EIMR 2014

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

EIMR INTERNATIONAL CONFERENCE

Environmental Interactions of Marine Renewable Energy Technologies

28 April – 02 May 2014

Stornoway | Isle of Lewis | Scotland

The EIMR2014 organising committee would like to thank the following sponsors of the conference: University of the Highlands and Islands (UHI), Comhairle nan Eilean Siar, Visit Scotland, Highlands and Islands Enterprise (HIE), the Natural Environment Research Council (NERC), Marine Scotland Science (The Scottish Government), the U.S. Department of Energy with the Pacific Northwest National Laboratory and Annex IV initiative and Lews Castle College UHI. Our thanks also go to all members of the scientific steering group and other contributors to the event as are represented by the logos on this page.

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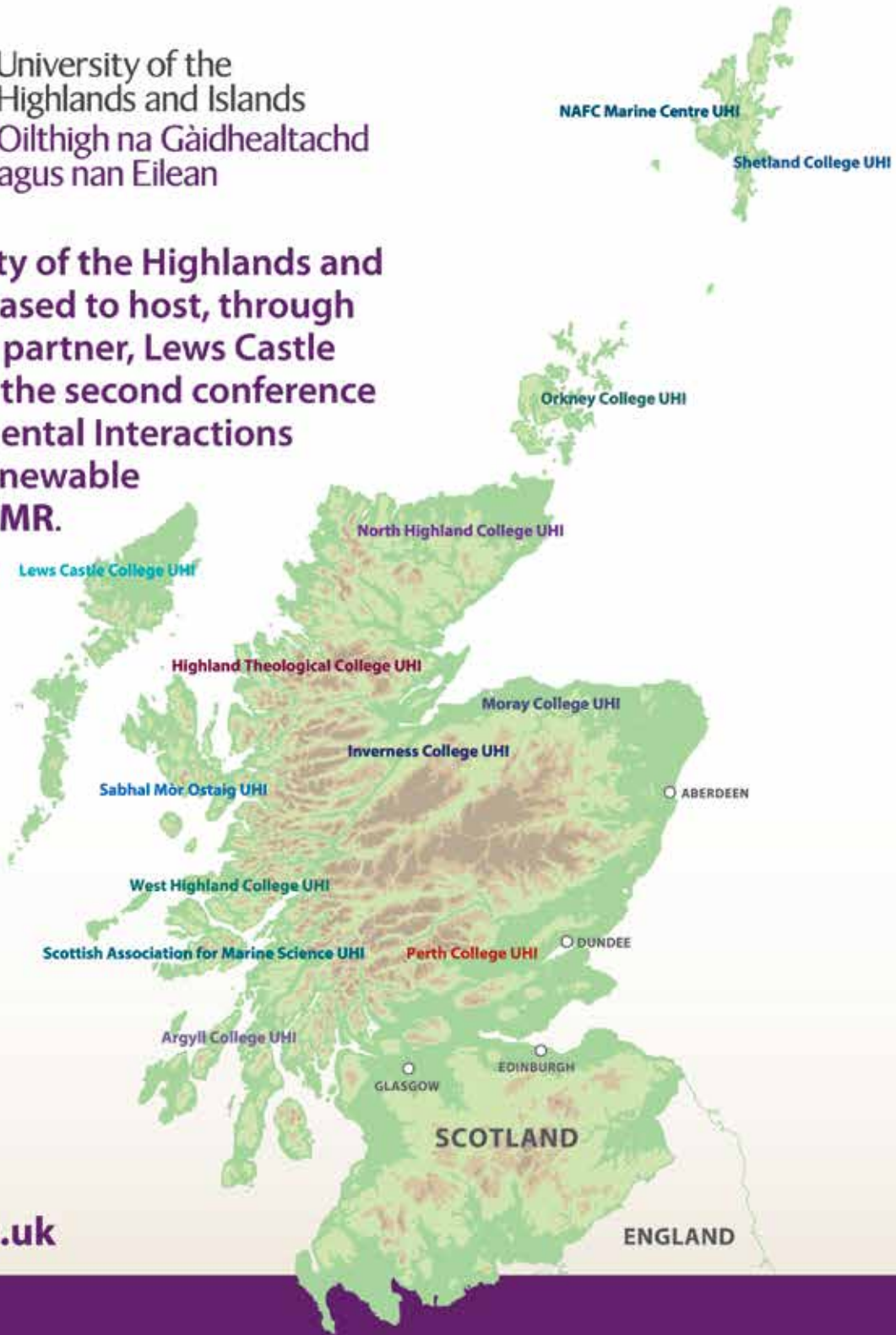
University of the Highlands and Islands
Oilthigh na Gàidhealtachd agus nan Eilean

The University of the Highlands and Islands is pleased to host, through its academic partner, Lews Castle College UHI, the second conference on Environmental Interactions of Marine Renewable energies – EIMR.



www.uhi.ac.uk

The University of the Highlands and Islands extends across thirteen different campuses and includes in this partnership the **Scottish Association of Marine Science UHI** (SAMS) at Dunstaffnage, Oban, the **Environmental Research Institute** (North Highland College UHI) at Thurso, Caithness and Lews Castle College UHI in Stornoway, the Isle of Lewis.

These organisations are located on the door-step of some of Europe's major potential sources of renewable energy, and are undertaking research into the potential for meeting future energy needs from the sea and the environmental interactions that may arise from the development of marine sources of energy.

Failte gu Eilean Leodhais agus Steornabhagh!
Welcome to the Isle of Lewis and Stornoway!

Arne Vögler

PI Marine Energy Research, University of the Highlands and Islands (Lews Castle College)

Almost exactly on the day two years ago many of us came together in Orkney at the inaugural conference on 'Environmental Interactions of Marine Renewable Technologies'. Immediately after the successful delivery of EIMR2012 in Kirkwall, and still influenced by a wealth of both interesting and relevant presentations, workshops and discussions commenced to repeat this international conference in a biennial cycle.

