specialist in terrestrial and marine spatial planning law with interests in interdisciplinary research.

Holt, A., Godbold, JA., White, PCL., Slater, A-M, Pereira, E. & Solan, M. (2011). 'Mismatches between legislative frameworks and benefits restrict the implementation of the Ecosystem Approach in coastal environments'. *Marine Ecology Progress Series*, vol 434, pp. 213-228. DOI: **[ONLINE]** DOI: 10.3354/MEPS09260

Slater, A-M (2005). 'Planning For Scottish Aquaculture: The Story Thus Far'. *Water Law*, vol 16, no. 4, pp. 122-130.

Full list of publications : http://www.abdn.ac.uk/law/people/profiles/a.m.slater

Prof. Paul Thompson – understanding and assessment of how natural and anthropogenic environmental variations influence the behaviour, physiology and dynamics of marine mammal and seabird populations

Edwards, EWJ., Quinn, LR. & Thompson, PM. (2016). 'State-space modelling of geolocation data reveals sex differences in the use of management areas by

breeding northern fulmars'. *Journal of Applied Ecology*, vol 53, no. 6, pp. 1880–1889. DOI: **[ONLINE]** DOI: 10.1111/1365-2664.12751 **[ONLINE]** AURA: EDWARDS_ET_AL_2016_JOURNAL_OF_APPLIED_ECOLOGY_1_.PDF

Farcas, A., Thompson, PM. & Merchant, ND. (2016). 'Underwater noise modelling for environmental impact assessment'. *Environmental impact assessment review*, vol 57, pp. 114-122. DOI: [ONLINE] DOI: 10.1016/J.EIAR.2015.11.012 [ONLINE] AURA: 1_S2.0_S0195925515300202_MAIN.PDF

Pirotta, E., Harwood, J., Thompson, PM., New, L., Cheney, B., Arso, M., Hammond, PS., Donovan, C. & Lusseau, D. (2015). 'Predicting the effects of human developments on individual dolphins to understand potential long-term population consequences'. *Proceedings of the Royal Society of London. B, Biological Sciences*, vol 282, no. 1818, 20152109. DOI: [ONLINE] DOI: 10.1098/RSPB.2015.2109

Cordes, LS. & Thompson, PM. (2015). 'Mark-resight estimates of seasonal variation in harbor seal abundance and site fidelity'. *Population Ecology*, vol 57, no. 3, pp. 467-472. DOI: [ONLINE] DOI: 10.1007/S10144-015-0496-Z

Bailey, H., Brookes, KL. & Thompson, PM. (2014). 'Assessing environmental impacts of offshore wind farms: lessons learned and recommendations for the future'. *Aquatic Biosystems*, vol 10, no. 8, pp. 1-13. DOI: **[ONLINE]** DOI: 10.1186/2046-9063-10-8

Full list of publications : https://www.abdn.ac.uk/ibes/people/profiles/lighthouse/?publications

Other key staff with relevant expertise :

Mr. John Scrimgeour – Director, Aberdeen Institute of Energy
Prof Rhona Flin – H&S offshore (Oil and gas)
Dr. David Toke – policy and energy security, community renewables
Dr. Paul Fernandez – MASTS fisheries scientist
Dr. Benjamin Williamson – KTP Associate - University of Aberdeen and Meygen Ltd
Dr. Kate Gormley - NERC Oil and Gas KE fellowship
Dr. Jacqueline Tweddle - NERC KE fellow with MMO
Prof. Vladimir Nikora - Chair in Environmental Fluid Mechanics School of Engineering

EXETER UNIVERSITY

Key staff directly involved ORE Environmental R&D :

Dr. Matthew Witt - Senior lecturer in Natural Environment
Dr. Helen Smith - Lecturer in Renewable Energy
Prof Patrick Devine – Wright - Professor in Human Geography
Prof Lars Johanning – Professor of Ocean Technology
Dr. Steve Votier - Senior Lecturer in Natural Environment
Dr. Steve Simpson - Associate Professor in Marine Biology and Global change

Prof Lars Johanning – Prof of Ocean Technology - hydrodynamic related topics for marine structures , with a focus on hydrodynamics and station keeping systems - include activities such as loading and dynamic response of mono-towers in steep and breaking waves, hydrodynamic and reliability studies on station keeping systems for offshore renewable energy devices.

Selected publications :

Flory JF, Banfield SJ, Ridge IML, Yeats B, Mackay T, Wang P, Hunter T, Johanning L, Herduin M, Foxton P. (2016) Mooring systems for marine energy converters, *OCEANS 2016 MTS/IEEE Monterey, OCE 2016*, DOI:10.1109/OCEANS.2016.7761007. [PDF]

Ning D-Z, Zhao X-L, Teng B, Johanning L. (2016) Wave diffraction from a truncated cylinder with an upper porous sidewall and an inner column, *Ocean Engineering*, volume 130, pages 471-481, DOI:10.1016/j.oceaneng.2016.11.043. [PDF]

Pillai AC, Chick J, Johanning L, Khorasanchi M, Barbouchi S. (2016) Comparison of offshore wind farm layout optimization using a genetic algorithm and a particle swarm optimizer, *Proceedings of the International Conference on Offshore Mechanics and Arctic Engineering - OMAE*, volume 6, DOI:10.1115/OMAE2016-54145.

Frost C, Findlay D, Johanning L, Macpherson E, Sayer P. (2016) Mapped economic modelling of wave energy, *2nd International Conference on Renewable Energy Ofshore*, Lisbon, 24th - 26th Oct 2016, *RENEW2016*. [PDF]

Harnois V, Thies PR, Johanning L. (2016) On Peak Mooring Loads and the Influence of Environmental Conditions for Marine Energy Converters, *Journal of Marine Sciences and Engineering*, volume Vol. 4, no. Issue 2, article no. 29, DOI:10.3390/jmse4020029. [PDF]

Full list of publications : http://emps.exeter.ac.uk/renewable-energy/staff/lj233/publications

Patrick Devine – Wright, Professor in Human Geography - policy-relevant environmental problems using an interdisciplinary collaborative approach that is theoretically informed and has clear pathways to impact

Devine-Wright P (2013). Explaining 'NIMBY' objections to a power line: the role of personal, place attachment and project-related factors. *Environment and Behavior*, *45*, 761-781.

Devine-Wright P (2013). Think global, act local? the relevance of place attachments and place identities in a climate changed world. *Global Environmental Change*, *23*, 61-69. Abstract.

Cotton M, Devine-Wright P (2012). Making electricity networks 'visible': industry actor constructions of 'publics' and public engagement in infrastructure planning. *Public Understanding of Science*, *21*, 17-35.

Devine-Wright P (2011). Place attachment and public acceptance of renewable energy: a tidal energy case study. *Journal of Environmental Psychology*, *31*, 336-343. Abstract.

Devine-Wright P, Heath Y (2010). Disruption to place attachment and the protection of restorative environments: a wind energy case study. *Journal of Environmental Psychology*, *30* Abstract.

Full publication list : http://geography.exeter.ac.uk/staff/index.php?web_id=Patrick_Devine_Wright&tab=pubs

Dr. Steve Votier - Senior Lecturer in Natural Environment – understanding the impact of global change on marine top predators. Most my work is field-based, where I study how key stressors - such as fish extraction, climate change, pollution and industrial development - have impacts at the individual, population and community levels. This work is also heavily influenced by the recently emerging fields of bio-logging and analysis of intrinsic biogeochemical markers.

Selected publications :

Wakefield ED, Cleasby IR, Bearhop S, Bodey TW, Davies R, Miller PI, Newton J, Votier SC, Hamer KC (In Press). Long-term individual foraging site fidelity – why some gannets don't change their spots. *Ecological Monographs*- Abstract.

Votier SC, Cox SL, Miller PI, Embling CB, Scales KL, Bicknell AWJ, Hosegood PJ, Morgan G, Ingram SN (In Press). Seabird diving behaviour reveals the functional significance of shelf-sea fronts as foraging hotspots. *Royal Society Open Science* Full text.

Bicknell AWJ, Godley BJ, Sheehan EV, Votier SC, Witt MJ (2016). Camera technology for monitoring marine biodiversity and human impact. *Frontiers in Ecology and the Environment*, *14*(8), 424-432. Abstract. Full text. Altmetric 89

Thaxter CB, Ross-Smith VH, Clark JA, Clark NA, Conway GJ, Masden EA, Wade HM, Leat EHK, Gear SC, Marsh M, et al (2016). Contrasting effects of GPS device and harness attachment on adult survival of Lesser Black-backed Gulls Larus fuscus and Great Skuas Stercorarius skua. *Ibis*, *158*(2), 279-290. Abstract. Altmetric 54

Carter MID, Cox SL, Scales KL, Bicknell AWJ, Nicholson MD, Atkins KM, Morgan G, Morgan L, Grecian WJ, Patrick SC, et al (2016). GPS tracking reveals rafting behaviour of Northern Gannets (Morus bassanus): implications for foraging ecology and conservation. *Bird Study*, 1-13. Abstract. Altmetric 50

Full list of Publications : http://biosciences.exeter.ac.uk/staff/index.php?web_id=Stephen_Votier&tab=pubs

Dr. Steve Simpson, Associate Professor in Marine Biology and Global change - impact of anthropogenic noise on marine ecosystems, effects of climate change on fish and fisheries, Sensory and orientation behaviour of marine organisms, dispersal, connectivity and biogeography, Management

Simpson SD, Radford AN, Nedelec SL, Ferrari MCO, Chivers DP, McCormick MI, Meekan MG (2016). Anthropogenic noise increases fish mortality by predation. *Nature Communications*, *7*, 10544-10544. Full text.

Radford AN, Lèbre L, Lecaillon G, Nedelec SL, Simpson SD (2016). Repeated exposure reduces the response to impulsive noise in European seabass. *Glob Chang Biol*, *22*(10), 3349-3360. Abstract. Author URL. Full text.

Simpson SD, Purser J, Radford AN (2015). Anthropogenic noise compromises antipredator behaviour in European eels. *Glob Chang Biol*, *21*(2), 586-593. Abstract. Author URL. Full text.

Rutterford L, Simpson SD, Jennings S, Johnson MP, Blanchard JL, Schön P-J, Sims DW, Tinker J, Genner MJ (2015). Future fish distributions constrained by depth in warming seas. *Nature Climate Change* Full text.

Nedelec SL, Campbell J, Radford AN, Simpson SD, Merchant ND (2016). Particle motion: the missing link in underwater acoustic ecology. *Methods in Ecology and Evolution*, *7*(7), 836-842.

Full list of publications : http://biosciences.exeter.ac.uk/staff/index.php?web_id=Stephen_Simpson&tab=pubs

Dr. Helen Smith Lecturer in Renewable Energy - resource assessment for marine energy developments, application and development of numerical wave models for both resource prediction and assessment of potential impacts due to marine energy devices; hydrodynamics, marine operations and offshore reliability.

Harnois V, Smith HCM, Benjamins S, Johanning L. (2015) Assessment of entanglement risk to marine megafauna due to offshore renewable energy mooring systems, *International Journal of Marine Energy*, volume 11, pages 27-49, DOI:10.1016/j.ijome.2015.04.001.

van der Molen J, Smith HCM, Lepper P, Limpenny S, Rees J. (2014) Predicting the large-scale consequences of offshore wind turbine array development on a North Sea ecosystem, *Continental Shelf Research*, volume 85, pages 60-72, DOI:10.1016/j.csr.2014.05.018. [PDF]

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Ashton I, Van-Nieuwkoop-McCall JCC, Smith HCM, Johanning L. (2014) Spatial variability of waves within a marine energy site using in-situ measurements and a high resolution spectral wave model, *Energy*, volume 66, pages 699-710, DOI:10.1016/j.energy.2013.12.065.

Full list publications : http://emps.exeter.ac.uk/renewable-energy/staff/hcms201/publications

Dr. Matthew Witt : Senior lecturer in Natural Environment - distribution and behaviour of mobile marine species, using a wide range of technologies, including satellite tracking and acoustic detection.

Bicknell AWJ, Godley BJ, Sheehan EV, Votier SC, Witt MJ (2016). Camera technology for monitoring marine biodiversity and human impact. *Frontiers in Ecology and the Environment*, *14*(8), 424-432. Abstract. Full text.

Garrett JK, Blondel P, Godley BJ, Pikesley SK, Witt MJ, Johanning L (2016). Long-term underwater sound measurements in the shipping noise indicator bands 63Hz and 125Hz from the port of Falmouth Bay, UK. *Marine Pollution Bulletin*, *110*(1), 438-448. Full text.

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Merchant ND, Brookes KL, Faulkner RC, Bicknell AWJ, Godley BJ, Witt MJ (2016). Underwater noise levels in UK waters. *Scientific Reports*, *6*, 36942-36942. Full text.

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Full list of publications: http://biosciences.exeter.ac.uk/staff/index.php?web_id=matthew_witt&tab=pubs

Other key staff with relevant expertise :

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Dr. Bridget Woodman – Deputy Director Energy Policy Group http://geography.exeter.ac.uk/staff/index.php?web_id=Bridget_Woodman&tab=pubs

Prof Mike Belmont - Professor in Marine Dynamics http://emps.exeter.ac.uk/engineering/staff/MRBelmon/publications

Dr. Fiona Mathews – Associate Prof in Mammalian Biology - http://biosciences.exeter.ac.uk/staff/index.php?web_id=fiona_mathews&tab=pubs

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Key staff directly involved in ORE R&D :

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Dr. Robert Harris – Assistant Professor of Energy Geoscience Infrastructure and society
Dr. David Woolf - Assistant Professor of Energy Geoscience Infrastructure and society
Dr. Sandy Kerr – Director of International Centre for Island technology (ICIT)
Dr Kate Johnson – Assistant Professor of Energy Geoscience Infrastructure and Society

Prof Jon Side – Professor of Energy Geoscience Infrastructure and Society

Developing methodologies for large scale wave and tidal stream marine renewable energy extraction and its environmental impact: An overview of the TeraWatt project. Side, J., Gallego, A., James, M., Davies, I., Heath, M., Karunathra, H., Venugopal, V., Vögler, A. & Burrows, M. 13 Dec 2016 In : Ocean and Coastal Management. Research output: Contribution to journal › Article E-pub ahead of print

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Dr. Robert Harris – Assistant Professor Energy Geoscience Infrastructure and society

Sensitivity Analysis of the Turbulence Closure Models in the Assessment of Tidal Energy Resource in Orkney Baston, S., Harris, R. E., Woolf, D. K., Hiley, R. A. & Side, J. C. 2013 *Proceedings of the 10th European Wave and Tidal Energy Conference.* (EWTEC conference proceedings)

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Pitchai, K. P., Osalusi, E., Ruscoe, J. P., Side, J. C., Harris, R. E., Kerr, S. & Bullen, C. R. 2010 In : Journal of Oceanography and Marine Science. 1, 1, p. 1-10 10 p.

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Dr. David Woolf – Associate Professor of Energy Geoscience Infrastructure and society

Waldman, S. M., Side, J. C., & Woolf, D. K. (2017). *Numerical investigation of tidal resource & far field effects of energy extraction in Lashy Sound, Orkney*. Paper presented at 12th European Wave and Tidal Energy Conference 2017, Cork, Ireland

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Waldman, S., Yamaguchi, S., O'Hara Murray, R., & Woolf, D. (2017). Tidal resource and interactions between multiple channels in the Goto Islands, Japan. DOI: 10.1016/j.ijome.2017.09.002

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Dr. Sandy Kerr – Director ICIT, Stromness, Orkney

Johnson, K. R., Kerr, S. & Side, J. C. (Sep 2016) The Pentland Firth and Orkney Waters and Scotland - Planning Europe's Atlantic gateway
In : Marine Policy. 71, p. 285–292.

Dalton, G., Allan, G. J., Beaumont, N., Georgakaki, A., Hacking, N., Hooper, T., Kerr, S., O'Hagan, A. M., Reilly, K., Ricci, P., Sheng, W. & Stallard, T. Integrated methodologies of economics and socio-economics assessments in Ocean Renewable Energy: private and public perspectives
(Apr 2016) In : International Journal of Marine Energy.

Kerr, S., Johnson, K. R., Colton, J. & Glen, W. (Feb 2015) Rights and Ownership in Sea Country: Implications of marine renewable energy for indigenous and local communities. In : Marine Policy. 52, p. 108-115 8 p.

Kerr, S., Johnson, K. R. & Side, J. C. (Jul 2014) Planning at the edge: Integrating across the land sea divide. In : Marine Policy. 47, p. 118–125 8 p.

Kerr, S., Watts, L., Colton, J., Conway, F., Hull, A., Johnson, K. R., Jude, S., Kannen, A., MacDougall, S., McLachlan, C., Potts, T. & Vergunst, J. (Apr 2014) Establishing an agenda for social studies research in marine renewable energy. In : Energy Policy. 67, p. 694-702 9 p.

Full list of publications : https://pureapps2.hw.ac.uk/portal/en/persons/sandy-kerr(43c9a123-75fe-4627-9c2f-a88a1a0be91f).html

Dr. Kate Johnson – Assistant Professor of Energy Geoscience Infrastructure and Society

Johnson, K. & 22 others (Jan 2017)Maritime ecosystem-based management in practice: Lessons learned from the application of a generic spatial planning framework in Europe
In : Marine Policy. 75, p. 174-186 13 p.