Many marine energy activities and developments continue to take place in Pentland Firth and Orkney waters and the time since the last EIMR conference has seen an abundance of monitoring, measuring and modelling activities around energy installations. This conference, together with the associated workshops, will serve as a platform to disseminate results of recent undertakings and will allow the global research community to exchange knowledge and ideas to prepare the ground for future activities.

A wide range of marine energy related activities has taken place in other parts of the world too, and this is also very true for other parts of the Highlands and Islands of Scotland.

The world's largest fully consented wave power project is based on the Outer Hebrides off the Isle of Lewis and successful long term sensor deployments have helped to enhance the understanding of the physical processes along a coastline with one of the best wave resources globally.

But the coastline is not only extremely energetic, it also features picturesque scenery with spectacular beaches, rugged cliffs made of Lewisian gneiss, dynamic machair lands and a large variety of birds and creatures of the sea. And if there are clouds and rain, the stunning rainbows and amazing light reflections in the area will give you a truly memorable island experience any day!

I would like to offer a personal welcome to EIMR2014 in Stornoway and trust that together we will build on the success of the previous event to further our knowledge and enable marine energy activities to progress fully through to the commercial stages at a steady pace.

Tha mi an Dòchas gum bi tìde mhath agaibh!

Have a good time!

Welcome

Professor Ian Bryden

Vice Principal (Research)/ Associate Principal (Specialist Colleges), University of the Highlands and Islands

Not far from here, the west coast of Lewis is one of the most energetic coastlines in the world, experiencing waves driven by westerly winds acting on the massive fetch of the North Atlantic. In future years, I fully expect to see a burgeoning wave power industry developing on these islands. Elsewhere, tidal currents offer significant opportunities for economic development, especially within the Pentland Firth, Orkney, Shetland and the Inner Hebrides.

The University of the Highlands and Islands is located across the most promising territory for the economic development of wave and tidal current energy. The marine environment is fragile, however, and it is essential that development is in harmony with that environment and the communities which depend upon it. This requires enhanced understanding of the relationships between technology and ecological and social processes. These processes cover a broad domain of time scales. Some have immediate consequences, while others relate to prolonged activity. Accommodating such a range of time scales is always a challenge, especially when set against external influences such as climate variability.

Defining the geographic extent of interactions is also non trivial. Some are local, while others could extend over many tens or even hundreds of kilometres! We are dealing with interactions which are multi-scale and require interdisciplinary analysis if they are to be understood. This is simultaneously a challenge and an opportunity to project developers and researchers.

The EIMR2014 conference will allow delegates to hear about research from the leading edge of marine energy development and participate in the ongoing debates on how development can be optimised for environmental benefit.

Angus Campbell

Councillor/Council Leader,
Comhairle nan Eilean Siar

On behalf of Comhairle nan Eilean Siar, I am pleased to welcome you to the Outer Hebrides for EIMR2014.

It is fitting that the Outer Hebrides have been chosen to host this conference given the wealth and abundance of our natural marine resources, combined with our emerging expertise in marine energy research and deployment. The West Coast of Lewis is the proposed site for the world's largest fully-consented wave energy project, the 40MW Aquamarine proposal, and has the building blocks in place to actively support the sector through research capabilities at Lews Castle College UHI, device fabrication facilities at Arnish in Stornoway and an active supply chain.

As a local authority, we are keen to support the development of renewable energy technologies not just because of the potential economic benefits it could bring to our islands but also because, as an island chain with the highest levels of fuel poverty in the UK, we understand the potential consequences of increasing energy demands, finite resources and climate change.

There are significant challenges ahead as we all seek to work together to harness our marine resources and develop these emerging technologies in order to balance our future energy needs against the complex dynamics within our marine environment. I hope this conference will give an opportunity to discuss these challenges and share emerging ideas on tangible solutions.

Finally, Lewis and Harris were recently voted 'best island in Europe' by Trip Advisor and I hope that while you are here you have the opportunity to sample our stunning natural environment, rich culture and heritage and Hebridean hospitality.

Andrea Copping

Research Lead for Pacific Northwest National Laboratory, US

From the perspective of the marine energy research community in the United States, this is the foremost conference that specifically addresses potential environmental effects of wave and tidal development worldwide. For many of us who attended the conference two years ago, in addition to a really informative program, we were able to connect with colleagues from other nations, meet many of the practitioners we knew only by name, and engage in discussions that informed our research directions since the 2012 meeting.

This year EIMR2014 will also host a workshop sponsored by Annex IV. This international collaborative initiative was created by the 20 member nations of the Ocean Energy System (under the International Energy Agency) to investigate and share information on environmental effects of marine energy development, to learn collectively about effective monitoring programs and mitigation strategies, to enable governments to appropriately oversee the developing industry, and to allow developers to understand the science needed to support siting and permitting of their devices. Annex IV is entering a second 3-year term; we see this workshop and the gathering at EIMR as an important touchpoint for furthering our work. The workshop, to be held April 29th, will focus on best practices for monitoring around marine energy devices.

The excellent science, intense collegial discussions, and wonderful Scottish hospitality combine to generate a lot of interest in participating in EIMR from our side of the pond. I hope to welcome all of you to the event in Stornoway.

Sincerely,

Andrea Copping

Brian Polagye

University of Washington, Northwest National Marine Renewable Energy Center, Seattle, WA

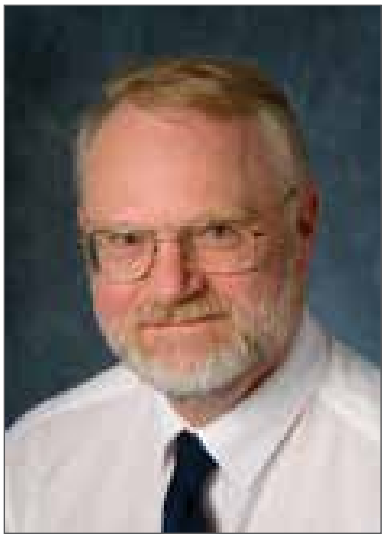
While there are many conferences where one can learn about marine energy, EIMR is the only meeting focused solely on the environmental compatibility of these emerging energy generation technologies.

Having missed the inaugural EIMR meeting in 2012 (and spent the last two years regretting the missed opportunity), I am delighted to be involved this time around and look forward to several days of productive discussion this April in the natural splendor of the Outer Hebrides.

I am particularly excited to have the chance to hear first-hand about the progress being made by my European colleagues and to explore opportunities for international collaboration that moves marine renewable energy forward in a sustainable, responsible manner.

Welcome

Ian Davies



Marine Renewable Energy Programme Manager, Marine Scotland Science, Scottish Government

The key role of science in the growth of the new marine renewables industries is to ensure that development is sustainable. Marine spatial planning, the underlying framework for development, looks to scientists for methods to identify "preferred" development areas taking account of energy resource and capacity estimation, integrating socio-economic factors with interactions with other uses of the marine area. How can renewables best benefit our communities? How can we increase our confidence that environmental impacts will be limited to acceptable levels? Regulators and advisers look to marine and social scientists to provide robust impact assessments, based on well-designed site characterisation and monitoring protocols. What constitutes best practice in monitoring and assessment? How can we use early projects to inform future risk assessments? What issues will emerge as critical as the scale of development increases? Recent years have seen innovative application of fundamental marine science to the new questions presented by the drive for renewables, and the growth of research programmes aimed at specific planning and licensing questions. How can we observe the behaviour of protected species around tidal turbines?

EIMR2014 is a major opportunity in the international conference programme to share the latest research outputs, network with key members of the scientific community, and develop new ideas. It is an exciting time to be involved in applied aspects of marine science!

Ben Wilson

MASTS Marine Energy Forum Convener, SAMS, UHI

The production and consumption of energy impinges all parts of our lives and the societies that we move in. While we remain reliant on fossil fuels, the global hunt for sustainable and cost competitive alternatives is truly on. Of the many prospects being explored, among the most exciting are the bountiful supplies of kinetic energy held within the waves and tidal streams that pound and scrape our shores. However, harvesting this energy is no small feat and a multitude of companies has been endeavouring to devise machines that can tame these two awesome dragons.

While the wave and tidal-stream energy sector remains embryonic, it has made great strides in recent years with a clutch of companies successfully moving beyond prototypes to real machines being tested by the harsh realities of their intended future homes. With this have come the unforgiving ordeals of reliability, cost, infrastructure and fit to the environment. It is this latter challenge that this conference sets out to explore and progress. What precisely is the resource that these devices will operate within? How will the existing wildlife and people be impacted by these new machines and what environmental opportunities will they bring?

Industry at sea is not new, but working in these particularly harsh environments is. So too, and shared with offshore wind, are the challenges of installing and operating the necessary tens to hundreds of devices needed to generate nationally relevant power. In parallel, the science to understand the environmental issues is far from established, not only to understand device-receptor interactions but more fundamentally how these environments and associated communities already operate. These challenges combine to produce an exciting time for marine scientists brave enough to accompany these pioneering marine renewable industries.

While marine energy is rapidly becoming a global pursuit, Scotland is at the forefront of the charge. There is no better place to have this conference, than a place that is surrounded by the resource and poised to be a significant stepping stone for a more sustainable future.

In the spirit of collaboration and endeavour, I would like to offer then a personal welcome to Stornoway and EIMR2014.

Neil Kermode

Managing Director,
The European Marine Energy Centre (EMEC) Limited

It gives me great pleasure to welcome you to the 2nd Environmental Interactions of Marine Renewables Energy Technologies Conference, in Stornoway.

EMEC attended the inaugural EIMR conference in Orkney in 2012, and we were thoroughly impressed by the international researchers and professionals who came together to present the latest research results and ideas on the oceanographic, ecological and societal interactions of wave and tidal-stream energy devices. In the 2 years since then we have seen 11 different prototype technologies active in Orkney, and the first commercial sites are under development worldwide, including right here in the Western Isles.

The wave and tidal energy industry has taken huge steps forward in the course of the last decade, and as commercialisation becomes a tangible reality, research into the environmental interactions of marine renewables technologies – based on real sea experience – is going to become even more crucial. The need to address the environmental challenges and opportunities of harnessing our vast marine resources has never been greater. I look forward to seeing this event tackle these challenges by bringing together people from different disciplines and cultures to encourage collaboration and develop ideas.

Even with all that has been achieved, I know there is much, much more that we still need to learn. For this reason, the EIMR conference is an important event to build on learning which is fundamental to driving the research agenda – informed by, and for the good of, this burgeoning industry of clean marine energy.

Scientific Steering Committee

Professor Ian Bryden, Vice Principal (Research)/Associate Principal (Specialist Colleges), University of the Highlands and Islands, Executive Office, Jubilee Lodge, Ness Walk, Inverness IV3 5SQ.

Dr Ben Wilson, MASTS Marine Energy Forum Convenor, Principal Investigator in Mammalogy and Marine Renewables, SAMS, Scottish Marine Institute, Oban, Argyll PA37 1QA.

Arne Vögler, Principal Investigator Marine Energy, Lews Castle College UHI, Stornoway, Isle of Lewis, Outer Hebrides HS2 0XR.

Dr Annie Linley, NERC MREKE Programme, The Innovation Centre, University of Exeter, Exeter EX4 4RN.

Dr Andrea Copping, Senior Program Manager for Coastal and Marine Waters, Pacific Northwest National Laboratory, 1100 Dexter Ave N. Suite 400, Seattle WA 98109.

Dr Beth Scott, Senior Lecturer, School of Biological Sciences, University of Aberdeen, Tillydrone Avenue, Aberdeen AB24 2TZ.

Dr Ian Davies, Marine Renewable Energy Programme Manager, Marine Scotland Science, Scottish Government, Marine Laboratory, 375 Victoria Road, Aberdeen AB11 9DB.

Professor Stuart Gibb, Director, Environmental Research Institute, North Highland College UHI, Thurso, Caithness KW14 7EE.

Dr George Lees, Policy & Advice Manager (Marine Renewables), Scottish Natural Heritage, Battleby, Redgorton, Perth PH1 3EW.

Dr Jennifer Norris, Research Director, The European Marine Energy Centre (EMEC) Limited, Old Academy Business Centre, Stromness, Orkney KW16 3AW.