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In : Marine Policy. 51, p. 151-162 11 p.

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Johnson, K. R. & 34 others Jan 2013) Monitoring and evaluation of spatially managed areas: a generic framework for implementation of ecosystem based marine management and its application In : Marine Policy. 37, n/a, p. 149-164 16 p.

Full list of publications : https://pureapps2.hw.ac.uk/portal/en/persons/kate-r-johnson(21a833e0-4726-41d0-a6d9-8cb5416b63e4)/publications.html

Other key staff with relevant expertise in renewable energy sector :

Dr. Mike Bell – Benthic ecology and Fisheries and shell fisheries management
Dr Colin Bullen - Energy technology interactions / simulations
Dr. Andrew Want – Benthic ecologist, Biofouling, hydrodynamics

PLYMOUTH MARINE LABORATORY

Prof Mel Austen - Head of Science Sea and Society
Dr.Tara Hooper – Environmental economist
Dr.Caroline Hattam – Environmental economist
Dr.Nicola Beaumont - Environmental economist
Dr.Peter Miller – Senior Earth Observation Scientist
Dr.Pierre Cazenave – Numerical modeller

Prof Mel Austen - leads a broad spectrum of interdisciplinary research projects from the socio-economics of marine ecosystems and their services through to environment and human health, and marine bio discovery.

Austen MC, Hattam C, Borger T. Chapter 2: Ecosystem services and benefits from marine ecosystems. In: Crowe, TP; Frid, CLJ, (eds.) Marine ecosystems: human impacts on biodiversity, functioning and services. Cambridge University Press, 21-41.

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Borger T., Beaumont N.J., Pendleton L., Boyle K.J., Cooper P., Fletcher S., Haab T., Hanemann M, Hooper T.L., Hussain S.S., Portela R., Sitithou M., Stockill J., Taylor T., Austen M.C., (2014) Incorporating Ecosystem Services in marine planning. The role of valuation. Marine Policy 46, 161-170.

Hooper T., and Austen M. 2014 A methodology for the assessment of local-scale changes in marine environmental health benefits and its application. Ecosystem services 8, 65-74

Dr. Tara Hooper – Environmental economist

Hooper, T., Hattam, C. and Austen, M. 2017. Recreational use of offshore wind farms: Experiences and opinions of sea anglers in the UK. *Marine Policy* 78: 55-60

Hooper, T., Beaumont, N., and Hattam, C. 2017. The implications of energy systems for ecosystem services:
A detailed case study of offshore wind. *Renewable and Sustainable Energy Reviews* 70:230-241

Hooper, T., Langmead, O. and Ashley, M. 2016. Ecosystem Services in Marine Environmental Impact Assessment: Tools to support marine planning at project and strategic scales. In: Geneletti D. (Ed) *Handbook on biodiversity and ecosystem services in impact assessment.* Edward Elgar.

Boerger T, Hooper TL, Austen MC. Valuation of ecological and amenity impacts of an offshore windfarm as a factor in marine planning. Environmental Science & Policy 54, 126-133.

Hooper T, Ashley M, Austen MC. Perceptions of fishers and developers on the co-location of offshore wind farms and decapod fisheries in the UK. Marine Policy 61, 16-22.

Dr. Caroline Hattam – Environmental economist

Hattam C, Atkins JP, Beaumont N, Boerger T, Bohnke-Henrichs A, Burdon D, de Groot R, Hoefnagel E, Nunes PALD, Piwowarczyk J, Sastre S, Austen MC. Marine ecosystem services: Linking indicators to their classification. Ecological Indicators 49, 61-75.

Hattam C, Bohnke-Henrichs A, Boerger T, Burdon D, Hadjimichael M, Delaney A, Atkins JP, Garrard S, Austen MC. Integrating methods for ecosystem service assessment and valuation: Mixed methods or
mixed messages? Ecological Economics 120, 126-138.

Hattam, C., Hooper, T. and Papathanasopoulou E. 2017. A Well-Being Framework for Impact Evaluation: the Case of the UK Offshore Wind Industry. *Marine Policy* 78: 122-131

Dr. Nicola Beaumont – Environmental economist

Bateman, I.J., D.Abson, N.Beaumont, A.Darnell, C. Fezzi, N. Hanley, A. Kontoleon, D.Maddison, P.Morling, J. Morris, S. Mourato, U. Pascual, G. Perino, A. Sen, D.Tinch, K.Turner and G.Valatin (2011) Economic Values from Ecosystems. Chapter 22 . In: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

Beaumont N.J**.**, M.C. Austen, S.C. Mangi, M. Townsend. Economic valuation for the conservation of marine biodiversity. Marine Pollution Bulletin 56 (2008) 386–396

Beaumont N.J.**,** M.C. Austen, J. Atkins, D. Burdon, S. Degraer, T.P. Dentinho, S. Derous, P. Holm, T. Horton, E. van Ierland, A. H. Marboe, D.J. Starkey, M. Townsend, T. Zarzycki. Identification, Definition and Quantification of Goods and Services provided by Marine Biodiversity: Implications for the Ecosystem Approach. Marine Pollution Bulletin 54 (2007) 253-265

Papathanasopoulou E, Beaumont NJ, Hooper TL, Nunes J, Queiros AM. Energy systems and their
impacts on marine ecosystem services. Renewable and Sustainable Energy Reviews, 52. 917-926.

Dr. Peter Miller – Senior Earth Observation Scientist

Miller, P.I. & Christodoulou, S. (in press) Frequent locations of ocean fronts as an indicator of pelagic diversity: application to marine protected areas and renewables. Marine Policy

Miller, P.I.**,** Read, J.F. & Dale, A.C. (in press) Thermal front variability along the North Atlantic Current observed using satellite microwave and infrared data. Deep Sea Research Part II: Topical Studies in Oceanography.

Scales, K.L., P.I. Miller, S.N. Ingram, E.L. Hazen, S.J. Bograd and R.A. Phillips. 2016. Identifying predictable foraging habitats for a wide-ranging marine predator

using ensemble ecological niche models. *Diversity and Distributions* 22(2), 212-224. doi:10.1111/ddi.12389

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Dr. Pierre Cazenave – Numerical modeller

Cazenave, P**.** W**.,** Torres, R., Allen, J. I. (2016) Unstructured grid modelling of offshore wind farm impacts on seasonally stratified shelf seas, Progress in Oceanography.

Waggitt, J., Cazenave, P**.,** Torres, R., Williamson, B., Scott, B.(2016) Predictable hydrodynamic conditions explain temporal variations in the density of benthic foraging seabirds in a tidal stream environment, ICES Journal of Marine Science.

Skakala, J**.,** Cazenave, P**.** W**.,** Smyth, T. J., Torres, R. (2016) Multifractal metrics for the model skill evaluation, Journal of Geophysical Research.

Holland, R.A., Kate Scott, Hinton, E.D., Melanie C. Austen, Barrett, J., Beaumont, N., Blaber-Wegg, T., Brown, G., Carter-Silk**, E.,** Cazenave, P**., Eigenbrod**, F., Hiscock, K., Hooper, T., Lovett, A., Papathanasopoulou, E., Smith, P., Thomas, A., Tickner, R., Torres, R., Taylor, G., (2016) Bridging the gap between energy and the environment, Energy Policy.

Waggitt, J., Cazenave, P. W., Torres, R. Williamson, B., Scott, B. (2016) Quantifying Pursuit Diving Seabirds' Associations with Fine- Scale Physical Features in a High Tidal Energy Environment, Journal of Applied Ecology.

Other staff with relevant interests in ORE :

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Dr. Ricardo Torres – Hydrodynamic modeller
Dr. Eleni Papathanasopoulou – Environmental economist

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Dr. Emma Sheehan – Marine Institute Research Fellow
Prof Ian Bailey – Professor of Environmental Politics
Dr. Clare Embling - Lecturer in Marine Ecology
Prof Gerd Messerlink – Professor of Coastal Engineering
Dr. Dan Conley - Associate Professor (Reader) in Coastal Dynamics Modelling

Prof Deborah Greaves - Professor in Ocean Engineering and Director of the Coast Laboratory

Collins KM, Meng M, Le HR, Greaves D & Bellamy NW 2017 'Modelling of the buckling of a diaphragm–spine structure for a wave energy converter' Materials & Design 119, 159-170 , DOI PEARL

Vyzikas T, Deshoulières S, Giroux O, Barton M & Greaves D 2017 'Numerical study of fixed Oscillating Water Column with RANS-type two-phase CFD model' Renewable Energy 102, 294-305 , DOI

Abo AA, Muhammad RJ, Raby A, Kyte A & Greaves DM 2016 'Analysis of high velocity free surface flow interaction with a bridge pier in a trapezoidal channel using CFD' NAFEMS International Journal of CFD Case Studies PEARL

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Dr. Emma Sheehan - Marine Institute Research Fellow

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Prof Ian Bailey - Professor of Environmental Politics

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Prof Gert Messerlink - Professor of Coastal Engineering

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Dr. Clare Embling – Lecturer in Marine Ecology

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Prof Dan Conley - Associate Professor (Reader) in Coastal Dynamics Modelling

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Bergsma EWJ, Conley DC, Davidson MA & O'Hare TJ 2016 'Video-based nearshore bathymetry estimation in macro-tidal environments' MARINE GEOLOGY 374, 31-41 Author Site , DOI PEARL

Other staff with relevant expertise :

Dr. Steve Fletcher – Associate Professor (Reader) in Marine Policy – coastal governance and marine planning
Dr Lynda Rodwell - Associate Professor (Reader) in Ecological Economics
Dr. Phil Hosegood – Reader in Physical Oceanography
Dr. Simon Ingram – Lecturer in Marine Conservation
Prof Alison Anderson – Professor in Sociology - Mass Media and Culture; Risk; Environmental Sustainability; Social Movements; Science Communication

ST ANDREWS UNIVERSITY - (SMRU and CREEM)

Staff with direct involvement in ORE R&D :

Dr Dave Thompson – Senior research scientist
Dr. Gordon Hastie – Research Fellow – marine mammal ecology
Dr. Bernie McConnell – Senior Research Fellow – instrumentation for movement and behaviour of mammals
Dr. Debbie Russell – Senior research scientist
Dr. Jonathan Gordon – Research Fellow

Dr. Dave Thompson – Senior research scientist

Chen, F, Shapiro, GI, Bennett, KA, Ingram, SN, Thompson, D, Vincent, C, Russell, DJF & Embling, CB 2017, 'Shipping noise in a dynamic sea: a case study of grey seals in the Celtic Sea' *Marine Pollution Bulletin*, vol 114, no. 1, pp. 372-383. DOI: 10.1016/j.marpolbul.2016.09.054

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Dr. Gordon Hastie - Research Fellow

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Dr. Bernie Mc Connell - Senior Research Fellow

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Additional researchers with relevant expertise :

Prof Vincent Janik - Professor in Mammal Biology, Director of Scottish Oceans Institute

Dr. Doug Gillespie – Research Fellow – passive acoustic monitoring

Prof John Harwood – Professor in population and conservation biology

Dr. Eric Rexstad – Software development small mammal population dynamics

SWANSEA UNIVERSITY

Prof Ian Masters – Director of Marine Energy Research group (MERG)

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Prof Harshinie Karunarathna – Prof in Engineering

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Dr. Hannah Nuuttila – SEACAMS research scientist - bioacoustics, acoustic monitoring, statistical modelling.

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Dr. Ruth Callaway - SeaCAMS researcher - marine ecologist

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University of Highlands and Islands including SAMS, ERI and Lewes College

Prof Ben Wilson – Associate Director for Science and Research (interim)

Dr Tom Wilding – Lecturer - Benthic ecologist, impact of offshore structures

Dr. Steven Benjamins – Research associate in marine mammal ecologist

Dr. Denise Risch – Research associate in acoustic ecology

Dr Arne Vogler – Ocean energy engineer

Dr Liz Masden – Research scientist

Prof Ben Wilson – Associate Director for Science and Research (interim)

Findlay, C.R., Ripple, H.D., Coomber, F., Froud, K., Harries, O. van Geel, N.C.F., Calderan, S.V., Benjamins, S., Risch, D., Wilson, B**. (**2018). Mapping widespread and increasing underwater noise pollution from acoustic deterrent devices. *Marine Pollution Bulletin*, 135. pp 1042-1050.

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Dr Tom Wilding – Lecturer - Benthic ecologist, impact of offshore structures

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Dr. Steven Benjamins – Research associate in marine mammal ecologist

Findlay, C.R., Ripple, H.D., Coomber, F., Froud, K., Harries, O. van Geel, N.C.F., Calderan, S.V., Benjamins, S., Risch, D., Wilson, B. (2018). Mapping widespread and increasing underwater noise pollution from acoustic deterrent devices. *Marine Pollution Bulletin*, 135. pp 1042-1050. https://doi.org/10.1016/j.marpolbul.2018.08.042

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Dr. Denise Risch – Research associate in acoustic ecology

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Dr. Arne Vogler – Ocean energy engineer – Ocean Energy Engineering; Wave and Tidal Energy Resource Assessment; Ocean data acquisition systems

Vögler, A., & Venugopal, V. (2016). Wave data analysis for a semi-sheltered site in the Inner Hebrides of Scotland suitable for small scale WEC development. *Ocean Engineering*, *126*(C), 374-383. [OE3995]. 10.1016/j.oceaneng.2016.09.028

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Elizabeth Masden – Research Scientist

Modelling flight heights of Lesser Black-backed Gulls and Great Skuas from GPS: a Bayesian approach
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Additional staff with relevant expertise :

Prof Mike Burrows –Marine ecologist

Dr. Andy Dale – PI in Numerical modelling

Dr. Raeanne Miller – Biofouling NERC KE fellow wave and tidal energy

Dr. Tom Adams – Ecological modeller

Appendix 2 : Centres with three or less staff research active in ORE

BANGOR UNIVERSITY
Dr. Simon Neill - Senior lecturer, School of Ocean Sciences Neill, S.P., Hashemi, M.R. and Lewis, M.J. (2016) Tidal energy leasing and tidal phasing. *Renewable Energy* 85, 580-587. (Open access) Roche RC, Walker-Springett K, Robins PE, Jones J, Veneruso G, Whitton TA, Piano M, Ward SL, Neill SP, Lewis MJ, King JW, Waggitt JJ., 2016. Marine renewable energy for Wales: Research priorities for assessing potential impacts of emerging technologies. *Renewable Energy*, 99, pp 1327–1341 Hashemi, M. R., Neill, S. P., Robins, P. E., Davies, A. G., and Lewis, M. J. (2015) Effect of waves on the tidal energy resource at a planned tidal stream array. *Renewable Energy* 75, 626-639 Lewis, M.J., Neill, S.P., Robins, P.E. and Hashemi, M.R. (2015) Resource assessment for future generations of tidal-stream energy arrays. *Energy* 83, 403-415. Robins, P.E., Neill, S.P., Lewis, M.J. and Ward, S.L. (2015) Characterising the spatial and temporal variability of the tidal-stream energy resource over the northwest European shelf seas. *Applied Energy* 147, 510-522. **Dr. Matt Lewis –Research fellow in marine renewable energy –** Mejia-Olivares, C, Haigh, ID, Wells, N, Coles, D, Lewis, M & Neill, S 2018, 'Tidal-stream energy resource characterisation for the Gulf of California, México' *Energy*, vol. 156, pp. 481-491. DOI: 10.1016/j.energy.2018.04.074 Ward, S, Robins, P, Lewis, M, Iglesias, G, Hashemi, MR & Neill, S 2018, 'Tidal stream resource characterisation in progressive versus standing wave systems' *Applied Energy*, vol. 220, pp. 274-285. DOI: 10.1016/j.apenergy.2018.03.059 Neill, S, Angeloudis, A, Robins, P, Walkington, I, Ward, S, Masters, I, Lewis, M, Piano, M, Avdis, A, Piggott, M, Aggidis, G, Evans, P, Adcock, T, Zidonis, A, Ahmadian, R & Falconer, R 2018, 'Tidal range energy resource and optimization – past perspectives and future challenges' *Renewable Energy*, vol. 127, pp.

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Dr. James Waggitt – Lecturer in Marine Biology

Lieber, L, Nimmo-Smith, A, Waggitt, J & Kregting, L 2018, 'Fine-scale hydrodynamic metrics underlying predator occupancy patterns in tidal stream environments' *Ecological Indicators*, vol. 94, no. part 1, pp. 397-408.

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UNIVERSITY OF BATH

Dr. Philippe Blondel – Senior lecturer Dept of Physics - marine acoustics, seabed and habitat mapping, ambient noise underwater, marine renewable energies, innovative imaging tools

Walsh, J., Bashir, I., Garrett, J., Thies, P. R., Blondel, P. and Johanning, L., 2017. Monitoring the condition of Marine Renewable Energy Devices through underwater Acoustic Emissions:Case study of a Wave Energy Converter in Falmouth Bay, UK. *Renewable Energy*, 102 (Part A), pp. 205-213.

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BRITISH TRUST FOR ORNITHOLOGY

Dr. Phil Atkinson – Research ecologist and science director focussing on impacts of environmental change on bird populations and their ecology

Warwick-Evans, V., Atkinson, P.W., Arnould, J.P.Y., Gauvain, R., Soanes, L., Robinson, L., Green J.A. 2016. Changes in behaviour drive inter-annual variability in the at-sea distribution of northern gannets. *Marine Biology.* 163:156.

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Dr. Chris Thaxter – Research Ecologist - Wetland and Marine Research

Ross-Smith, V.H., Thaxter, C.B., Masden, E.A., Shamoun-Baranes, J., Burton, N.H.K., Wright, L.J., Rehfisch, M.M. & Johnston, A. 2016. Modelling flight heights of lesser black-backed gulls and great skuas from GPS: a Bayesian approach. *Journal of Applied Ecology* doi: 10.1111/1365-2664.12760.

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CENTRE FOR ECOLOGY AND HYDROLOGY

Dr. Francis Daunt – Animal population ecologist - Full list of publications : **http://www.ceh.ac.uk/staff/francis-daunt**

Kogure Yukihisa; Sato Katsufumi; Watanuki Yutaka; Wanless Sarah; Daunt Francis; , 2016, European shags optimize their flight behavior according to wind conditions. , 219, 311-318

Heidinger Britt J.; Herborn Katherine A.; Granroth-Wilding Hanna M.V.; Boner Winnie; Burthe Sarah; Newell Mark; Wanless Sarah; Daunt Francis; Monaghan Pat; , 2016, Parental age influences offspring telomere loss.

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CRANFIELD UNIVERSITY

Dr. Simon Jude - Lecturer – Centre for Resilient Futures - specialist in risk analysis and management; Full list of publications : https://www.cranfield.ac.uk/people/dr-simon-jude-1347315

Jude SR, Drew GH, Pollard SJT, Rocks SA, Jenkinson K & Lamb R (2017) Delivering organisational adaptation through legislative mechanisms: Evidence from the Adaptation Reporting Power (Climate Change Act 2008), *Science of the Total Environment*, 574 (January) 858-871.

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Kerr S, Watts L, Colton J, Conway F, Hull A, Johnson K, Jude S, Kannen A, MacDougall S, McLachlan C, Potts T & Vergunst J (2014) Establishing an agenda for social studies research in marine renewable energy, *Energy Policy*, 67 694-702.

Dr. Athanasios Kolios - Senior Lecturer in Risk Management and Reliability Engineering - Full list of publications : https://www.cranfield.ac.uk/people/dr-athanasios-kolios-728915

Okoro U, Kolios A & Cui L (2017) Multi-criteria risk assessment approach for components risk ranking - The case study of an offshore wave energy converter, *International Journal of Marine Energy*, 17 21-39.

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Kolios A & Martínez-Luengo M (2016) The end of the line for today's wind turbines, *Renewable Energy Focus*, 17 (3) 109-111.

UNIVERSITY OF EAST ANGLIA

Prof Steve Dorling - Senior Lecturer in Atmospheric Sciences – operational weather forecasting, spatial / temporal variability, control factors and modelling approaches

Holley, D.M., Dorling, S.R., Steele, C.J. and Earl, N. (2014) A climatology of convective available potential energy in Great Britain. *International Journal of Climatology* 34(14), pp3811-3824. DOI: 10.1002/joc.3976

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Earl, N., Dorling, S.R., von Glasow, R. and Hewston, R. (2013) 1980-2010 variability in UK surface wind climate. *J. Climate*, 26(4), 1172-1191. doi: 10.1175/JCLI-D-12-00026.1

Steele, C.J., Dorling, S.R., von Glasow, R. and Bacon, J.D. (2013) Idealized WRF model sensitivity simulations of sea breeze types and their effects on offshore windfields. *Atmospheric Chemistry and Physics,* 13, 443-461.

Dorling, S.R., Earl, N. and Steele, C. (2014) Spatial and temporal variability in the UK wind resource: Scales, controlling factors and implications for wind power output. In "Weather Matters for Energy", Troccoli A, Dubus L and Haupt SE, eds, Springer Academic Publishers.

HULL UNIVERSITY – IECS

Professor Mike Elliott – Director, Institute of Estuarine and Coastal Studies and Professor of Estuarine & Coastal Sciences

http://www2.hull.ac.uk/science/pdf/Prof%20Mike%20Elliott%20-%20Publication%20List.pdf

Turner, R.K., Mee, L., Elliott, M., Schaafsma, M., Burdon, D., Atkins, J.P., Saunders, J., Potts, T., Jickells, T, Beaumont, N. & Bee, E., (2015). Chapter 2: Conceptual framework. In: Turner, R.K. & Schaafsma, M. (Eds.) Coastal zones ecosystem services: from science to values and decision making. Springer Ecological Economic Series, Springer Internat. Publ. Switzerland, ISBN 978-3-319-17213-2; p11-40.

Borja, A, Elliott, M, Andersen, JH, Berg, T, Carstensen, J, Halpern, BS, Heiskanen, A-S, Korpinen, S, Lowndes, JSS, Martin, G, Rodriguez-Ezpeleta, N (2016). Integrative assessment of marine systems: the Ecosystem Approach in practice. Frontiers in Marine Science March 2016 Volume 3 Article 20, doi: 10.3389/fmars.2016.00020.

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Dr. Daryl Burdon - Senior Ecological Economist

Elliott, M., Burdon, D., Atkins, J.P., Borja, A., de Jonge, V.N. & Turner, R.K., 2017. '"And DPSIR begat DAPSI(W)R(M)!" – a unifying framework for marine environmental management'. *Marine Pollution Bulletin*, 118, pp. 27-40.

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Hattam, C., Atkins, J.P., Beaumont, N., Borger, T., Böhnke-Henrichs, A., Burdon, D., De Groot, R., Hoefnagel, E., Nunes, P., Piwowarczyk, J., Sergio, S. & Austen, M., 2015. 'Marine ecosystem services: linking indicators to their classification'. *Ecological Indicators*, 49, pp. 61–75.

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Dr. Sue Boyes – Marine policy specialist

Boyes, S.J. and Elliott, M. 2014. 'Marine Legislation – the ultimate 'horrendogram': International Law, European Directives and National Implementation'. *Marine Pollution Bulletin*, 86, pp. 39-47

Boyes, S.J. & Elliott M. 2016. 'Viewpoint: Brexit: The marine governance horrendogram just got more horrendous!', *Marine Pollution Bulletin*, 111: 41-44

Boyes, S.J., Elliott, M., Murillas, A., Papadopoulou, N. and Uyarra, M.C. 2016. 'Is existing legislation fit-for-purpose to achieve Good Environmental Status in European seas?', *Marine Pollution Bulletin*, 111: 18-32

Burdon, D., Boyes, S.J., Elliott, M., Smyth, K., Atkins, J.P., Barnes, R.A. and Wurzel, R.K., in press. 'Integrating natural and social marine science to manage sustainably vectors of change: Dogger Bank transnational case study'. *Estuarine, Coastal and Shelf Science* (2015)

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LOUGHBOROUGH UNIVERSITY

Dr. Paul Lepper – Senior lecturer - underwater acoustics, bioacoustics and underwater technologies.

Lloyd, S, Lepper, PA, Pomeroy, S (2016) Evaluation of UAVs as an underwater acoustics sensor deployment platform, *International Journal of Remote Sensing*, pp.1-10, ISSN: 1366-5901. Full text: http://www.tandfonline.com/doi/full/10.1080/01431161.2016.1259686. DOI: 10.1080/01431161.2016.1259686.

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Lepper, PA, Robinson, SP, Theobald, PD, Pangerc, T (2013) A Monte Carlo approach to determining marine mammal exposure risk to long term marine piling operations., *J Acoust Soc Am*, 134(5), p.4059, DOI: 10.1121/1.4830812.

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NATIONAL OCEANOGRAPHY CENTRE

Dr. Paul Bell – Associate Head Ocean technology

McCann, D.L.; Bell, P.S.. 2017 Visualising the aspect-dependent radar cross section of seabirds over a tidal energy test site using a commercial marine radar system. International Journal of Marine Energy, 17. 56-63.10.1016/j.ijome.2017.01.002

McCann, David L.; Bell, Paul S.. 2017 Observations and tracking of killer whales (Orcinus orca) with shore-based X-band marine radar at a marine energy test site. Marine Mammal Science. (In Press)

Bird, Cai O.; Bell, Paul S.; Plater, Andrew J.. 2017 Application of marine radar to monitoring seasonal and event-based changes in intertidal morphology. Geomorphology. 10.1016/j.geomorph.2017.02.002 (In Press)

Williamson, Benjamin J.; Blondel, Philippe; Armstrong, Eric; Bell, Paul S.; Hall, Chris; Waggitt, James J.; Scott, Beth E.. 2016 A self-contained subsea platform for acoustic monitoring of the environment around marine renewable energy devices - field deployments at wave and tidal energy sites in Orkney, Scotland. IEEE Journal of Oceanic Engineering, 41 (1). 67-81.10.1109/JOE.2015.2410851

Bell, Paul S.; Bird, Cai O.; Plater, Andrew J.. 2016 A temporal waterline approach to mapping intertidal areas using X-band marine radar. Coastal Engineering, 107. 84-101.10.1016/j.coastaleng.2015.09.009

Dr. Judith Wolf - Marine systems modelling

Bricheno, Lucy M.; Wolf, Judith; Islam, Saiful. 2016 Tidal intrusion within a mega delta: an unstructured grid modelling approach. Estuarine, Coastal and Shelf Science, 182 (A). 12-26.10.1016/j.ecss.2016.09.014

Bricheno, Lucy M.; Wolf, Judith; Aldridge, John. 2015 Distribution of natural disturbance due to wave and tidal bed currents around the UK. Continental Shelf Research, 109. 67-77.10.1016/j.csr.2015.09.013

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Yates, Nicholas; Walkington, Ian; Burrows, Richard; Wolf, Judith. 2013 The energy gains realisable through pumping for tidal range energy schemes. Renewable Energy, 58. 79-84.10.1016/j.renene.2013.01.039

Dr. Michela De Dominicis - Marine Systems modeller

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READING UNIVERSITY

Dr. David Brayshaw - Associate Professor in Climate Science and Energy Meteorology - Large-scale atmospheric dynamics and extratropical storm tracks; Impacts of weather and climate on human and environmental systems, especially energy - Weather and climate forecasting for risk management.

Cannon, D., Brayshaw, D., Methven, J. and Drew, D. (2016) *Determining the bounds of skilful forecast range for probabilistic prediction of system-wide wind power generation.* Meteorologische Zeitschrift. ISSN 0941-2948 doi: 10.1127/metz/2016/0751

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QUEENS UNIVERSITY BELFAST

Dr. Louise Kregting – Research fellow - environmental impacts of large marine energy arrays using hydrodynamic and ecological modelling

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SOUTHAMPTON UNIVERSITY

Dr. Justin Dix – Associate Prof in Marine Geophysics – specialises in development of new 3D high-resolution acoustic tools for marine investigation, scour evolution

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Prof Ian Masters – Director of Marine Energy Research group (MERG)

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Dr. Ruth Callaway - SeaCAMS researcher - marine ecologist

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Appendix 3 : UK / EU funded collaborative projects relevant to ORE development

PROJECT DESCRIPTION	Delivery partners	FUNDING
***CBESS* – (2012 – 2016) Coastal Biodiversity and Ecosystem Services Sustainability** - Scale-dependency and the influence of environmental context on Biodiversity-Ecosystem Service relationships in salt marsh to mudflat landscapes of the UK. The health of the UK's coastlines is inextricably linked to our success as an island nation, and resonates through our economy, our recreation, and our culture. One of the most sensitive environments to the pressures of climate change are coastal habitats. Salt marshes, mudflats, beaches and rocky shores will all be affected. Of these areas, the most sensitive are mudflats and salt marshes, both common features of our coastal environment and comprise just over half of the UK's total estuarine area. Not only do mudflats and salt marshes support a wide range of economically valuable animal and plant species, they also act as sites of carbon storage, nutrient recycling, and pollutant capture and destruction. We know quite a lot about individual small areas but coastal managers require evidence to understand how ecosystem service flows operate at much larger spatial scales, e.g. entire salt marshes or regions of intertidal flat and salt marshes. The CBESS project will help deliver this understanding. https://synergy.st-andrews.ac.uk/cbess/	Univ of St Andrews, Cambridge Coastal Research Unit, Univ of Essex, Univ of Bangor	NERC
CORPORATES - "The Cooperative Participatory Evaluation of Renewable Technologies on Ecosystem Services"The aim of the project was to exchange knowledge between researchers and a range of public and private sector stakeholders around the understanding of marine ecosystem services (ES), in the context of marine spatial planning decisions around marine renewable energy. The project developed a pilot study located at the Firth of Forth, Scotland, considering current development of a number of large windfarms in an area important to both fishing and nature conservation. The project included the involvement of a wide range of highly experienced stakeholders over the course of two day-long workshops in November 2014 and March 2015. While the process centred on a 'live' decision-making case study, the focus of the CORPORATES project was to provide an example of a decision support tool for knowledge exchange around ES rather than influencing decision-making in the Forth. The project design and delivery was highly transdisciplinary, involving experts with backgrounds in ecology, oceanography, marine management, policy, law, environmental psychology, anthropology and ecological economics as well as public and private sector stakeholders.	Univ of Aberdeen, James Hutton Inst, SAMS	NERC

http://www.corporatesproject.co.uk/		
Designing for Survivability - The primary aim of the project is the assessment of the extreme wave loads on WECs using numerical models validated against experimental observations and full-scale prototype data. The project team combines institutions with significant experience in research into extreme waves (Imperial College), wave energy converters (Queen's University Belfast) and numerical modelling (Manchester Metropolitan University), forming a strong and well- balanced consortium. They will be supported by a steering committee comprising a number of key industrial practitioners and stakeholders, bringing in a wide range of backgrounds from device developers, certifying bodies and the offshore industry. In designing wave energy converters (WECs), scientists and engineers face the challenge of having to compromise between two competing criteria. The power take-off, with all associated mechanical and electrical components having to be optimised for an annual average or nominal sea state. At the same time all these components will have to withstand large storm events, where the applied fluid loads are substantially higher compared to the nominal sea state. A successful design is inevitably characterised by one that balances these two criteria. Identifying such a balance at an early design stage (prior to expensive small or large scale physical model testing) requires accurate, reliable and efficient numerical models appropriate to both design criteria. Survivability defines the long term success of a WEC, and must be addressed by design. http://www.supergen-marine.org.uk/supergen-grand-challenges/designing-survivability	Imperial College	EPSRC
DEVOTES - DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status (2012-2016) aims to develop innovative tools for understanding marine biodiversity and assessing Good Environmental Status (GES) and **improving understanding of human activities impacts (cumulative, synergistic, antagonistic) and variations due to climate change on marine biodiversity, using long-term series (pelagic and benthic). DEVOTES** main objectives are therefore to: i) improve our understanding of the impact of human activities and climate change on marine biodiversity; ii) identify the barriers and bottlenecks that prevent Good Environmental Status from being achieved; iii) test indicators and develop new, innovative ones to assess biodiversity in a harmonized way throughout the 4 regional seas; iv) develop, test and validate innovative integrative modelling and monitoring tools to improve our understanding of ecosystem and biodiversity changes, for integration into a unique and holistic assessment; v) propose and disseminate strategies and measures for ecosystems' adaptive management, including the active role of industry and relevant stakeholders. DEVOTES will address three main challenges in determining environmental status: (i) assessment of anthropogenic pressures, including climate change, to which biodiversity responds; (ii)	AZTI-Tecnalia, Pasaia (Spain) with Univ of Hull (IECS) leading on socio-economic WPs	FP7

selection of appropriate indicators to assess the status; and (iii) integration of those indicators across a number of ecological scales, into a unique biodiversity assessment. http://www.devotes-project.eu/publications/		
EBAO - Optimising Array Form for Energy Extraction and Environmental Benefit (2011 – 2014) aims to establish a robust methodology to ensure that future large scale marine energy developments are designed to maximise their economic energy potential, while ensuring that constraints set by consideration of ecological consequences are recognised and respected. This will involve establishing how projects will impact on the environment, how the acceptability of such impact is quantified and how the designs of technology and energy projects can be evolved to ensure energy production optimisation subject to ecological constraints. The project will represent "proactive resource assessment", in which assessment of the limits to acceptable ecological impact will be used to inform the system and project design processes to ensure than prospective energy extraction levels are maximised without unacceptably compromising the environment	Edinburgh, SMRU, SAMS, Univs of Loughborough, Exeter	NERC / DEFRA
ECOWATT 2050 - The Scottish Government is committed to promoting substantial sustainable growth in its marine renewable industries. Agreements for sea bed leases are already in place for 2GW of wave and tidal developments, and projects are progressing through the licensing process. Strategic marine planning for future phases of wave, tidal and offshore wind development is now in progress. For marine renewables to significantly contribute to the low-carbon energy mix towards 2050, significant offshore development in the form of very large scale arrays will be needed. In planning for such a future, the Government must consider the mix of technologies, the locations and configurations of very large scale arrays and their performance, and the implications of anticipated changes to the marine environment from climate change. In establishing its strategic policy positions, the Government must also ensure that legal obligations are met, particularly those under the European Marine Strategy Framework Directive (MSFD) to achieve Good Environmental Status (GES) by 2020. http://www.supergen-marine.org.uk/supergen-grand-challenges/ecowatt2050	Heriot Watt University, NOC, Univ of Strathclyde, Aberdeen, Edinburgh, Swansea, Marine Scotland	EPSRC
EQUIMAR - EquiMar involved working together to find ways to measure and compare the dozens of tidal and wave energy devices, proposed locations and management systems currently competing for funds, so governments can invest in the best ones and get marine energy on tap fast. The team has delivered a suite of "high level" protocols – general principles to allow fair comparison of marine energy converters testing and	Univ of Edinburgh and 60 scientists from 11 countries	FP7