Marc Murray, Senior Site Developer, Aquamarine Power, Elder House, 24 Elder Street, Edinburgh EH1 3DX.

Joe Kidd, Project Development Manager, Marine Current Turbines Ltd, Bristol and Bath Science Park, Dirac Crescent, Emersons Green, Bristol BS16 7FR.

Dr Joe Irvine, Head of Knowledge Exchange, University of the Highlands and Islands, Unit 2G, Toll Clock Centre, Lerwick, Shetland Isles ZE1 0PE.

Dr Mike Bell, International Centre for Island Technology (ICIT), Heriot-Watt University, Old Academy, Back Road, Stromness, Orkney KW16 3AW.

Dr Sandy Kerr, International Centre for Island Technology (ICIT), Heriot-Watt University, Old Academy, Back Road, Stromness, Orkney KW16 3AW.

Dr David Woolf, Reader, International Centre for Island Technology (ICIT), Heriot-Watt University, Old Academy, Back Road, Stromness, Orkney KW16 3AW.

Programme – Day 1

Wednesday 30th April 2014

8:00 – 8:30	Registration
8:30 – 8:40	Welcome to Stornoway and EIMR2014 (Arne Vögler, Ian Bryden)
8:40 – 8:55	Opening address (Scottish Government)

Session 1: Policy & Consenting – *Chair: Marc Murray*

8:55 – 9:15	**137_Davies:** Practical experience of sectoral planning for marine renewable energy development in Scotland.
9:15 – 9:30	**140_Isaacman:** A framework for Environmental Risk Assessment and Decision-making for Tidal Energy Development in Canada.
9:30 – 9:45	**130_Turnbull:** Councils in Partnership: A local authority perspective on Marine Spatial Planning.
9:45 – 10:00	**125_Copping:** Annex IV – International Collaboration to Investigate Environmental Effects of Wave and Tidal Devices.
10:00 – 10:15	**194_Bell:** Management of sustainable fisheries alongside marine renewables: Modelling the spatial interactions.
10:15 – 10:30	**141_Wei:** Environmental effects of ocean renewable energy development and countermeasures in China.
10:30 – 11:00	Coffee break, poster exhibition.

Session 2: Policy & Consenting; Society & People – *Chair: Sandy Kerr*

11:00 – 11:15	**209_Kafas:** New perspectives on fisheries: Combining the distribution of inshore and offshore commercial fisheries in Scotland.
11:15 – 11:30	**202_Davies Ward:** Development and Consenting of Carnegie Wave Energy's Perth Wave Energy Project, Experiences from Down Under.
11:30 – 11:45	**293_Reilly:** The attitudes of fishermen on the island of Ireland towards the development of marine renewable energy in their locality – preliminary survey results.
11:45 – 12:00	**259_Jansujwicz:** Human Dimensions Research on Marine Hydrokinetic Energy Development in Maine.
12:00 – 12:15	**204_Stokes:** Perceptions of the Inshore Wave Resource by Beach Water Users in the Lee of Wave Hub.
12:15 – 12:30	**2120_Robertson:** Historic Environment Guidance for Wave and Tidal Renewable Energy.
12:30 – 12:50	Poster elevator pitches (40 seconds each).
12:50 – 14:00	Lunch.

Session 3: Faunal Interactions 1 – *Chair: Ben Wilson*

14:00 – 14:15	**326_Godfrey:** Salmon in Scottish coastal waters: Recent advancements in knowledge in relation to their interactions with marine renewable energy installations.
14:15 – 14:30	**348_Hawkins:** Responses of free-living coastal pelagic fish to impulsive sounds.
14:30 – 14:45	**357_Barbin Zydlewski:** Fish interactions with marine renewable devices: Lessons learned, from ecological design to improving cost-effectiveness.
14:45 – 15:00	**361_Ward:** Assessing the impact of man-made underwater noise from marine renewables in the Outer Hebrides.
15:00 – 15:15	**345_Want:** Littoral characterisation of West Mainland Orkney: The relationship between Wave Energy, Topography and the Biological Community.
15:15 – 15:30	**305_Waggitt:** 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.
15:30 – 15:50	Poster elevator pitches (40 seconds each).
15:50 – 16:15	Coffee break, poster exhibition.

Session 4: Methodology – *Chair: Ian Davies*

16:15 – 16:35	**406_Polagye:** Integrated Instrumentation for Marine Energy Monitoring.
16:35 – 16:50	**488_Wilson:** Marine mammals and tidal turbines: What are the issues of concern and how are they being resolved?
16:50 – 17:05	**477_O'Hagan:** Analysis of experience from Environmental Impact Assessments of Wave Energy Test Centres.
17:05 – 17:20	**463_Williamson:** Using the FLOWBEC seabed frame to understand underwater interactions between diving seabirds, prey, hydrodynamics and tidal and wave energy structures.
17:20 – 17:35	**4121_Kolios:** Multi-disciplinary risk identification and evaluation for the tidal industry.
17:35 – 17:50	**4123_Jackson:** Seabird surveys in high energy marine sites; marrying best practice and guidance.
17:50 – 17:55	Organisational information (conference dinner, etc.)
	End of day 1.

Programme – Day 2

Thursday 1st May 2014

Session 5: Ecological Modelling – *Chair: Mike Bell*

8:10 – 8:25	**575_Guerin:** Exploring the movements of Atlantic salmon around Scottish coasts, using historical tagging data and a simple agent-based modelling approach.
8:25 – 8:40	**586_Bruintjes:** A tool to predict the impact of anthropogenic noise on fish.
8:40 – 8:55	**573_Robbins:** A review of marine bird diving behaviour: Assessing underwater collision risk with tidal turbines.
8:55 – 9:10	**524_Benjamins:** Understanding the potential for marine megafauna entanglement risk from renewable marine energy developments.
9:10 – 9:25	**560_Donovan:** An overview of a simulation approach to assessing environmental risk of sound exposure to marine mammals.
9:25 – 9:40	**598_De Silva:** Use of population viability analysis (PVA) to assess the potential for long term impacts from piling noise on marine mammal populations – a case study from the Scottish east coast.
9:40 – 9:55	**596_Scott-Hayward:** Modelling impact assessment in renewables development areas using the new R package, MRSea v0.1.1.
9:55 – 10:10	**518_Robins:** Impacts of Tidal-stream Energy Converter (TEC) arrays in relation to the natural variability of sedimentary processes.
10:10 – 10:45	Coffee break, poster exhibition.