evaluation procedures. EquiMar protocols cover site selection, device engineering design, scaling up designs, deployment of arrays, environmental impact on flora, fauna & landforms, and economic issues. The final EquiMar protocols establish a sound base for future marine energy standards currently being developed by IEC Technical Committee 114. http://www.equimar.org/		
FLOWBEC – FLOW and benthic ecology in 4D – (2011 – 2016) The FLOWBEC project aims to investigate the potential impacts that tidal and wave energy harnessing devices may have on the marine environment. Through FLOWBEC, scientists hope to understand how changes to water flow and turbulence introduced by tidal technology might affect the various types of marine wildlife. As part of its research, Flowbec uses sonar technology to monitor fish and diving seabirds, assessing how they interact with the installation.The knowledge gained through Flowbec will help to inform important environmental considerations when reviewing sustainable energy generation sites. The knowledge will also be shared through providing an open data resource for environmental scientists. The tools developed in Flowbec will allow for direct simulations and evaluation of ecosystem impacts related to a large variety of factors, such as pollution from human activities, CO_2 leaks arising from carbon capture and storage actions and marine renewable energy devices. http://noc.ac.uk/project/flowbec	NOC, Univs of Aberdeen, Bath, Exeter, SMRU, PML	NERC / DEFRA
FORESEA –The FORESEA (Funding Ocean Renewable Energy through Strategic European Action) project (2016 – 2019) aims to help bring ocean energy technologies to market by providing access to North-West Europe's world-leading network of test centres. Through the project, the performance of innovative ocean renewable energy technologies will be demonstrated in real sea conditions, helping to leverage the investment needed to take these new products to market. Access to test sites will be provided through a programme of competitive calls, run by the project's consortium. The programme covers the following test centres: European Marine Energy Centre (EMEC): Orkney Islands, UK; SmartBay: Galway, Ireland; SEM-REV: Nantes, France; Tidal Testing Centre: Den Oever, Netherlands. The test centres are supported by European industry group Ocean Energy Europe, based in Brussels. European technologies are the clear global leader in ocean energy. To translate this leadership into a new industrial sector, it is essential that a critical mass of technologies receive enough private investment to take them to the marketplace. The cost of pre-commercial testing and demonstration for ocean energy is high and investors are reluctant to invest until the technology has been proven in the sea at scale. The result is that precisely at the point when risks are highest and capital requirements most intensive – (e.g. open ocean testing and demonstration) – technology developers hit a funding brick wall. The FORESEA programme will encourage longer term testing and technology de-risking,	EMEC	INTERREG 1VA NW Europe

thereby leveraging further investment and enabling progression towards the marketplace. http://www.nweurope.eu/projects/project-search/funding-ocean-renewable-energy-through-strategic-european-action/		
InterFLO - Interactions of Flow, Tidal Stream Turbines and Local Sediment Bed Under Combined Waves and Tidal Conditions - Flow passing Tidal Stream Turbines (TST) support structure combined with the rotation of the turbine rotors produces a turbulent downstream wake that can be sufficiently energetic to disturb the sediments on the sea bed on which the turbine is constructed and affect the sediment suspension. This may have significant impact on the sea floor topography and adverse consequences for the indigenous marine flora and fauna. Thus far, little is known about the nature of the turbulent wakes of the rotors and the mechanisms by which these wake flows perturb the sediments in water and on the seabed. For cases in which several tidal stream turbines are constructed in an array, the configuration of the sea bed sediments is subjected to complex pressure distributions arising from each of the constituent installations and the prediction of sea floor sediment response is even more uncertain. http://www.supergen-marine.org.uk/supergen-grand-challenges/interactions-under-combined-waves-tides	Univ of Dundee, NOC	EPSRC
Increasing the life of Marine Turbines by Design and Innovation - Unsteady loads on tidal turbines are much larger than in wind turbines because of the high density of water and the high levels of unsteadiness in offshore marine environments. In addition the welded mild steel structures normally used to support marine turbines have a low fatigue life in salt water. This can lead to life of 30 months or less instead of the design requirement of 30 years. In addition fatigue life limits the number of locations where tidal turbine can be deployed, limiting the overall practical UK tidal resource. This project aims to develop innovative technologies which will reduce the unsteady loads which result from flow unsteadiness and thus increase the longevity of a marine turbine by an order of magnitude. http://www.supergen-marine.org.uk/supergen-grand-challenges/increasing-life-marine-turbines	Univ of Cambridge	EPSRC

MaREE: Marine Renewable Energy and the Environment - In support of the development of marine renewable energy in the Highlands and Islands of Scotland, the MaREE project explores the environmental and socio-economic issues related to these developments. The programme seeks to build on existing expertise in marine environmental sciences and the unique resource potential of the region in order to develop an integrated, holistic understanding of the environmental considerations surrounding marine renewable energy development in Scotland. The MaREE project works towards delivering and sustaining a step-change in capacity and quality in research across the University of the Highlands and Islands partnership and establishing research excellence in niche areas. The project is based on an integrated collaborative programme across three themes: (1) Resource and Risk; (2) Environmental Impacts and (3) Towards sustainability management, policy and communities . **https://tethys.pnnl.gov/annex-iv-research/marine-renewable-energy-and-environment-maree**	UHI - Environmental Research Institute and SAMS	European Regional Development Fund, Scottish Funding Council, Highlands and Islands Enterprise
MAREN - MAREN investigates the marine renewable energy forms of; offshore wind, tidal current, tidal barrage and lagoons, and wave, in the Atlantic Area to produce the following main outputs: • Country Modelling Case Studies • High resolution modelling and mapping of the resource potential • Assessment of marine renewable energy device performance • Assessment of the Environmental Impact • Future climate change scenarios – for resource, impacts and design requirements • Carbon emission life-cycle analysis • Comparative analysis of EIA and SEA protocol across the Atlantic corridor MAREN has worked on the following case study sites: tidal barrage and tidal stream – Severn estuary & Llanelli-Loughor barrage, tidal impoundments – Rhyl, Bridgewater bay & potentially Swansea bay ; wave –SW Cornwall, Pembrokeshire, the Severn estuary, and offshore wind around the whole Welsh coastline and Severn estuary. http://www.marineenergypembrokeshire.co.uk/publications-resources/	Cardiff University National University of Ireland, Galway; University of Cantabria, Spain, Centec, Instituto Superior Tecnico, Portugal, and Ifremer, France	EU ERDF Atlantic Area Programme
MARIBE – (ie. Marine investment for the Blue economy) is a project exploring cooperation opportunities for companies that combine different Blue Growth and Blue Economy sectors. Economic activities in Europe's seas and coasts are expected to intensify, diversify and expand further offshore. The development of large scale activities offshore and in deep sea areas requires overcoming a series of technological and non-technological challenges and assessment of the most promising and	11 EU countries – coordinated by Univ college Cork	HORIZON 2020

sustainable business models. One way to make use of our seas in a smarter, more sustainable and less disruptive manner is to combine different activities at sea on a same location with multi-use offshore platforms. The MARIBE team will work with selected EU-funded consortia (particularly those involved in the Oceans of Tomorrow projects) to develop their cross-sectoral projects. It will also focus on additional sectoral combinations that present potential for synergistic collaboration. The MARIBE partners will work with stakeholders in these sectors to broker partnerships and to create action plans that will develop cooperation. By working with stakeholders, MARIBE will directly encourage cooperation and multi-use of space with a view to strengthening Blue Growth sector.		
MERIFIC - Marine Energy in Far Peripheral and Island Communities - The MERiFIC project seeks to advance the adoption of marine energy across the two regions of Cornwall and Finistère and the island communities of le Parc Naturel Marin d'Iroise and the Isles of Scilly. Project partners will work together to identify the specific opportunities and issues faced by peripheral and island communities in exploiting marine renewable energy resources with the aim of developing tool kits and resources for use by other similar communities. The project will develop and deliver joint activities between the two regions, looking at issues such as : Marine energy resource assessment/mapping; Policy issues and potential barriers to marine energy development; Business and commercial opportunities for island/mainland communities; Island/mainland interaction on appropriate infrastructure and Community and stakeholder engagement with key groups (e.g. fishing, wave farm developers, and investors). http://www.merific.eu/partners	Univ of Exeter , Plymouth, IFREMER, Pole mer Bretagne Cornwall County Council	INTERREG IV A France (Channel) – England, co-funded by the ERDF.
MERP - Marine Ecosystems Research Programme set out to integrate existing marine data and target new data with current models and knowledge of marine ecosystem services, in order to improve our understanding of the whole UK marineecosystem. The 5 year, £5 million programme has brought together more than 50 scientists from 12 research institutes and a large number of supporting organizations that have made data and expertise available to achieve MERP's aim. The strength of MERP and the quality of its outputs are a testament to the approach which: brought together scientists with different expertise and experience to work together; utilised and developed the best available modelling approaches; merged existing data from a range of sources and added new data where necessary; linked process understanding and ecosystem state to services; and related its outputs to better understanding relevant to policies. It has been an underlying target that MERP would bring together and further develop a suite of marine ecosystem models, provide vital evidence and tools and advice to support Marine Strategy Framework Directive (MSFD), the Marine and Coastal Act Access Act, the	Plymouth Marine Laboratory coordinating	NERC and DEFRA

Marine (Scotland) Act, the Common Fisheries Policy (CFP) and inform the OSPAR Joint Assessment and Monitoring Programme. MERP science has already fed into these and other guidelines, directives and legislations. Applying MERP outputs to forecasting any changes in the provision of ecosystem services as a result of natural and human pressures is an equally important outcome of MERP. The approach has been to follow The National Ecosystem Assessment (2011) guidance, focussing on: food provision, biological checks and balances, leisure and recreation and bioremediation of waste. http://marine-ecosystems.org.uk/Contact/MERP_Scientists		
MER INNOVATE - The Mer-Innovate project is a Franco-British collaboration that aims to address the cost of maintenance programmes of assets at sea (Marine Renewables) through the development of new procedures, protocols and modeling tools. Through the use of these project outputs, the Marine Renewable sector will be able to deploy more intelligent maintenance strategies and lower the number of unnecessary intervention exercises at sea. Reduced operations to offshore assets will also reduce the impact on the environment programs and contribute to a lower operational cost for these offshore installations. The Mer-Innovate consortium will also be investigating the development e-maintenance ICT tools, which includes the decision support systems, which will be freely disseminated to the renewable marine energy community. http://www.merinnovateproject.eu/en/partners-and-supports/partners/	Univ Exeter, KTN, CESI, Technopole Cherbourg	European Regional Development Fund (ERDF) / INTERREG IVA France (Channel)
MUSES - The Multi-Use in European Seas (MUSES) project is a Horizon 2020 funded project that is exploring the opportunities for Multi-Use in European Seas across five EU sea basins (Baltic Sea, North Sea, Mediterranean Sea, Black Sea and Eastern Atlantic). There are increasing demands on ocean resources as well as increasing pressure on the use of ocean space, as a result ocean space is a valuable asset deserving our special attention. Challenges may arise from tensions between maritime activities demanding marine space, and combining compatible activities in the same marine space can serve to share and reduce costs, and generate further synergies between those activities. MUSES builds on existing knowledge to explore the real opportunities for Multi-Use in European Seas, including the scope for innovation and Blue Growth potential and to present practical solutions on how to overcome existing barriers and minimize risks associated with Multi-Use development. https://www.submariner-network.eu/news/general-news/168-multi-use-in-european-seas-horizon-2020-muses-project-approved	Marine Scotland Science the lead organisation with 11 European partners	HORIZON 2020
NORTHSEE - is an Interreg project on improving coordination of North Sea marine spatial planning Our funds are allocated within four main priority themes that are of primary importance in the North Sea Region. These	Joint secretariat based in Denmark	InterReg Vb

are : (1) Thinking growth - building strong partnerships and innovation capacity, with a special focus on small and medium sized companies and public service delivery. (2) Eco-innovation – to accelerate the region's circular economy, development of green products and services, and the green energy transition. (3) Sustainable North Sea Region - to catalyse climate resilience, ecosystem management, blue growth, and maritime spatial planning. (4) Green transport and mobility – to foster sustainable freight and passenger transport, shared mobility and accessibility. http://www.northsearegion.eu/northsee/		
Predictive tidal data products - The independent consultant will be required to report on the following:- Task 1 Internet based research to substantiate knowledge and information in each of the pre-identified 10 market areas and any additional found during the search. 1a) Assessment of market size, growth rates and future projections. 1b) Understanding of current market pricing and business models. 1c) Identification of the competition in each market sector and provide brief overview of strengths & weakness of their offering compared to NOC proposed product. Outcome: Market Opportunity report, with suggestions of business models and pricing and identification of technical features of greatest importance per sector. Task 2 In consultation with NOC, the consultant will identify a list of 30 companies and contacts, covering the full range of the 10 market applications areas of interest (or those we decide to focus on), specifically targeting one end user and two potential licensees in each market area. The consultant will then interview these contacts directly to understand:- 2a) licensee and user-group requirements for data in terms of accessibility, frequency of access and specific data content of interest; 2b) what the industry likes about current methods for obtaining this information; 2c) what the industry feels is missing from current data sets and data presentation; 2d) what, if any, potential barriers to market (e.g. warranty requirements from NERC/NOC); Outcome: Licensee and End-User Requirements. Task 3 Creation of a spreadsheet to provide a comparison of financial outcomes of various	NOC	

user numbers against different business models of payment. Outcome: Business Model comparison spreadsheet The consultant, or consultants, would be encouraged to think laterally to identify other applications/markets but it would be required at the very least to research the markets listed in the Beneficiaries section below. How will the commissioned research inform our understanding? This market report will provide us with the optimum mix of information to judge whether further development of the Data Product is desirable, viable and achievable, and therefore worthwhile investing in. How will the research help shape the development and execution of our proposed Follow-on project work programme? This report will inform the following three key areas of:- 1. Potential Applications / Markets 2. Licensee and end-user requirements 3. NOC's Technology and Commercialisation Plan for the Data Product This will inform:- 1. Whether NERC/NOC continues to invest in the Data Product - Stop/Go; 2. If yes, how NERC/NOC needs to deliver the Data Product, and/or support services, to meet specific licensee/end-user requirements; and 3. How best NERC/NOC commercialises the Data Product to achieve Impact and licensing revenue.		
QBEX - Quantifying benefits and impacts of fishing exclusion zones around Marine Renewable Energy Installations – (2011 – 2016) a novel combination of behavioural tracking, density estimations and modelling approaches to address whether 'spillover' of species abundance (fish, shellfish) as a consequence of the no-fishing area around MREIs enhance adjacent areas. We propose to conduct research at a small-spatial scale, wave energy test site (the Wave Hub, off Hayle, Cornwall) and a Round 1 (R1) 30-turbine offshore wind farm (North Hoyle, off Rhyl, North Wales) and the area north of this towards the R2 Gwynt-y-Mor wind farm currently under construction. Our approach in these locations will be to quantify where large numbers of fish and shellfish of several species (e.g. edible crab, lobster, Atlantic cod, thornback ray) are located in relation to MREI, adjacent and more distant areas, and how much time they spend in those locations over annual cycles. We will then use this precise spatial information for several hundred individuals to scale up to potential population levels using relative abundance data from surveys for these focal species in those areas. From this, empirical estimates of the magnitude of spillover and its spatio-temporal dynamics will be made. These will be compared with spatial fishery models, to assess how rates of exchange of animals between areas accessible and inaccessible to fishing determine outcomes in terms of both spawning potential and fishery yield. We will use an individual-based modelling approach to identify how patterns of space use by fish/shellfish determine these outcomes when MREIs are introduced into stock areas. This research will also undertake a socio-economic analysis of the impacts and benefits to fisheries of MREIs that exclude fishing, and the effects of displacement of fishing exploitation to adjacent areas. http://gtr.rcuk.ac.uk/projects?ref=NE/J012343/1	MBA, PML, Exeter, HeriotWatt Univ	NERC/ DEFRA

QUOTIENT - **Quantification, Optimization and Environmental Impacts of Marine Renewable Energy** - The QUOTIENT Research Cluster will examine how wave and tidal energy resources interact with one another, over a variety of spatial and temporal scales, from centimetres to kilometres and from sub-second to multi-decadal. Research within the cluster will determine how we can best manage marine renewable energy extraction, for multiple resource types, for future energy extraction scenarios, informing future energy policy and investment in the electricity network. The cluster will also investigate how feedbacks between energy extraction and the resource influence dynamical processes that are driven by the resource, such as sediment transport and the maintenance of beaches and offshore sand banks. http://www.marineenergywales.co.uk/developers/research/quotient/	National Research Network for Low Carbon, Energy and Environment (NRN-LCEE). Bangor University, Swansea, Cardiff University and the University of South Wales	HEFCW
RESILCOAST is a multi-disciplinary project to deliver fundamental biological and geo-morphological research to understand what governs marsh resilience to change, and to numerically model how state shifts will be affected by climate change and interactions from human exploitation, such as livestock grazing. Our research uses state of the art hydrological flumes as well as extensive field experimentation to examine the resilience of marshes to environmental disturbance or change. Using historical fly-over photography of marshes, we will develop novel approaches to forecasting state shifts - something that is lacking for most global ecosystems. http://www.nrn-lcee.ac.uk/resilcoast/	University, research and Government partners from Wales, England and the Netherlands.	HEFCW
RESPONSE - Understanding How Marine Renewable Device Operations Influence Fine Scale Habitat Use and Behaviour of Marine Vertebrates – (2011 – 2016) The RESPONSE project is a multi-disciplinary study focussing on causal links between marine renewable devices and changes in the fine-scale distribution and behaviour of marine vertebrates. The overall aim of the project is to identify and quantify actual risk of negative consequences and therefore remove one key layer of uncertainty in the scale of risk to the industry and natural environment. The main objectives are to: 1. understand how stakeholders see the risks to the industry and to the environment. 2. measure the fine scale distribution of marine wildlife in high tidal and wave energy sites to understand how seals, cetaceans, birds and large fish use such areas.3. characterise acoustic, visual and electromagnetic signals that MRDs produce and assess the reactions of marine wildlife to those cues. 4. use the results in habitat preference models to infer zones of influence and avoidance associated with MRDs at both small and large scales. 5. develop effective mitigation methods http://gtr.rcuk.ac.uk/projects?ref=NE%2FJ004251%2F1	SMRU, SAMS, Univ Loughborough, Aberdeen.	NERC / DEFRA
RICORE - **Risk based consenting for offshore renewables – (2014 – 2016**) - The aim of the RiCORE project was to establish a risk-based approach to consenting where the level of survey requirement is based on the	Robert Gordon University,	European Union's Horizon 2020

environmental sensitivity of the site, the risk profile of the technology and the scale of the proposed project. The consenting of offshore renewable energy is often cited as one of the main non-technical barriers to the development of this sector. A significant aspect of this is the uncertainty inherent in the potential environmental impacts of novel technology. To ensure consents are compliant with EU and national legislation, such as the Environmental Impact Assessment and Habitats Directive, costly and time consuming surveys are required even for perceived lower risk technologies in sites which may not be of highest environmental sensitivity. http://ricore-project.eu/	Marine Scotland, University College Cork,WavEC, AZTI-Tecnalia, E-Cube Strategy Consultants	research and innovation programme
SMARTY - SuperGen Marine Technology Challenge Marine renewable energy devices, be they wave, current or wind, are exposed to an incredibly hostile and complex environment. Accurate prediction of extreme loading events on marine renewable devices and their implications for survivability and operating limits remains an extremely challenging and in many ways unsolved problem. This proposal is aimed at bridging the gap between the hydrodynamic loads that actually occur on real devices and what can be predicted using current engineering best practice. http://www.supergen-marine.org.uk/supergen-grand-challenges/smarty	Univ of Oxford	EPSRC
SOWFIA - Streamlining of Ocean Wave Farm Impacts Assessment (2010-2013) The SOWFIA project drew together partners in Europe who have a focus in planned wave farm developments. The aim was to facilitate the development of European wide coordinated, unified and streamlined environmental and socio-economic Impact Assessment (IA) practice for offshore wave energy conversion developments. Wave farm demonstration projects have been studied in each of the collaborating EU countries. Rather than focus on one specific device, this project benefited from the range of wave energy converters (WECs) being tested at each of the wave farm demonstration sites and the staggered time frames. By utilising the findings from technology specific monitoring at multiple sites, SOWFIA aimed to accelerate knowledge transfer and jump start European-wide expertise on environmental and socio-economic IA of large scale wave energy projects. https://ec.europa.eu/energy/intelligent/projects/en/projects/sowfia	University of Plymouth	Intelligent Energy Europe
TERAWATT - As part of the licensing arrangements for wave and tidal arrays, environmental effects in the immediate vicinity of devices and arrays will be addressed in the EIA (Environmental Impact Assessment) process that each developer must undertake. The regulatory authorities need to understand, however, how a number of multi-site developments collectively impact on the physical and biological processes over a wider region. The objectives of TeraWatt are fourfold: Firstly to minimise delays in array licensing by	Heriot Watt Univ, NOC, Marine Scotland	EPSRC

providing answers to 3 specific questions faced by the regulatory authorities, responsible for the licensing of wave and tidal developments; and secondly to collect the methodologies used to answer these into a methods toolbox that can be more widely utilised for such assessments, and in which the marine developer community has confidence. (1)What is the best way to assess the wave and tidal resource and the effects of energy extraction on it? (2)What are the physical consequences of wave and tidal energy extraction? (3) What are the ecological consequences of wave and tidal energy extraction? (4) The assembly of all appropriate methods, their review, and synthesis in a standardised methods toolbox. http://www.supergen-marine.org.uk/supergen-grand-challenges/terawatt		
The Effects of Realistic Tidal Flows on the Performance and Structural Integrity of Tidal Stream Turbines - The project investigates the effects of extreme conditions on marine energy generators when installed as a single device or in arrays or farms. By combining the results of experiments, computer predictions and real life expertise, the research will enable the industry to produce, design and manufacture better tidal stream turbines (TST) that can be optimised to suit the prevailing sea conditions. Deployed devices will need to remotely monitor their condition and manage their operation during their life time. This research will deliver a system that will allow the owners of the devices to remotely monitor their condition and performance to ensure they achieve optimal energy production whilst maximising their life span. This will enable the electricity suppliers using this source of renewable energy to achieve the best possible long term economic performance. Finally, the environmental impact of such installations will be considered to ensure the positioning of these devices is not detrimental to the surrounding sea, coast and seabed. http://www.supergen-marine.org.uk/supergen-grand-challenges/realistic-flows-tidal-turbines	Cardiff University	EPSRC
VECTORS (2011-2015) As the ability of societies to exploit marine resources expands and evolves, the pressures we exert on the marine environment are increasing and diversifying. These resources include traditional goods such as food and emerging benefits including energy. All of our interactions with the ocean, from leisure to transport activities, have individual effects but these pressures can also interact to cause further cumulative impacts.These pressures are driving new and challenging changes in marine ecosystems that are compounded by environmental influences, including climate change. Key changes of concern are: species outbreaks, invasive alien species and changes in the productivity and distribution of commercially important species. Changes in the marine environment are, in-turn, impacting the goods and services that the oceans provide to society, therefore, affecting our use of the sea for leisure and commercial purposes and causing both	Plymouth Marine Labs – 16 countries and 200 researchers	FP7

cultural and economic impacts. The VECTORS project **(VECTORS of Change in European Marine Ecosystems and their Environmental and Socio-Economic Impacts)** has developed integrated, multidisciplinary research-based understanding of these changes, the mechanisms for them and the ecological and socio-economic impacts expected from them. It has also examined the many drivers of change in the marine environment and improved our understanding of the mechanisms by which these pressures cause changes in marine life and how human activity and behaviour propels them. http://www.marine-vectors.eu/About_the_project		
VERTLBASE - Supporting evidence-based decision-making on marine vertebrate interactions with wave and tidal energy technologies - Ambitious plans for the large-scale deployment of wave and tidal energy are underway to meet carbon reduction targets, with the deployment of 1.6GW of generation planned for the Pentland Firth and Orkney Waters (PFOW), and smaller deployments planned off the coast of Wales and Isle of Wight. In parallel, numerous wave and tidal energy technologies are under development by companies ranging from small embryonic SMEs to multinational engineering companies, whilst test sites, including the European Marine Energy Centre (EMEC) have been established, seabed leases awarded by the Crown Estate, and the deployment of the first, small scale, arrays of devices underway. Amongst this race to develop technology and sites, concerns regarding potential interactions between wave and tidal energy devices/developments and marine mammals, seabirds and fish have emerged. These have formed the basis for the NERC/Defra Understanding How Marine Renewable Device Operations Influences Fine Scale Habitat Use and Behaviour of Marine Vertebrates (RESPONSE) (NE/J004251/1; NE/J000884/1). The study has provided new multi-disciplinary perspectives of the issue, from field studies investigating potential interactions, to the risk management challenges it poses across the wave and tidal sector. The project will directly address the challenges associated with potential marine vertebrate interactions by translating the new emerging evidence and lessons learned from the RESPONSE, FLOWBEC and MREKEP risk and uncertainty study, to inform decision-making on this potentially significant risk to the development of the wave and tidal energy sector. Through direct engagement with a community of stakeholders, incorporating device and site developers, regulators, advisory bodies, NGOs and industry associations, the embedding of this evidence in site scoping, technology design, monitoring, mitigation and consenting processes will be a practical outcome of this work.	Cranfield University	NERC
WINSPEC - Wind Turbine Foundation Ultrasonic Spectral Characterisation - WINSPEC will study the feasibility and specification of a marine operated, low frequency modulated ultrasonic 'pulse-echo' method for monitoring the structure and condition of the layered foundations of offshore wind turbines. Numerical modelling and some laboratory testing will be undertaken to evaluate the sensitivity and characteristics of the	British Geological Survey	NERC

spectral response to differing layered model representations of the foundation structure with various condition 'defects' built in. This work will provide experimental and modeled analyses to support a feasibility assessment of the 'pulse-echo' approach, where possible, identifying characteristic acoustic patterns (or signatures) that relate to varying the material properties of the layers and structure of the layered sequence, such as thickness and density and the introduction of inter-layer water. This work will be supported by E.ON Technologies (Ratcliffe) Ltd. who are responsible the maintenance of many of the UK's offshore wind farms such as Robin Rigg in the Solway Firth. These wind farms are national assets; for example Robin Rigg provides 180 MW of power to the National Grid (enough energy for over 100, 000 households). This method could form the basis for a safe, low power technology for deployment on underwater unmanned vehicles for inspecting the inner structure and condition of offshore wind turbine foundations. In so doing, WINSPEC would stimulate a shift towards improved asset inspection technologies supporting preventative interventions maintaining wind farm operation at higher generating capacities.		
X-MED - Extreme Loading of Marine Energy Devices Due to Waves, Currents, Flotsam and Mammal Impact - There is a growing capability and confidence in the loading and performance of marine energy devices in operating conditions as designs rapidly develop. However knowledge of extreme loading is less mature and indeed there is uncertainty about their origin. Tidal conditions are relatively well defined in terms of water levels and mean flows but large scale turbine deployment will have an uncertain effect (not considered here). Tidal flows particularly in areas of high velocity attractive for energy extraction are however bathymetry dependent. For example headlands and islands cause large-scale unsteady eddy structures affecting extreme loads. To complicate matters further tidal turbulence in the horizontal plane has length scales about six times those in the vertical giving a horizontal length scale of about half the water depth, similar to a typical turbine diameter. This will affect extreme loading to an uncertain degree and is not understood. In addition waves superimposed on currents cause unsteadiness which penetrates below the water surface; this may be due to long swell waves or breaking waves where concentrated, generally oblique, vortex structures propagate downwards. http://www.supergen-marine.org.uk/supergen-grand-challenges/xmed	Univ of Manchester	EPSRC

Appendix 4 : Summary of UK funded ORE R&I - work in progress

CROWN ESTATE – Ed Salter	
Offshore Wind Research Coordinating Framework – Review and recommendations	GoBe Consultants
EPSRC	
Supergen Wind – Prof Bill Leithead	
Servo-aeroelastic tailoring of wind turbines using new active-to-passive control systems .	University of Bristol ; Offshore Renewable Energy Catapult; Vestas; DNV GL; (UK);
MAXFARM (MAXimizing wind Farm Aerodynamic Resource via advanced Modelling)	B M T Fluid Mechanics Ltd, Garrad Hassan & Partners Ltd; Offshore Renewable Energy Catapult; Renewable Energy Systems Ltd; SATAPPS Catapult; Sgurr Energy Ltd; Zenotech Ltd; ZephIR Lidar;
Maximising the Carbon Impact of Wind Power	Imperial College, ERP, CCC, National Grid, Circular ecology
Screw piles for wind energy foundation systems	University of Dundee; Cathie Associates, SeaRoc Group, Screwfast Foundations Ltd, Soil Machine Dynamics UK
Supergen marine – Prof Robin Wallace	
EcoWatt2050 – (2014- 2017) aiming to provide underpinning science for the strategic policy development and planning being undertaken by the regulatory authorities for marine renewable energy. Using state of the art hydrodynamic models, and ecological modelling techniques, the project is aiming to better understand the impacts of very large scale marine renewable energy development, and in the context of climate change. http://www.masts.ac.uk/research/ecowatt2050/	Heriot-Watt University Prof Jonathan Side

The Hydrodynamics of Deformable Flexible Fabric Structures for Wave Energy Conversion	University of Plymouth Prof Deborah Greaves
Reducing the Costs of Marine Renewables via Advanced Structural Materials (ReC-ASM)	University of Strathclyde Prof Margaret Stack
All Electrical Drive Train for Marine Energy Converters (EDRIVE-MEC)	University of Edinburgh; Prof Markus Mueller
Response of Tidal Energy Converters to Combined Tidal Flow, Waves, and Turbulence (FloWTurb)	University of Edinburgh; Dr. Venki Venugopal
Dynamic Loadings on Turbines in a Tidal Array (DyLoTTA)	Cardiff University Prof Tim O'Doherty
INNOVATE UK – David Hytch	
LOBSTER GROWER 2 - This project will investigate the use of sea-based container culture (SBCC) as a low-carbon method for rearing lobsters, with no feed costs. Researchers will use containers specifically designed for lobsters, developed in an early stage project, to assess performance and develop holistic application of SBCC systems. Lobster Grower 2 will run a pilot-scale lobster culture site to gather practical, operational, environmental, biological, economic and social data that can be used to develop an aqua-economic model to encourage and inform future investment.	Univ of Exeter CEFAS Padstow Lobster hatchery
Cost Reduction for Offshore Wind Now (CROWN) –	DONG / TWI / Metallisation EDF / Universal coatings / Wilton
Cable Lifetime Enhancement via Monitoring using Advanced Thermal and electrical Infrastucture Sensing	EMEC Ltd, Synaptec Frauhofer

EPICTidal : "Establishing the performance implications of employing lower cost methods for the manufacture of large scale tidal turbine rotors"	Design craft Ltd Cranfield University
INSITE - Influence of man-made structures in the ecosystem – Richard Heard	
Assessing the Ecological Connectivity between man-made structures in the North Sea (EcoConnect)	CEFAS – Dr. Kieran Hyder
Investigating food web effects due to man-made structures using Coupled Spatial Modelling (COSM)	CEFAS - Dr Christopher Lynam
Reef effects of structures in the North Sea: Islands or connections? (RECON)	IMARES, Texel Prof. Dr. Han Lindeboom
Measuring the shadow of artificial structures in the North Sea and its effect on the surrounding soft bottom community	(NIOZ), Texel Prof dr Gert-Jan Reichart
Appraisal of Network Connectivity between North Sea subsea oil and gas platforms" ANChor	Edinburgh University : Dr. Lea-Anne Henry
Influence of Man-Made Structures in the ecosystem: is there a planktonic signal?	SAHFOS – Prof Willie Wilson
UNDerstanding the INfluence of man-made structures on the Ecosystem functions of the North Sea (UNDINE)	Alfred Wegener Institute (AWI), Dr Jennifer Dannheim
Man-made structures and Apex Predators: Spatial interactions and overlap (MAPS)	SMRU, Dr Deborah Russell
MARINE SCOTLAND SCIENCE – Ian Davies / Finlay Bennett	
ECOMMAS east coast marine mammal and underwater noise monitoring study (now in its 5th year)	SAMS/ Aberdeen / St Andrews (SMRU)
West coast MPA monitoring project with EMFF money – commencing May 2017	

COMPASS Interreg project – cetacean and underwater noise monitoring – commencing autumn 2017	
Fate of displaced birds - The aim of this research project is to estimate the cost to individual seabirds, in terms of changes in adult survival and productivity, of displacement or barrier effects resulting from marine licensed activity. It is anticipated that using existing seabird tracking and demographic data, the project will produce a model that estimates the costs of displacement or barrier effects on individuals in terms of changes in adult survival and productivity. The focus species for this project are anticipated to be common guillemot, razorbill, Atlantic puffin, black-legged kittiwake and northern gannet. The lead contractor is CEH and the project is due to be delivered by 31st March 2017. It builds upon previous modelling work on displacement delivered by CEH. See: http://www.gov.scot/Topics/marine/science/MSInteractive/Themes/ceh	CEH
How high do birds fly? – Contract awarded a week ago. LIDAR technology is being trialled as a method for gathering data to estimate the heights at which seabirds fly.	
Apportioning –Producing a GIS tool to allow individuals at sea to be apportioned at appropriate colony. Needed for scoping advice, impact assessments and sectorial planning	CEH awarded contract report due 31st March 2017
Stochastic CRM – building on work done by Masden (see Appx 5) to make more user friendly model, and more usuable outputs.	
Smolts - acoustic tracking - 2 projects are attempting to answer some questions surrounding the direction of smolt migrations around Scotland and the potential interaction with renewable energy devices these fish may have: 1. Moray Firth - Last year MSS deployed and recovered 40 acoustic receivers in the Moray Firth this is currently being written up. 2. Dee - This year we are hopefully deploying 60 acoustic tags in smolts on the Dee and tracking there direction with an array about 4km off the harbour. We will repeat this with the array in various configurations over the next 3 years. We aim to write up and complete everything by the end of 2020.	