Session 6: Faunal Interactions 2 – *Chair: Beth Scott*

10:45 – 11:00	**614_Carter:** Tidal Energy, Underwater Noise & Marine Mammals.
11:00 – 11:15	**629_Macaulay:** Tracking porpoise underwater movements in Tidal Rapids using drifting Hydrophone Arrays. Filling a Key Information Gap for Assessing Collision Risk.
11:15 – 11:30	**662_Wood:** Listening for canaries in a tornado: Acoustic monitoring for harbour porpoise at the FORCE site.
11:30 – 11:45	**683_Hastie:** Movement patterns of seals in tidally energetic sites: Implications for renewable energy development.
11:45 – 12:00	**6115_Sparling:** Marine mammals and tidal turbines: Understanding true collision risk.
12:00 – 12:15	**622_Bald:** Environmental impacts over the seabed and benthic communities of submarine cable installation in the Biscay Marine Energy Platform (BIMEP).
12:15 – 12:30	**681_Carlier:** Monitoring benthic habitats and biodiversity at the tidal energy site of Paimpol-Bréhat (Brittany, France).
12:30 – 13:45	Lunch.

Programme – Day 2

Session 7: Resource Modelling – *Chair: Ian Bryden*

13:45 – 14:00	**770_Woolf:** Better together: The implications of tidal resource interactions from resource calculation to policy and governance.
14:00 – 14:15	**776_Ashton:** Monitoring spatial variability for marine energy sites.
14:15 – 14:30	**723_Christie:** The Hebridean Wave Model.
14:30 – 14:45	**7105_Smith:** Modelling changes to physical environmental impacts due to wave energy array layouts.
14:45 – 15:00	**780_Hashemi:** The implications of wave-tide interactions in marine renewables within the UK shelf seas.
15:00 – 15:15	**7118_Kramer:** The modelling of tidal turbine farms using multi-scale, unstructured mesh models.
15:15 – 15:30	**713_Neill:** The role of tidal asymmetry in characterising the tidal energy resource of Orkney.
15:30 – 16:00	Coffee break, poster exhibition.

Session 8: Overviews – *Chair: David Woolf*

16:00 – 16:20	**885_Bell:** Flow and Benthic Ecology 4D – FLOWBEC – An overview.
16:20 – 16:35	**8111_Scott:** What's Next and Why? A look ahead at strategic ecological research direction.
16:35 – 16:50	**846_Henkel:** Estimating distribution of sedimentary benthic habitats and species on the eastern Pacific shelf and detecting effects of device deployment.
16:50 – 17:05	**8114_Redden:** Use of animal tracking technology to assess potential risks of tidal turbine interactions with fish.
17:05 – 17:20	**839_Brown-Saracino:** Advances in research to understand the impacts of wave and tidal energy devices in the United States.
17:20 – 17:35	**887_Bell:** Marine radar derived current vector mapping at a planned commercial tidal stream turbine array in the Pentland Firth.

Closing Session:

17:35 – 17:40	Organisational information (ceilidh, workshops).
17:40 – 17:55	Closing summary and comments, awards for best poster and paper (Ian Bryden, Andrea Copping, Jenny Norris).
	End of day 2.

Poster Exhibition

The poster exhibition is open from Tuesday to Thursday with all displays on show during the main conference days. The main poster gallery is on the ground floor opposite the reception area with additional displays shown on the 2nd floor and basement.

91_Rumes	Offshore wind in the Belgian part of the North Sea: Understanding environmental impacts.
93_Tweddle	From national to regional locational guidance for renewables.
98_Haverson	Changes to eddy propagation due to tidal array at Ramsey Sound.
911_Johnson	Advancing social studies of marine energy.
915_Fairley	The morphodynamics of a beach in the lee of wave energy converter arrays.
916_Lomax	Identifying gaps related to potential impacts of offshore renewable energy devices.
917_Chimienti	Linking foraging theory and behavioural data: Understanding foraging behaviour and the impact of tidal renewable devices.
919_Lewis	Tidal energy resource assessment including the local wave climate.
921_Sheehan	Benthic Interactions with Renewable Energy installations in a temperate ecosystem.
927_Garrett	Underwater sound levels at a wave energy device testing facility in Falmouth Bay, UK.
928_Gordon	Improved arrays for towed hydrophone surveys of small cetaceans at offshore marine energy sites.
931_Coppinger	A 3D far-field model for predicting the hydrodynamic impacts of tidal turbine arrays.
932_Greenwood	A frequency dependant method for the simulation of disturbances around a small scale ware farm using a Boussinesq simulation.
933_Bristow	Has the deployment of Marine Energy Conversion Systems at EMEC's full-scale test sites caused any discernible displacement of key wildlife species?
934_Cowan	Synchronisation of environmental monitoring across European wave and tidal test centres (Part of the FP7 MaRINET Project).
935_Norris	Further development and testing of the EMEC integrated environmental monitoring platform.
936_Vybulkova	The role of the seabed composition in the placement of tidal turbines – sediment motion in a turbine wake.
938_Pratt	Sectoral planning for marine renewable energy development in Scottish waters.
942_Eastham	The use of breeding seabird foraging ranges for assessing impacts to Special Protection Areas (SPAs) from wave and tidal renewable energy proposals.
943_Adams	Sticking together: Movement of marine mammals and response to underwater noise.
944_Macleod	Exploring the interactions between wave energy extraction and kelp communities in Scotland.

949_O'Hara Murray Modelling offshore wind farms off the east coast of Scotland using the Finite-Volume Coastal Ocean Model (FVCOM).

951_Waldman Comparison of two types of hydrodynamic model for investigating the environmental impacts of energy extraction from tidal flows.