Smolts - netting MSS are testing a smolt net for use in the marine environment this year. The aims of this are again to find the migration pathways of smolts emigrating from the rivers to feeding grounds at sea. The net is intended to allow MSS to gather information on the migration of smolts where arrays of acoustic receivers would be difficult to locate.	
Kelts - We have 2 small work packages tracking kelt (salmon that have spawned and are returning to sea) migration from river to feeding grounds. One using satellite tags to find out where kelts go when the return to sea. The other estimating their migration pathways similar to the smolts above using acoustic tags. This work will last approximately 2 years.	
Scottish Shelf Model and other in house MSS hydrodynamic modelling The Pentland Firth and Orkney Waters (PFOW) case study has been used to produce *layers* of tidal stream and wave energy in/around the Orkney Islands at high spatial resolution. The PFOW model has also been used internally to investigate the physical impact of large scale tidal stream developments (contributing to EcoWatt2050) and to investigate the tidal stream resource of the Pentland Firth. The EcoWatt2050 outputs include SSM model runs including large scale energy extraction and/or projected 2050 climate change. These model runs are being used in house to examine biological connectivity between Marine Protected Areas (MPAs) and how this could change due to large scale tidal stream development and climate change. MSS have recently been using an in house model of the Moray Firth to understand the circulation in the Inner Moray Firth to help with the salmon tracking (post consent work) being done by the Renewables and Energy programme. As part of this we have done some simple particle tracking simulations to understand where salmon smolts may go if they were passive particles (no behaviour).	
Power analysis tool Building upon the development in 2013 of the MRSea package that is a statistical model for estimating abundance and distribution, CREEM have been commissioned to develop power analysis software for use with the MRSea package. The aim is to provide a tool for developers to aid in the planning of monitoring programmes. Final report is due for delivery on 31st March 2017.	CREEM
Population metrics CEH were commissioned by Marine Scotland in 2014 to undertake Population Viability Analysis of various seabird colonies. CEH are undertaking a further project which is analysing the sensitivity to miss-specification of various metrics (units of measurement) used to describe changes to populations as outputs of PVA (e.g. growth rate, % decline, number of individuals, x% probability of y% decline). The project	CEH

is aimed at understanding which of these metrics provide reliably robust descriptions, particularly at the magnitudes of change typically associated with regulatory decision making. Final report is due for delivery on 31st March 2017. The results will be applicable to non seabird populations. A separate project is currently due out to tender, which is looking to develop a standardised PVA specifically for use in populations for which there is relatively limited data on demographic rates. The timescale for this project is to be complete before March 2018.	
MMO – Adam Cook	
Trends in Marine Activities in the North West, North East, South East and South West English marine plan regions	ABP mer
NERC – Sophie Laurie	
Improving marine growth estimates using 3D photogrammetry	NE/R014698/1
Radar-model-fusion approach for high-resolution marine resource mapping (RAW Mapping)	NE/R014779/1
Novel low-cost methods for marine mammal and environmental monitoring	NE/R014884/1
Development of a standardised marine mammal monitoring system for the tidal energy industry	NE/R014639/1
Measuring ADD Noise in TIdal Streams (MANTIS): Could Acoustic Deterrent Devices (ADDs) reduce risk of marine mammal collisions with tidal turbines?	NE/R014132/1
Monitoring and forecasting avian collision risk at an operational offshore wind farm	NE/R014701/1
Evaluating the impacts of wind turbines on bat populations	NE/M021882/1

Linking evidence and operation in ecosystem service-based decision support tools	NE/M021505/1
Novel interpretation of oceanographic measurements: Development and application at the Wave Hub demonstration site	NE/M007847/1
Developing an avian collision risk model to incorporate variability and uncertainty	NE/L002728/1
Tracking small cetaceans under water to inform collision risk: developing a tool for industry.	NE/L002795/1
Climate science support for robust decision making in wind energy investments and policies	NE/M008428/1
WINSPEC - Wind Turbine Foundation Ultrasonic Spectral Characterisation	NE/M008444/1
Predictive Tidal Data Products	NE/N009231/1
HydroPinPoint - Optimising the site selection of micro-hydro turbines in rivers in the UK and Overseas	NE/N020790/1
Supporting evidence-based decision-making on marine vertebrate interactions with wave and tidal energy technologies	NE/N01765X/1
Blue Opportunities from the future: knowledge and tools to inform sustainable growth for an integrated terrestrial, coastal and marine zone economy	NE/N017323/1
SWEEP – (2016 – 2019) The new **South West Partnership for Environment & Economic Prosperity (SWEEP)** will enable experts and businesses to work together to solve some of the challenges caused by these natural hazards. This will drive sustainable economic growth, help create new products and services, safeguard jobs and create new employment, improve policies, and enhance the health and wellbeing of people living in the South West. The team will be conducting reviews of, and developing position papers from, existing	Univ of Exeter

information on environmental consenting issues. The reviews will be standardised, presented in an accessible summary format and regularly updated, and will include critical evaluation of, and recommendations from the research. We will also be developing a spatial mapping tool that combines the location of energy resource areas with environmental and socio-economic information.	
OFFSHORE ENERGY SEA projects – John Hartley	
High resolution tagging of west coast Lesser black backed gulls	BTO
Long-term investigation of adult seabird survival to improve population modelling – Pilot study	BTO
Movement and behaviour of gannets: new insights from tagging data on immature birds	University of Leeds
Understanding animal behaviour at tidal turbines – full algorithm development at MeyGen	University of Aberdeen
Confidence in strain gauge data for collision detection on tidal turbines – novel methodology to remove turbulent flow interference	University of Aberdeen
Behavioural responses by seals to offshore energy activities	University of St. Andrews (PhD studentship)
Seal habitat preference and distribution on west and north UK coasts	SMRU
Improving the performance of population effects assessment frameworks through targeted expert elicitation workshops	University of Aberdeen / SMRU
Range dependent characteristics of impulsive sound	SMRU, Cefas, University of Aberdeen
Modelling of received sound levels by marine mammals during geophysical surveys	JASCO
Defining the potential influence of internal waves on offshore energy activities (Phase II)	University of Plymouth
British bivalve identification tools: deep-sea species	National Museum of Wales
Review of seabed sediment characterisations in the North Sea	Hartley Anderson
OFFSHORE WIND ORJIP – Eloise Burnett	
Understanding bird avoidance behaviour within and around a wind farm	
Understanding the efficacy of devices that deter marine mammals from construction zones	
Defining fish spawning populations to determine the impact of piling on fish populations	
SEACAMS – Nicole Esteban (see on line summaries of projects below)	
Use of experimental wave tank for testing equipment	Swansea University with Wave-Tricity

Development of micro-bubble barriers for coastal silt management	Swansea Univ and Frog Environmental
Distribution and identification of fish of conservation importance using hydro-acoustics	Swansea Univ and Tidal Lagoon Power
Ecological engineering to improve coastal biodiversity and resilience	Swansea Univ and Tidal lagoon power
Floating and fixed artificial reefs as biodiversity enhancement in coastal waters	Swansea Univ and Tidal Lagoon Power
Biodiversity enhancement of tidal lagoons using seagrass restoration	Swansea Univ and Tidal Lagoon Power
Modelling sediment transport around Swansea Bay and sandbank systems of the Bristol Channel	Swansea Univand Tidal Lagoon Power
Monitoring of intertidal morpho dynamics around Swansea Bay	Swansea Univ and Tidal Lagoon Power
Assessing the distribution of diving birds in relation to current strength and renewable energy devices	Swansea Univ and Marine Energy Pembs
Assessing the impact of a tidal device on grey seals movements and energy expenditure	Swansea Univ and Marine Energy Wales
Data review and methods development for habitat use by marine mammals	Swansea Univ and Nova Innovations Ltd
Exploring acoustic and photo / video graphic techniques to study marine mammals and their prey at a tidal turbine site	Swansea Univ and Nova Innovations Ltd
Validation of HF radar measurement of wave energy resource	Swansea Univ and Neptune Radar
High resolution assessment of Pembrokeshire wave energy resources	Swansea Univ and Wave Hub
Assisting with site selection for a community tidal turbine project	Swansea Univ and Transition Bro Gwaun
Improving baited video methods for assessing fish around marine renewable energy structures	Swansea Univ and Ocean Ecology
Developing protocols for datacollection handling and analysis in line with NRW requirements for baseline monitoring at a tidal energy site	Swansea Univ and the SeaTrust
SNH – George Lees	
Development and application of a Power Analysis Tool (MS led with SNH contribution)	CREEM
Scottish Government Demonstration Strategy: Trialling methods for tracking the fine scale underwater movements of marine mammals in areas of marine renewable energy development (MS led with SNH contribution)	SMRU
ADVENT - Implications of Mixed Marine Energy Sources for Cultural Ecosystem Benefits - The Bristol Channel-Severn Estuary (BC-SE) will be used as a case study to explore (i) the implications of a mixture of potential marine renewable energy production methods on the cultural ecosystem benefits (primarily for different forms of recreation and residents) and (ii) the extent to which people are willing to trade-off between biodiversity/cultural ecosystem benefits and the need for a clean, affordable, renewable and secure source of energy. http://www.ukerc.ac.uk/programmes/advent/implications-of-mixed-marine-energy-sources-for-cultural-ecosystem-benefits.html#sthash.9n00qw1y.dpuf	Plymouth Marine Laboratory

VATTENFALL	
Salmon and sea trout tracking array will be deployed to determine the migration routes of salmon and sea trout from the rivers Dee, Don and Ythan, all with fisheries of economic value, and assess how these routes relate to the physical marine environment within 10km of the EOWDC.	**The River Dee Trust, Aberdeenshire, and Marine Scotland Science**
Improving understanding of bottlenose dolphin movements along the east coast of Scotland - Project will help to understand the potential impacts of offshore windfarms on bottlenose dolphins, identified individually from photographs of natural markings on their dorsal fins	**SMRU Consulting and University of St Andrews**
Tracking guillemots and razorbills - the project will obtain detailed and accurate data on the year-round movements of adult guillemots and razorbills through collecting movements over a period of several years using small geolocator tags	**MacArthur Green, Glasgow**
The socio-economic impact of offshore wind farms on the human environment - project will investigate how strengthening security of low carbon electricity reduces reliance on imported energy and fossil fuels, whilst contributing to mitigating global climate change, creating employment and stimulating inward investment	**Oxford Brookes University, Oxford**

Appendix 5 – Outputs of R&D : BEIS – OFFSHORE ENERGY SEA, MARINE SCOTLAND SCIENCE, MMO, MSS, NERC, TCE etc.

BEIS Offshore Energy SEA Research

Birds

1. Wakefield ED, Bodey TW, Bearhop S, Blackburn J, Colhoun K, Davies R, Dwyer RG, Green J, Grémillet D, Jackson AL, Jessopp MJ, Kane A, Langston RHW, Lescroël A, Murray S, Le Nuz M, Patrick SC, Péron C, Soanes L, Wanless S, Votier SC & Hamer KC (2013). Space partitioning without territoriality in gannets. *Science* **341**: 68-70.

2. Thaxter C, Ross-Smith V, Burton N, Wade H, Masden E & Bouten W (2013). Connectivity between seabird features of protected sites and offshore wind farms: lesser black-backed gulls and great skuas through breeding, migration and non-breeding seasons. BOU proceedings – Marine Renewables and Birds.

3. Thaxter CB, Ross-Smith VH, Clark JA, Clark NA, Conway GJ, Marsh M, Leat EHK & Burton NHK (2014). A trial of three harness attachment methods and their suitability for long-term use on lesser black-backed gulls and great skuas. *Ringing & Migration* **29**: 65-76.

4. Wade HM, Masden EA, Jackson AC, Thaxter CB, Burton NHK, Bouten W & Furness RW (2014). Great skua (*Stercorarius skua*) movements at sea in relation to marine renewable energy developments. *Marine Environmental Research* **101**: 69-80.

5. Thaxter CB, Ross-Smith VH, Bouten W, Clark NA, Conway GJ, Rehfisch MM & Burton NHK (2015). Seabird-wind farm interactions during the breeding season vary within and between years: A case study of lesser black-backed gull *Larus fuscus* in the UK. *Biological Conservation* **186**: 347-358.

6. Cleasby IR, Wakefield ED, Bearhop S, Bodey TW, Votier SC & Hamer KC (2015). Three-dimensional tracking of a wide-ranging marine predator: flight heights and vulnerability to offshore wind farms. *Journal of Applied Ecology* **52**: 1474-1482.

7. Thaxter CB, Ross-Smith VH, Clark JA, Clark NA, Conway GJ, Masden EA, Wade HM, Leat EHK, Gear SC, Marsh M, Booth C, Furness RW, Votier SC & Burton NHK (2016). Contrasting effects of GPS device and harness attachment on adult survival of lesser black-backed gulls *Larus fuscus* and great skuas *Stercorarius skua*. *Ibis* doi: 0.1111/ibi.12340.

8. Shamoun-Baranes J, van Gasteren H & Ross-Smith V (in press). Sharing the Aerosphere: Conflicts and Potential Solutions, Chapter 18 in Aeroecology, Springer.

9. Ross-Smith V, Thaxter C, Clark N, Shamoun-Baranes J, Bouten W & Burton N (2016). GPS telemetry reveals differences in the foraging ecology of breeding lesser black-backed gulls between three Special Protection Area colonies. BOU Proceedings – Birds in time and space: avian tracking and remote sensing.

10. Thaxter CB, Ross-Smith VH, Clark NA, Bouten W & Burton NHK (2015). GPS telemetry reveals within-wind farm behavior of lesser black-backed gulls during the breeding season. In: Köppel J & Schuster E (eds.) Book of Abstracts (page 65). Conference on Wind energy and Wildlife impacts (CWW 2015), March 10-12, 2015. Berlin, Germany.

11. Thaxter CB (2017). Chapter 15: Tracking and telemetry of marine birds. In: Perrow, M. (ed.) Wildlife and Wind Farms: Offshore Volume 2: Conflicts and Solutions. Conservation Handbooks. Pelagic Publishing.

12. Ross-Smith V, Thaxter CB, Masden EA, Shamoun-Baranes J, Burton NHK, Wright LJ, Rehfisch MM & Johnston A (2016). Modelling flight heights of lesser black-backed gulls and great skuas from GPS: a Bayesian approach. *Journal of Applied Ecology* **53**: 1635-1891.

13. Thaxter CB, Clark NA, Ross-Smith VH, Conway GJ, Bouten W & Burton NHK (submitted). How Many for how Long? The Number of Animals and Duration of GPS Tracking Required to Characterise Area Use of Central-place Foraging Seabirds. *Journal of Wildlife Management.*

Marine mammals (and noise)

14. McClintock BT, Russell DJF, Matthiopoulos J & King R (2013). Combining individual animal movement and ancillary biotelemetry data to investigate population-level activity budgets. *Ecology* **94**: 838-849.

15. Russell DJ, McConnell BJ, Thompson D, Duck CD, Morris C, Harwood, J & Matthiopoulos J (2013). Uncovering the links between foraging and breeding regions in a highly mobile mammal. *Journal of Applied Ecology* **50**: 499-509.

16. Silva MA, Jonsen I, Russell DJF, Prieto R, Thompson D & Baumgartner MF (2014). Assessing performance of Bayesian state-space models fit to Argos satellite telemetry locations processed with Kalman filtering. *PLoS ONE* **9**(3): e92277. doi:10.1371/journal.pone.0092277.

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18. Hastie GD, Donovan C, Götz T & Janik VM (2014). Behavioral responses by grey seals (*Halichoerus grypus*) to high frequency sonar. *Marine Pollution Bulletin* **79**: 205-210.

19. Hastie GD, Russell DJF, McConnell B, Moss S, Thompson D & Janik VM (2015). Sound exposure in harbour seals during the installation of an offshore wind farm: predictions of auditory damage. *Journal of Animal Ecology* **52**: 631–640.

20. Jones EL, McConnell BJ, Smout S, Hammond PS, Duck CD, Morris CD, Thompson D, Russell DJF, Vincent C, Cronin M, Sharples RJ & Matthiopoulos J (2015). Patterns of space use in sympatric marine colonial predators reveal scales of spatial partitioning. *Marine Ecology Progress Series* **534**: 235–249.