952_Burrows Detecting onshore impacts of wave power devices: Mapping intertidal rocky shores with remotely piloted aircraft.

953_Samuel Modelling and comparing the seasonal and diurnal components of electricity demand, wind speed, wave height and wave period; for the Isles of Lewis and Harris.

954_Garcia-Olivia Modelling the impact of tidal farms on flood risk in the Solway Firth estuary.

955_Lieber Introducing novel uses of multibeam sonar to study basking sharks in the light of marine renewable energy extraction.

956_Billing A qualitative, mixed methods approach to finding the role of agents for change in the development of marine renewable energy in island regions.

958_Miller No Title.

964_Voellmy Assessing effects of increased noise levels on fish behaviour.

966_Rouse Benthic productivity on artificial structures.

967_Wilding Effects of man-made structures on sedimentary oxygenation: Extent, seasonality and implications for offshore renewables.

968_Gleizon Modelling wave energy in archipelagos – Case of Northern Scotland.

969_Ashley Research needs to reduce environmental, social and economic impacts of marine renewable energy development and streamline the consenting process: An industry perspective.

972_Robbins Diving and foraging behaviour of seabirds in a high-energy tidal stream: Implications for encountering tidal stream devices.

978_O'Hagan Learning from test centre experience to improve consenting for larger, commercial scale wave energy development.

979_Christie Making landfall: The importance of the intertidal and coastal zones to marine renewable energy development.

984_Guerin The Pentland Salmon Initiative: A new research partnership exploring the potential interactions between migratory fish and marine renewables.

990_Beharie Wave action measurements of the intertidal zone to enable long-term environmental monitoring and predictions of ecological impact due to wave energy converter arrays.

992_Broudic Underwater noise emission from the NOAH's drilling operation at the Narec site, Blyth, UK.

995_Hiley Energy Extraction in an Idealised Tidal Channel: A Comparison of Three-Dimensional and One-Dimensional Models.

999_Callaway A Tidal Energy Lagoon in Swansea Bay: Optimising its value for biodiversity by creating an artificial reef.

9100_O'Hagan Delivering ocean energy in the context of increasing maritime uses: The need for a coherent and integrated policy and planning framework.

Additional Papers

9101_Elliot	Advances in studying vocalising cetaceans in energetic coastal sites using moored and drifting passive acoustic detectors.
9102_Morrison	Time series analysis of displacement data with respect to sensor artifacts.
9103_Mackey	The use of adaptive management in addressing risk and uncertainty in the potential impacts on marine mammals from tidal energy developments: Lessons learned from SeaGen.
9104_Hutchison	Altered sedimentation: Gradual burial of two species of biogenic reef-forming mussels.
9106_Nall	Biosecurity planning for the wave and tidal stream energy industry.
9107_Gay	Spatial Analysis of Fish Distribution in Relation to a Marine Renewable Energy Development.
9110_Fraser	Turbulence, trophic interactions and sustainable energy extraction.
9113_Jackson	Riding the waves: Use of the pelamis device by seabirds.
9116_Turnock	Influence of turbulent flow on the environmental noise of tidal turbine arrays.
9117_Ashley	Effects of offshore wind farms (OWFs) on fishing activity and landings.
9119_Walkington	Changing the Tides.
9125_Golmen	The multipurpose offshore TROPOS platform: Environmental and societal issues.
9126_Scott	Exposure Time Modelling for Tidal Turbines and Diving Birds.
9127_O'Carroll	FLOWBEC: Assessing spatial variation in epifaunal communities in response to flow modification by a tidal stream turbine.

Additional papers for presentation at Workshops (Monday & Friday)

A10_Daborn	Best Practice in MRE Risk Assessment: Experience from the Bay of Fundy.
A12_Hutchison	Consolidation of wave and tidal energy EIA/HRA issues and research priorities.
A20_Masden	Uncertainty in the assessment of cumulative impacts: The case of marine renewable energy in the UK.
A65_Wilding	Offshore renewables and impacts: who cares, how much and why?
A74_Mackenzie	Quantifying environmental impacts for two Danish off-shore wind farms using the complex region spatial smoother (CReSS).
A108_Gill	Development of a spatio-temporal risk assessment methodology applicable to the marine environment.
A112_Horne	Predicting risk of catastrophic events at Marine Renewable Energy Sites.
HMEF02_Vögler	Hebridean Wave Data (HebMEF dissemination event).
HMEF04_Lees	Investigating the potential effects of Wave Renewable Energy Devices on Seabirds (HebMEF dissemination event).

Supplementary Events

EIMR2014 is supported by a number of supplementary events and workshops around the following themes:

Monday 28th April

Hebridean Marine Energy Futures: Dissemination Event (Stornoway Town Hall)

14:00 – 14:30	Arrival
14:30 – 14:40	Welcome and overview
	Technical Presentations (dissemination of project outcomes)
14:40 – 14:55	**The Hebridean Resource model** *(Christie, D., Venugopal, V.)*
14:55 – 15:10	**Hebridean wave data** *(Vögler, A., Morrison, J.)*
15:10 – 15:25	**Hebridean grid/power flow study** *(Samuel, B., MacMillan, D.)*
15:25 – 15:40	**Interaction between birds and the Pelamis wave energy converter** *(Lees, K.)*
15:40 – 15:45	**Benthic observations at a wave energy converter test site** *(tbc)*
15:45 – 16:00	**Development and testing of a harbour porpoise monitoring system at a WEC test site** *(Wilson, B., Benjamins, S.)*
16:00 – 16:15	**Noise monitoring at a wave energy test site** *(Bell, M.)*
16:15 – 16:30	Break
16:30 – 17:00	**Knowledge exchange in complex partnerships: Lessons learned in a collaboration between SMEs, Utility Companies and Academia** *(panel discussion with representatives from HebMEF partners, Chair: Laura Carse)*
	MERIKA project launch *(Marine Energy Research Innovation and Knowledge Accelerator)*
17:00	**Introduction to MERIKA, followed by networking reception** *(Prof Ian Bryden, Damian Collins)*
18:30	End

Tuesday 29th April

Best Practices for Monitoring Environmental Effects of Marine Energy Devices (An Lanntair, Stornoway Town Hall)

09:00 – 17:00	**All day event, sponsored by Annex IV** *(http://mhk.pnnl.gov/wiki/index.php/About_Annex_IV)*

Friday 2nd May

Workshops – Parallel Sessions (sponsored by NERC) (Stornoway Town Hall, secondary venue TBC)

09:00 – 12:30

1. **Understanding cumulative impacts, from pre-consent predictive CIA to post-consent monitoring at multiple project scales**

In this workshop we will explore issues relating to both predictive impact assessment during the application for development-consent (CIA) and the subsequent post-consent monitoring. Assisted by recent experience of CIA in relation to offshore wind projects*, delegates will be asked to consider methodological standardisation, appropriate impact-thresholds, 'significance', the organisation of field surveys, relevant

spatial and temporal scales, the apportioning of impacts to individual developments and the need to accommodate risk/uncertainty in the assessment process.

**https://ke.services.nerc.ac.uk/Marine/Members/Documents/Guidance%20documents/Cumulative%20Impact%20Assessment%20Guidelines.pdf*

Chairing panel: Tom Wilding [SAMS], Ian Davies [Marine Scotland].

2. Managing Risk: From generic risk management to developer's perspectives

Although the technological risks associated with deployment of wave and tidal energy devices have attracted significant attention, environmental, social and economic risks potentially contribute an important role in the development of projects. Consequently, it may be beneficial for the industry to share a comprehensive risk register for risks which affect all developers, and address the problems collectively. This workshop aims to encourage discussion between industrial and academic stakeholders, and to evaluate the relative importance of these types of risk, based on research and experience from deployment of the first generation of wave and tidal projects.

Chairing panel: Simon Jude, Athanasios Kolios [Cranfield University].

12:30 – 13:30 Lunch

13:30 – 17:00 **3. Statistics, data analysis, survey design**

Recent advances in environmental statistics have led to the emergence of more sophisticated analyses which show greater potential for the detection of changes in the patterns of species distribution within a study area than traditional approaches. The purpose of this workshop is to provide an update on the development of statistical modelling and its potential in Site Characterisation and Impact Monitoring.

Chair: Jared Wilson [Marine Scotland Science].

4. Quantifying wildlife collision risks with tidal turbines

One of the key stakeholder concerns is the potential for mobile wildlife species to be injured by the moving parts of tidal turbines. Impact predictions are necessary elements of project licence applications, but there is generally a lack of empirical evidence to give guidance on the true risk. This workshop will provide a forum for discussion of the interaction processes, field observations and of the capabilities of modern equipment to observe collision and avoidance behaviour around turbines.

Chairing panel: Beth Scott [Aberdeen], Ben Wilson [SAMS], George Lees [SNH].

Abstracts for oral presentations to be presented to the conference are arranged numerically according to submitting Author's ID

EIMR2014-125: ANNEX IV – INTERNATIONAL COLLABORATION TO INVESTIGATE ENVIRONMENTAL EFFECTS OF WAVE AND TIDAL DEVICES

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ABSTRACT: The pace of development for wave and tidal energy projects worldwide continues to be hindered by uncertainty surrounding potential environmental effects of the devices and the balance of system. To respond to this uncertainty the Ocean Energy Systems (OES) international agreement developed a collaborative initiative (Annex IV). Over an initial three-year period (2010-2012) Annex IV collected metadata on environmental effects around marine energy projects, as well as ongoing research into interactions of wave and tidal devices and the marine environment. Housed on the US-based Tethys online knowledge base the Annex IV metadata was used to investigate high priority interactions. The work of Annex IV was guided by expert input at two workshops held in Dublin (2010 and 2012). The three priority environmental interactions are documented in a report available from OES and on Tethys:

1. The interaction of aquatic animals with turbine blades;
2. The effects of underwater noise from tidal and wave devices on marine animals; and
3. The effects of energy removal on physical systems.

Each priority interaction (or "case study") examined published literature, compliance and investigative reports, and information gathered directly from device developers and researchers. This information was used to reach preliminary conclusions on the importance of each interaction to the environment; assess the level of certainty surrounding each interaction; and highlight key research gaps that hinder a deeper understanding of the interaction.

EIMR2014-130: COUNCILS IN PARTNERSHIP: A LOCAL AUTHORITY PERSPECTIVE ON MARINE SPATIAL PLANNING

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ABSTRACT: Many studies have shown that effective stakeholder engagement, including local communities, is vital for the success of any marine planning project. In the UK, local authorities can play a vital, if often overlooked, role in building bridges between developers, academics and local communities. They can facilitate knowledge exchange and co-operation, using their local understanding of the economic, social and ecological make-up of an area. Thus, Highland Council and Orkney Islands Council are using a mix of traditional terrestrial planning techniques and innovative marine approaches to enable, support and engage stakeholders. Examples include sub-station applications, harbour upgrades, marine spatial planning, master-planning and business and community engagement. The local authorities are therefore pivotal in helping to address the complex challenge of marine energy developments in the north of Scotland.

EIMR2014-137: PRACTICAL EXPERIENCE OF SECTORAL PLANNING FOR MARINE RENEWABLE ENERGY DEVELOPMENT IN SCOTLAND

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ABSTRACT: Sectoral marine planning (SMP) for marine renewables is providing a foundation for the development of these new offshore industries. The planning process combines technical analyses of opportunities and constraints, together with broad public consultation to ensure that resultant Plans are a robust basis for sustainable development. Practical experience has emphasised the importance of using the best available data relating to the available resource, environmental characteristics, and current uses. A number of examples are described for which data improvements are needed.