21. Russell DJF, McClintock BT, Matthiopoulos J, Thompson PM, Thompson D, Hammond PS, Jones EL, MacKenzie ML, Moss S & McConnell BJ (2015). Intrinsic and extrinsic drivers of activity budgets in sympatric grey and harbour seals. *Oikos* **124**: 1462–1472.

22. Hastie GD, Russell DJF, McConnell BJ, Thompson D & Janik VM (2016). Multiple-pulse sounds and seals: results of a harbour seal (*Phoca vitulina*) telemetry study during windfarm construction. *Advances in Experimental Medicine and Biology* **875**: 425-430.

23. Farcas A, Thompson PM & Merchant ND (2016). Underwater noise modelling for environmental impact assessment. *Environmental Impact Assessment Review* **57**: 114-122.

24. Russell DJF, Hastie GD, Thompson D, Janik V, Hammond P, Scott-Hayward L, Matthiopoulos J, Jones E & McConnell B (2016). Avoidance of windfarms by harbour seals is limited to pile driving activities. *Journal of Applied Ecology* DOI: 10.1111/1365-2664.12678

25. Lucke K, Hastie GD, Jurczynski K, McConnell B, Moss S, Russell DJF, Weber H & Janik VM (2016). Aerial low frequency hearing in captive and free-ranging harbour seals (*Phoca vitulina*) using auditory brainstem responses. *Journal of Comparative Physiology A* **202**: 859-868.

26. Lonergan M, Sparling C & McConnell BJ (submission imminent). Behaviour of harbour seals (*Phoca vitulina*) around an operational tidal turbine.

27. Graham IM, Pirotta E, Merchant ND, Farcas A, Barton TB, Cheney B, Hastie GD & Thompson PM (submission imminent). Responses of bottlenose dolphins and harbour porpoises to variations in piling noise during harbour construction.

28. Russel DJF, Hastie GD, Thompson D, Janik VM, Hammond PS, Scott-Hayward LAS, Matthiopoulos J, Jones EL & McConnell BJ (2016). Avoidance of wind farms by harbour seals is limited to pile driving activities. *Journal of Applied Ecology* **53**: 1642-1652.

Seabed and water column

29. Hastie LC, Pierce GJ, Wang J, Bruno I, Moreno A, Piatkowski U & Robin JP (2009). Cephalopods in the north-eastern Atlantic: species, biogeography, ecology, exploitation and conservation. *Oceanography and Marine Biology: An Annual Review* **47**: 111-190.

30. Howell KL, Davies JS & Narayanaswamy BE (2010). Identifying deep-sea megafaunal epibenthic assemblages for use in habitat mapping and marine protected area network design. *Journal of the Marine Biological Association of the United Kingdom* **90**: 33–68.

31. Oliver PG, Holmes AM, Killeen IJ & Turner JA (2010). Marine bivalve shells of the British Isles (Mollusca: Bivalvia). Amgueddfa Cymru - National Museum Wales.

32. Gafeira J, Long D & Diaz-Doce D (2012). Semi-automated characterisation of seabed pockmarks in the central North Sea. *Near Surface Geophysics* **10**: 303-314.

33. Wasson B & de Blauwe H (2014). Two new records of cheilostome Bryozoa from British waters. *Marine Biodiversity Records* **7**: e123.

MARINE SCOTLAND SCIENCE

Fine-scale harbour seal at-sea usage mapping around Orkney and the north coast of Scotland, E L Jones, S Smout, C Blight, C Sparling and B McConnell

A quality management review of Scotland's sectoral marine plan for tidal energy S Sangiuliano

Refining Estimates of Collision Risk for Harbour Seals and Tidal Turbines B Band, C Sparling, D Thompson, J Onoufriou, E San Martin and N West

Swimming depth of sea trout J Sturlaugsson

The Co-operative Participatory Evaluation of Renewable Technologies on Ecosystem Services (CORPORATES) Scott, B.E., Irvine, K.N., Byg, A., Gubbins, M., Kafas, A., Kenter, J., MacDonald, A., O'Hara Murray, R., Potts, T., Slater, A.M., Tweddle, J.F., Wright, K., Davies, I.M.

Developing an avian collision risk model to incorporate variability and uncertainty Masden, E.

At-Sea Turnover of Breeding Seabirds - Final Report to Marine Scotland Science Searle, K., Butler, A., Mobbs, D., Bogdanova, M., Wanless, S., Bolton, M. and Daunt, F.

O'Hara Murray, R.B., Gallego, A., 2017. A modelling study of the tidal stream resource of the Pentland Firth, Scotland. Renew. Energy 102, 326–340. doi:10.1016/j.renene.2016.10.053. http://marine.gov.scot/information/scottish-shelf-model

Merchant et al. 2016 *Scientific Reports* – journal article using data collected by ECOMMAS project (KB as co-author)

Edwards, EWJ – poster presentation at MASTS Annual Science Meeting, October 2016

Williamson LD – conference talk at MASTS Annual Science Meeting, October 2016

Davies IM – presentation to Oil and Gas UK workshop, on marine mammal research at MSS

Gary Haskins/Denise Risch (SAMS) – conference talk at European Cetacean Society conference, Denmark, 2017 based on ECOMMAS sound recordings

ICES benthos working group publication: Wilding, T. A., Gill, A. B., Boon, A., Sheehan, E., Dauvin, J. C., Pezy, J. P., ... & De Mesel, I. (2017). Turning off the DRIP ('Data-rich, information-poor')–rationalising monitoring with a focus on marine renewable energy developments and the benthos. Renewable and Sustainable Energy Reviews, 74, 848-859. http://www.sciencedirect.com/science/article/pii/S1364032117303295

A review of the use of adaptive management in the context of renewable energy development undertaken by an international group called WREN:

https://tethys.pnnl.gov/publications/assessing-environmental-effects-wren-white-paper-adaptive-management-wind-energy

The reports/deliverables of the completed RiCORE project, funded by H2020, which looked at risk-based consenting of renewable energy technologies are available online. http://ricore-project.eu/downloads/

MMO

MMO (2014). Review of post-consent offshore wind farm monitoring data associated with licence conditions. A report produced for the Marine Management Organisation, pp 194. MMO Project No: 1031. ISBN: 978-1-909452-24-4.
Economic baseline assessment for the North East, North West, South East and South West marine plans (MMO 1119),

A Review of Access to Industry Marine Environmental Data (MMO1098),

Social impacts and interactions between marine sectors (MMO 1060)

South marine plan areas futures analysis (MMO 1039)

NERC

RESPONSE

Peer reviewed publications

Benjamins, S., van Geel, N., Hastie, G., Elliott, J., & Wilson, B. 2016. Harbour porpoise distribution can vary at small spatiotemporal scales in energetic habitats. Deep Sea Research Part II: Topical Studies in Oceanography. DOI:10.1016/j.dsr2.2016.07.002.

Benjamins, S., Dale, A., van Geel, N., & Wilson, B. 2016. Riding the tide: harbour porpoises' use of a moving tidal-stream habitat. Marine Ecology Progress Series 549: 275-288.

Benjamins, S, Dale, A , Hastie, GD , Waggitt, J, Lea, M-A, Scott, B & Wilson, B. 2015, ' Confusion reigns? A review of marine megafauna interactions with tidal-stream environments ' *Oceanography and Marine Biology: An Annual Review*, vol 53, pp. 1-54.

Hastie, GD, Russell, DJ, Benjamins, S, Moss, S, Wilson, B & Thompson, D 2016, 'Dynamic habitat corridors for marine predators: intensive use of a coastal channel by harbour seals is modulated by tidal currents' *Behavioral Ecology and Sociobiology*, vol 70, no. 12, pp. 2161–2174. DOI: 10.1007/s00265-016-2219-7

Hastie, G.D., Gillespie, D., Gordon, J., Macaulay, J., McConnell, B., and Sparling, C.E. (2014). Tracking technologies for quantifying marine mammal interactions with tidal turbines: pitfalls and possibilities. In M. A. Shields, A. I. L. Payne (eds.), *Marine Renewable Energy Technology and Environmental Interactions,* Humanity and the Sea, DOI 10.1007/978-94-017-8002-5_10, © Springer Science+Business Media Dordrecht 2014.

Lepper, P.A. & Robinson S.P., Theobald, P.D., Pangerc, T., 2014 Significance of dynamic variation in renewable energy device noise to background noise levels under varying conditions, OCEANS 2014, St Johns, Canada.

S.P. Robinson and P.A. Lepper, Acoustics and marine renewable energy developments, IEEE Book chapter, (2018)

Scott, BE, Langton, R, Philpott, E, and Waggitt, JJ. (2014) Seabirds and marine renewables: are we asking the right questions? In: Marine Renewable Energy and Environmental Interactions (Eds: M.A. Shields and A. I. L. Payne): Humanity and the Seas, Springer. ISBN 978-94-017-8002-5

Waggitt, JJ., Cazenave, P., Torres, R., Williamson, B. & Scott, BE. (2016). 'Quantifying pursuit-diving seabirds' associations with fine-scale physical features in tidal stream environments'. Journal of Applied Ecology, vol 53, no. 6, pp. 1653–1666. DOI: 10.1111/1365-2664.12646

Waggitt, JJ., Cazenave, PW., Torres, R., Williamson, BJ. & Scott, BE. (2016). 'Predictable hydrodynamic conditions explain temporal variations in the density of benthic foraging seabirds in a tidal stream environment'. ICES Journal of Marine Science, vol 73, no. 10, pp. 2677-2686. DOI:10.1093/icesjms/fsw100

Waggitt, J.J., Bell, P.S., Scott, B.E. (2015). An evaluation of the use of shore-based surveys for estimating spatial overlap between deep-diving seabirds and tidal stream turbines (2015) *International Journal of Marine Energy*, 8, pp. 36-49. DOI: 10.1016/j.ijome.2014.10.004

Waggitt J.J, Scott B.E (2014) Using a spatial overlap approach to estimate the risk of collisions between deep diving seabirds and tidal stream turbines: A review of potential methods and approaches. Marine Policy. 44:90-97 DOI: 10.1016/j.marpol.2013.07.007

Wilson, B., Lepper, PA, Carter, C & Robinson, SP (2014) Rethinking underwater sound recording methods to work in tidal-stream and wave energy sites. In: Marine Renewable Energy and Environmental Interactions (Eds: M.A. Shields and A. I. L. Payne): Humanity and the Seas, Springer. ISBN 978-94-017-8002-5

Papers in preparation/submitted

Hastie, G.D., Russell, D.J.F., Lepper, P., Elliott, J., Wilson, B., Benjamins, S. & Thompson, D. (In review) Harbour seals (*Phoca vitulina*) avoid tidal turbine noise; implications for collision risk. *Journal of Applied Ecology*

Hastie, G.D., Lepper, P., McKnight, C., Milne, R., Russell, D.J.F., & Thompson, D. (In prep) Man-made noise influences the foraging success of seals. *Proceedings of the Royal Society B*

James J. Waggitt, Pierre W. Cazenave, Ricardo Torres, Benjamin J. Williamson, Beth E. Scott (2018) Predictable hydrodynamic conditions explain temporal variations in the density of benthic foraging seabirds in a high tidal energy environment" . *ICES Journal of Marine Science.*

Hastie, G.D., Jepp, P., Coram, A., Gordon, J., Macaulay, J., Bivins, M., Gillespie, D., Sparling, C.E. & McConnell, B. (In prep) Three-dimensional movements of harbour seals in a tidally energetic channel: application of multibeam imaging sonar. *Marine Biology.*

Reports

Lepper, P. A 2014 Review of current knowledge of underwater noise emissions from wave and tidal stream energy devices, Crown Estate Report, 2014.

Lepper, P. A 2014 Underwater Acoustic Monitoring at Wave and Tidal Energy Sites: Guidance Notes for Regulators, EMEC report for Scottish Government, 2014

Good Practice Guide for Underwater Noise Measurement, National Measurement Office, Marine Scotland, The Crown Estate, Robinson, S.P., Lepper, P. A. and Hazelwood, R.A., NPL Good Practice Guide No. 133, ISSN: 1368-6550, 2014.

Presentations @ international meetings

All in : Proceedings of the 2nd International Conference on Environmental Interactions of Marine Renewables (EIMR 2014), 28 April – 02 May 2014, Stornoway, Isle of Lewis, Scotland.

Eliot, J., Advances in studying vocalising cetaceans in energetic coastal sites using moored and drifting passive acoustic detectors. (Poster)

Hastie, G. Movement patterns of seals in tidally energetic sites: Implications for renewable energy development.

Jude, S.R. Marine Vertebrate Interaction Risk Management Challenges.

Jude, S.R. Co-chaired workshop on Managing Risk: from generic risk management to developer's perspectives.

Thompson D., Tagging methods for tracking marine animals to inform collision risk assessment.

Waggitt JJ, Scott BE, Williamson BJ, Cazenave P, Torres R, Bell PS. A combination of empirical and modelled datasets reveals associations between deep diving seabirds and oceanographic processes at fine spatiotemporal scales in a high energy habitat.

Wilson, B., Marine mammals and tidal turbines: What are the issues of concern and how are they being resolved?

Benjamins, S., Hastie, G.D., Elliot.J, Thompson,D., Arne, Vogler & Wilson, B. (2015). Small-scale spatiotemporal heterogeneity in harbour porpoise site usage. 21st Biennial Conference on the Biology of Marine Mammals. 13-18 December 2015. San Francisco.

Bryant,E., Brodin,G., Thompson,D., Gordon, J. & Blight,C. (2015). A real time tracking system for acoustic disturbance studies of marine animals equipped with UHF linked Fastloc GPS tags. 21st Biennial Conference on the Biology of Marine Mammals. 13-18 December 2015. San Francisco.

Butler, M. A., Lepper, P. A., Pomeroy, S. C., & Norris, J. (2015). Acoustic Monitoring of Marine Energy Devices. In *European Wave and Tidal Energy Conference EWTEC2015*. Nantes, France.

Gordon, J., Bryant,E., Brodin,G., Blight,C. & Thompson,D. (2015) At Sea Controlled Exposure Experiments Reveal Responses of Harbour Seals to Mitigation Signals. 21st Biennial Conference on the Biology of Marine Mammals. 13-18 December 2015. San Francisco.

Hastie, G.D., Benjamins, S., Moss, S.E., Russell, D.J.F., Wilson, B. & Thompson,D. (2015). Dynamic habitat corridors for marine mammals; intensive use of a coastal channel by harbour seals is modulated by tidal currents. 21st Biennial Conference on the Biology of Marine Mammals. 13-18 December 2015. San Francisco.

Hastie,G., Wilson, B., Lepper, P. & Thompson,D. (2015). Behavioural responses by harbour seals to simulated tidal turbine sounds. 21st Biennial Conference on the Biology of Marine Mammals. 13-18 December 2015. San Francisco.

Hastie, G., Sparling,C., Gillespie,D., McConnell,B., Thompson,D., Bromley, P. & Boake, C. (2015) Issues at the interface of engineering and ecology. *MAST Annual Science Meeting Glasgow;*
1st October 2015

Paul Lepper, Helen Smith, Cumulative operational noise of large-scale arrays of offshore wind farms, OCEANOISE 2015 conference, Villanova, May 2015.

Paul Lepper, Stephen Robinson, Pete Theobald, Tanja Pangerc, Towards standards for measurement of radiated underwater noise from marine energy system: An update, Institute of Acoustics 40th Anniversary conference, Birmingham, October 2014.

Lepper, P.A. & Robinson S.P. 2014 Methods for measurement of long term radiated noise from a wave energy system, Underwater Acoustics Conference, Rhodes, 2014

Milne,R., Hastie,G., Lepper, P.P., McKnight, C., Russell, D.J. & Thompson,D. (2015). The influence of man-made noise on the foraging efficiency of seals. 21st Biennial Conference on the Biology of Marine Mammals. 13-18 December 2015. San Francisco.

Waggitt JJ, Armstrong E, Bell PS, Blondel Ph, Cazenave P. Hall C, Torres R, Williamson BJ, Scott BE. Using concurrent predator, prey and oceanographic information to understand seabird foraging distributions at fine spatio-temporal scales. Poster presentation at the 12th International Conference Of The Seabird Group, 21-23 March 2014, Oxford University, UK.

World Seabird Conference Symposium Cape Town, South Africa, October 26 – 30, 2015 at the Cape Town International Convention Centre 2015 Poster and Talk

TALK An importance of tidal stream energy among coastally foraging seabirds highlights indirect impacts of tidal stream turbine arrays James J. Waggitt ; Pierre W. Cazenave; Paul Bell ; Ian Davies ; Ricardo Torres ; Benjamin J. Williamson; P. Miller; J. Bowcott; Beth E. Scott.

POSTER Comparative studies reveal inconsistencies in seabirds' use of tidal pass habitats at a regional scale Waggitt, J.J.; Robbins, A.M.C. ; Wade, H. M. ; Masden, E. A ; Furness, R.W. ; Jackson, A.C. ; Mackay, Z. ; Scott, B.E.

2015 EWTEC (11th European Wave and Tidal Conference, Nantes, France 8-11 Sept 2015

CONFERENCE PAPER Understanding seabird species fine scale distributions in high-energy environments to predict interactions with wave and tidal stream turbines. James J. Waggitt, Paul S. Bell, Pierre W. Cavenaze Shaun J. Fraser, Ricardo Torres, Benjamin J. Williamson, Beth E. Scott

Wilson, B; Marmo, BA; Lepper, PA; Risch D., A framework to predict, validate and review the acoustic footprints of operating tidal turbines, OCEANOISE 2015 conference, Villanova, May 2015.

Ben Wilson & Ian Bryden Marine mammals and tidal stream turbines: what are the issues of concern and how are they being resolved? 3rd International symposium on energy challenges and mechanics-towards a big picture, 7-9 July, 2015 Aberdeen.

FLOWBEC

Scott, Beth, Philpott, Evelyn, Langton, Rebecca and Waggitt, James, 2012. Seabirds and marine renewables: Are we asking the right questions? The Environmental Interactions Of Marine Renewable Energy Technologies, EIMR International Conference, 1 - 3 May 2012, Kirkwall, Orkney.

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Bell, Paul; Lawrence, John; Norris, Jennifer. 2012 Determining currents from marine radar data in an extreme current environment at a tidal energy test site. In: *Proceedings of the IEEE International Geoscience and Remote Sensing Symposium 2012.* IEEE, July 22-27 2012, Munich.

Proença, B., Conley, D. & D. Greaves, 2012, "Initial Evaluation of a WERA HF Radar as a Resource Assessment Tool for Wave Energy". Proc. Intl. Conf. on Ocean Energy, Dublin

Blondel PH & Williamson BJ 2013. Long term multibeam measurements around a tidal turbine test site in Orkney, Scotland. Proceedings of the Institute of Acoustics, Institute of Acoustics Spring Conference, Nottingham, 13 May 2013, Vol 35 Pt 1. p. 322-329.

Waggitt J.J., Lieber L. Williamson B.,Blondel Ph., Brierley A., Fernandes P.G., Jones C.S., Noble L.R.,Scott B.E. Novel uses of Hydroacoustic Methods to record fine-scale Predator-Prey interactions in marine habitats. Poster presentation at the MASTS ASM. 27th-29th August 2013. Heriot-Watt University Conference Centre, UK.

Waggitt J.J.,Williamson B.,Bell P.S.,Blondel Ph., Scott B.E. Understanding seabird behaviours in high energy habitats: concurrent collection of physical and biological datasets. Oral presentation at the MASTS ASM. 27th-29th August 2013. Heriot-Watt University Conference Centre, UK.

Ian G.C. Ashton, Joana Van Nieuwkoop, Helen C.M. Smith, Lars Johanning, George H. Smith, Detailed resource assessment, including intra-site variability, for marine renewable energy. In proceedings of the 10th European Wave and Tidal Energy Conference, Aalborg, Denmark 2-5th Sep 2013

Lopez, G., Conley, D.C., Greaves, D. and D. Magagna, 2013, "Adjusting an Empirical algorithm for Extracting Wave Height from HF Radar", In proceedings of the 10th European Wave and Tidal Energy Conference 2013, Aalborg, Denmark 2-5th Sep 2013

Waggitt J.J., Williamson B.,Bell P.S.,Blondel Ph., Scott B.E. Using a multi-disciplinary approach to quantify spatial overlap between deep diving seabirds and tidal stream turbines. Oral presentation at the ICES ASM. 23rd-27th September 2013. Harpa Conference Centre, Reykjavík, Iceland

Waggitt J.J, Allcock, Z.; Robbins A.M,C.; Wade H.; Bell, P.S.; Scott B.E.; Masden, E.A.; Jackson, A.C ;Furness, R.W. The importance of collaborative research when making government level decisions: an example with top predators and marine renewable energy installations. Oral/Poster presentation at the ICES ASM. 23rd-27th September 2013. Harpa Conference Centre, Reykjavík, Iceland

B.J. Williamson, P.S. Blondel, J. Waggitt, P.S. Bell, B.E. Scott (2013). FLOWBEC: Long-term measurements of the environment around marine renewable energy devices. Poster and short talk at the ICES Annual Science Conference, 2013.

Waggitt, J.J.; Williamson, B.J.; Blondel, Ph.; Bell, P.S.; Scott, B.E. (2013) Investigating seabird associations with fine-scale hydrodynamic processes: how do individuals search for foraging opportunities. Poster presentation at the Movement and Dispersal Conference, Aberdeen University, 11-12 November 2013

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Waggitt JJ, Scott BE, Williamson BJ, Cazenave P, Torres R, Bell PS. (2014) A combination of empirical and modelled datasets reveals associations between deep diving seabirds and oceanographical processes at fine spatiotemporal scales in a high energy habitat. Proceedings of the 2nd International Conference on Environmental Interactions of Marine Renewable Energy Technologies (EIMR2014), 28 April – 02 May 2014, Stornoway, Isle of Lewis, Outer Hebrides, Scotland.

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Jack P.J. O'Carroll, Robert M. Kennedy, Angus Creech, Graham Savidge, (2014) FLOWBEC: Assessing spatial variation in epifaunal communities in response to flow modification by a tidal stream turbine. Poster Presentation, Proceedings of the 2nd International Conference on Environmental Interactions of Marine Renewable Energy Technologies (EIMR2014), 28 April – 02 May 2014, Stornoway, Isle of Lewis, Outer Hebrides, Scotland.

P. W. Cazenave, R. Torres (2014) , Modelling the coastal and nearshore zones with the FVCOM unstructured model. Challenger conference special interest group for Coastal and Nearshore Processes.

P. W. Cazenave, R. Torres, I. Allen (2014) , Offshore renewable energy device impacts on seasonally stratified seas around the UK: an unstructured modelling approach. Partnership for Research in Marine Renewable Energy (PRIMARE) 1st Annual conference, 4-5 June 2014, Plymouth

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Waggitt J.J., Bell P.S. & Scott B.E. (2014) An evaluation of the use of shore-based surveys for estimating spatial overlap between deep-diving seabirds and tidal stream turbines. International Journal of Marine Energy. (in Press) DOI: 10.1016/j.ijome.2014.10.004.

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Ocean Business : Special Session on Wave and Tidal energy - Update on technology and tools to de risk and streamline development, Seminar room, NOC Southampton SO14 3ZH, Thursday April 16th 2015, 12 til 6pm:

Paul Bell and David McCann – Application of X band radar for resource assessment : case studies from EMEC and the Inner Sound, Pentland Firth;

Benjamin Williamson and Beth Scott – Development of the FLOWBEC rig – monitoring wildlife interactions with tidal turbines;

Paul S. Bell, David L. McCann, John Lawrence, Jennifer V. Norris, 2015, Remote Detection of Sea Surface Roughness Signatures Related to Subsurface Bathymetry, Structures and Tidal Stream Turbine Wakes. 11th European Wave and Tidal Energy Conference (EWTEC 2015), Nantes, France, 6-11 September

Benjamin J. Williamson, Philippe Blondel, Shaun J. Fraser, James J. Waggitt, Paul S. Bell, Beth E. Scott, 2015, Field deployments of the self-contained FLOWBEC platform for acoustic monitoring of the environment around Marine Renewable Energy structures. 11th European Wave and Tidal Energy Conference (EWTEC 2015), Nantes, France, 6-11 September 2015

James J. Waggitt; Pierre W. Cazenave; Paul Bell ; Ian Davies ; Ricardo Torres ; Benjamin J. Williamson ; P. Miller ; J. Bowcott ; Beth E. Scott. An importance of tidal stream energy among coastally foraging seabirds highlights indirect impacts of tidal stream turbine arrays, Oral presentation at the 2nd World Seabird Conference, Cape Town, 26th-30th October 2015.

Waggitt, J.J.: Robbins, A.M.C. ; Wade, H. M. ; Masden, E. ; Furness, R.W. ; Jackson, A.C. ; Mackay, Z. ; Scott, B.E. Using comparative studies to test for consistencies in seabirds' spatial and temporal use of tidal pass habitats in Scotland, UK. Poster presentation at the 2nd World Seabird Conference, Cape Town, 26th-30th October 2015.

Waggitt, J.J. ; Cazenave, P.; Torres, P.; Williamson, B.J.; Scott, B.E., (2016), Quantifying pursuit diving seabirds' associations with fine-scale physical features in a high tidal energy environment. Journal of Applied Ecology. DOI: 10.1111/1365-2664.12646

Waggitt, J.J., (2016), 'Seabirds, Cetations and Tidal Energy', Guest Speaker at the RSPB Seabird Centre, South Stack, 16th January 2016

Meygen Newsletter, February 2016 , including FLOWBEC Project Update - FLOWBEC frame successfully deployed and recovered during October-November 2015

Williamson, B.J.; Fraser, S.; Blondel, Ph., Bell, P.S., Waggitt, J.J., Scott, B.E., (2016), 'Integrating a multibeam and a multifrequency echosounder on the FLOWBEC seabed platform to track fish and seabird behaviour around tidal turbine structures'. 4th Annual Marine Energy Technology Symposium (METS) 2016, 25-27 April 2016, Washington D.C., USA. WINNER OF BEST PRESENTATION AWARD!

Waggitt, J.J., Cazenave, P.W., Torres, R., Williamson, B.J., Scott, B.E., (2016), Predictable hydrodynamic conditions explain temporal variations in the density of benthic foraging seabirds in a tidal stream environment ICES J. Mar. Sci. DOI: 10.1093/icesjms/fsw100

S. Fraser, V. Nikora, B.J. Williamson, B.E. Scott (2016). Characterising turbulence in a tidal channel using observations from seabed platform deployments. Challenger Society for Marine Science 16th Biennial Conference. Liverpool, UK, September 2016. WINNER: NORMAN HEAPS PRIZE FOR BEST EARLY CAREER ORAL PRESENTATION!

B.J. Williamson, S. Fraser, Ph. Blondel, P. Bell, J.J. Waggitt, B.E. Scott (2016). Integrating a multibeam and a multifrequency echosounder on the FLOWBEC platform to track fish and seabird behaviour around tidal turbine structures. Challenger Society for Marine Science 16th Biennial Conference. Liverpool, UK, September 2016.

B.J. Williamson; S. Fraser 2; Ph. Blondel; P.S. Bell; J.J. Waggitt; B.E. Scott, (2016), Multi-Sensor Acoustic Tracking of Fish and Seabird Behavior Around Tidal Turbine Structures in Scotland, UK Accepted for publication in IEEE J.Oceanic Engineering

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Adams, T., Wilson, B., Hastie, G. & Lepper, P., 2014. Sticking together: movement of marine mammals and response to underwater noise. Proc. 2nd International Conference on Environmental Interactions of Marine Renewable Energy Technologies (EIMR 2014), 28 April – 02 May 2014, Stornoway, UK.

Adams, T., Wilson, B., Hastie, G. & Lepper, P., 2014. Sticking together: simulating movement of marine mammals and response to underwater noise. *Journal paper in preparation.*

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Smith, H.C.M, 2014. Modelling changes to physical environmental impacts due to wave energy array layouts. *Proc. 2nd International Conference on Environmental Interactions of Marine Renewable Energy Technologies (EIMR 2014)*, 28 April – 02 May 2014, Stornoway.

Smith, H.C.M. (2015) EBAO - Optimising Array Form for Energy Extraction and Environmental Benefit. Report of NERC / DEFRA project involving universities of Loughborough, Edinburgh, Exeter, CEFAS, SAMS and SMRU. 15p.

van der Molen, J., Rees, J. & Limpenny, S., 2013. Modelling potential changes in marine biogeochemistry due to large-scale offshore wind farms. *Geophysical Research Abstracts*, vol. 15, EGU2013-7233.

van der Molen, J., Smith, H.C.M., Lepper, P., Limpenny, S. & Rees, J., 2014. Predicting the large-scale consequences of offshore wind turbine array development on a North Sea ecosystem. *Continental Shelf Research,* 85, p.60-72.

van der Molen, J., van Leeuwen, S., Farcas, A., Limpenny, S. & Rees, J., 2014. Modelling hydro-biogeochemical effects of an offshore wind array. *AMEMR IV*, 30 June - 04 July 2014, Plymouth, UK.

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Hattam, C., Hooper, T. and Papathanasopoulou, E. 2015. 'Understanding the Impacts of Offshore Wind Farms on Well-Being', The Crown Estate, 77 pages, ISBN: 978-1-906410-65-0

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Good Practice Guide for Underwater Noise Measurement, National Measurement Office, Marine Scotland, The Crown Estate, Robinson, S.P., Lepper, P. A. and Hazelwood, R.A., NPL Good Practice Guide No. 133, ISSN: 1368-6550, 2014.

Guerin, A.J., Jackson, A.C., Bowyer, P.A. and Youngson, A.F. 2014.
'Hydrodynamic models to understand salmon migration in Scotland.' The Crown Estate, 116 pages. ISBN: 978-1-906410-52-0.

Saunders, J., Tinch, R., and Hull, S. (2010). Valuing the Marine Estate and UK Seas:

An Ecosystem Services Framework. The Crown Estate, 54 pages, March 2010. ISBN: 978-1-906410-15-5.

Saunders, J., Tinch, R., Ozdemiroglu, E. and Hull, S. (2010). Valuing the Marine Estate and UK Seas: Initial Static Baseline Assessment. The Crown Estate, 50 pages, 2010. ISBN: 978-1-906410-17-9.

Appendix 6 : UK PhD students and CASE awards

Student	Topic	Supervisors
Nils Piechaud 2015-2018	"The application of autonomous underwater vehicles to challenges in marine habitat mapping and predictive species distribution modelling."	Kerry Howell
Kirsty McQuaid 2015-2019	"The application of predictive modelling to marine spatial planning associated with deep-sea mining."	Kerry Howell
Leah Trigg 2016-2018	'Do marine mammals react to shipping noise? Assessing the exposure and behavioural response of grey seals to shipping noise'.	Clare Embling
Laura Williamson 2016-2018	"Spatio-temporal variation in harbour porpoise distribution and activity"	Paul Thompson, Beth Scott, Kate Brookes
Marianna Chimienti	Modelling FORaging STrategies In high energy Environments (FORSITE).	Beth Scott, Justin Travis Ellie Owen (RSPB) , Mark Bolton (RSPB), Dr Ian Davies
Sue Ranger (SAMS /UHI 2015-2020)	"Advancing methods for valuing cultural ecosystem services: A subjective well-being approach"	
Lucy Greenhill (SAMS / UHI 2014-2019)	'Evaluating marine planning approaches as a means to achieve sustainable marine development."	
Jacob Ainscough (SAMS U of Edinburgh, 2015-2019)	"From Arran to Arnavon: Dynamics of ecosystem service trade-offs and trajectories of environmental change of community based Marine Protected Areas"	
Lina Isacs (Royal Institute of	"Shared values: Challenging the boundaries of environmental economic valuation through deliberation, a comparison of marine and forest contexts"	

Technology Gothenburg, 2015-2018)		
Derek Purdy (University of New England, 2012-2016	"A cultural value for seagrass meadows in aquatic agricultural systems : Implications for aquaculture development projects"	
Katherine Whyte, University of St Andrews.	"Behavioural responses by seals to offshore energy activities".	Gordon Hastie, Debbie Russell, Len Thomas, Carol Sparling
Joe Onoufriou, University of St Andrews.	"Effects of tidal turbines on the movements of marine predators in tidally energetic areas".	Gordon Hastie Dave Thompson Liz Masden, Jared Wilson, John Baxter (SNH).
Gemma Veneruso, Bangor University.	"Investigating disturbance of small cetaceans from offshore anthropogenic developments".	Gordon Hastie, Line Cordes Lewis LeVay (Bangor).
J.Chris McKnight, University of St Andrews.	'Effects of tag attachment in a large marine vertebrate"	Debbie Russell Dave Thompson and Sophie Brasseur.
Matt Carter, University of Plymouth	"How do grey seal pups learn how to forage? Using telemetry data to understand development of foraging behaviour in relation to oceanography and potential disturbance". .	Debbie Russell Clare Embling, Phil Hosegood Kimberley Bennett
Milad Moghtadaei (Abdolmajid) 01/03/2018	*Fatigue assessment of composite blades of offshore wind turbines*	Bryden Centre
Heidi Schjøll Brede 2018-21	*Numerical method for Dynamic Analysis of Offshore Renewable Energy(ORE) devices*	Bryden Centre
Nuala Carr	*Transitioning towards socially acceptable use of the Marine Renewable energy in Ireland and Northern*	Bryden Centre

2017 – 20	*Ireland (working title)*	
Joanne Mitchell 2018 – 21	*An offshore wind turbine mechanical-power electronic coupled fault diagnostic tool*	Bryden Centre
Rowland Fraser 2018-21	*Develop a multi-disciplinary optimisationa method for application to the automotive, Energy and Environmental sectors*	Bryden Centre
Emma Whettall 2018-21	*Community scale tidal power generation – is it feasible in the INTERREG VA area?*	Bryden Centre