EIMR2014-140: A FRAMEWORK FOR ENVIRONMENTAL RISK ASSESSMENT AND DECISION-MAKING FOR TIDAL ENERGY DEVELOPMENT IN CANADA

Lisa Isaacman*, Fundy Energy Research Network, Wolfville, Nova Scotia, Canada, **Graham Daborn** and **Anna Redden,** Acadia Tidal Energy Institute Acadia University, Wolfville, Nova Scotia, Canada.
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ABSTRACT: In-stream tidal energy initiatives are rapidly developing in Nova Scotia, Canada, but there remains a high degree of uncertainty regarding the nature and extent (in space and time) of environmental implications of energy harvesting activities. To ensure the tidal energy industry in Nova Scotia (and elsewhere in Canada) develops in an environmentally safe and sustainable manner, regulators and industry are in need of a consistent, objective and efficient approach to assess and mitigate the risk of adverse environmental impacts of a proposed project. This paper presents a science-based environmental risk assessment and decision-making framework developed on behalf of the Nova Scotia Department of Energy and Fisheries and Oceans Canada (Federal). The framework offers key steps and considerations for identifying, assessing, and addressing the environmental risk of in-stream tidal energy projects based on the best available scientific knowledge, expert advice, and best practices for environmental risk and impact assessment. The risk assessment approach is based on a set of practical criteria and related risk indictors that are relevant, flexible and can be consistently applied to projects of any type, size or location. By following this approach, project planners and reviewers can also gain insights as to: site-appropriate project design and size consideration; the level and type of baseline studies and monitoring that may be required; methods of mitigating or reducing the level of risk of a project; and evaluation measures or trigger points for adaptive management actions. The guidance framework has been peer reviewed by scientists, industry and provincial and federal government agencies and is intended to form the basis of a joint Canada/Nova Scotia Statement of Best Practice for the management of in-stream tidal energy development.

EIMR2014-141: ENVIRONMENT EFFECTS OF OCEAN RENEWABLE ENERGY DEVELOPMENT AND COUNTERMEASURES IN CHINA

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ABSTRACT: Ocean Renewable Energy Development (ORED) has the potential to provide clean, reliable power. China government attaches great importance to rational use of ocean renewable energy resources. After summary of ORED status, we make analysis on the characteristics, trends and environment effects of such sea use in China. The environmental impacts are mainly the ocean physical, chemical, biological, ecological and other environmental changes of the renewable energy projects during construction, operation and equipment stages. These environmental potential impacts can be prevented and controlled by the marine environment protection systems developed by the Chinese Government, such as approval of marine projects, marine functional zoning, marine environmental impact assessment and feasibility assessment of the sea use. These four systems as the main countermeasures on negative environmental effects play an important role in the management process of ORED. They not only regulate the development of new energy projects with legal systems, but also guarantee the development space for ocean renewable energy strategic emerging industries. The systems have good effect on the prevention of environmental impacts and can ease considerably the sea use conflict.

EIMR2014-194: MANAGEMENT OF SUSTAINABLE FISHERIES ALONGSIDE MARINE RENEWABLES: MODELLING THE SPATIAL INTERACTIONS

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ABSTRACT: Extracting energy from waves and tides is seen as crucial to the achievement of ambitious national targets for meeting energy demands from renewable sources (e.g. 100% of electricity demand by

2020 in Scotland), but the requirements of this new industry must be balanced against the needs of traditional users of the sea, particularly marine fisheries. Whilst previous studies have indicated relatively little overlap between hydrodynamic energy resources and exploited marine fish stocks at national scales, there appears to be greater potential for locally-significant interactions involving inshore fisheries. Although interactions are expected to differ according to marine renewable energy development types and technologies, and to involve spatial scales ranging from devices and individual fish to regions and fish stocks, the first concern for fisheries is likely to centre on spatial occupancy of fishing areas by developments. Whilst exclusion from portions of traditional fishing grounds can be seen as a loss of fishing opportunity, it is also relevant to consider that spatial measures can be an important tool for fisheries management. We develop a spatial model of yield and spawning potential for inshore fisheries, demonstrating the sensitivity of sustainable management criteria to spatial exclusion of fisheries activities at scales relevant to marine renewable energy developments. We show that the sum effects of multiple exclusion zones depend on the interaction between spatial turnover of fish populations and the size and shape of these zones. Fish mobility is a primary factor in determining sensitivity to spatial management measures, but this factor is mediated by the ways in which patterns of individual movement and site fidelity determine spatial turnover at a population level. Managed sensitively with respect to potential impacts and opportunities, there appears to be considerable scope for positive working relationships between the marine renewable energy and fishing industries, but this depends to a large extent on the development of effective frameworks for marine spatial planning.

EIMR2014-202: DEVELOPMENT AND CONSENTING OF CARNEGIE WAVE ENERGY'S PERTH WAVE ENERGY PROJECT, EXPERIENCES FROM DOWN UNDER

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ABSTRACT: Carnegie Wave Energy Limited has been developing CETO wave energy technology for over 10 years and at a cost of $70 million. Carnegie is now in the construction phase of the Perth Wave Energy Project, a grid-connected CETO array off Garden Island, Western Australia. The Project will supply both power and desalinated potable water to the Australian Department of Defence. The Project is fully consented through a range of Federal, State and Local government permits and approvals, supported by a comprehensive community consultation program. This paper shares Carnegie's experience of consenting this project and implications for future development.

EIMR2014-204: PERCEPTIONS OF THE INSHORE WAVE RESOURCE BY BEACH WATER-USERS IN THE LEE OF WAVE HUB

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SOWFIA, Streamlining of Ocean Wave Farms Impact Assessment (http://www.sowfia.eu/).
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ABSTRACT: Recreational water-users are of great economic importance to Cornwall, UK. Concerns over the potential impact of the Wave Hub renewables test site in Cornwall on inshore recreational wave amenity has prompted research into potential changes to wave height and period. There is little existing research however to indicate what surf conditions are 'preferred' by various beach water-user groups, nor how they perceive the inshore wave resource. It is therefore unclear how likely they are to be affected by, or if they will correctly perceive, any changes to the wave climate caused by devices at Wave Hub or future renewables projects. Questionnaire data from 403 water-users collected at two beaches in the lee of Wave Hub reveal the characteristics of water-users in the region, including ideal conditions for water recreation, and their perception of the abundance of the wave resource.

EIMR2014-209: NEW PERSPECTIVES ON FISHERIES: COMBINING THE DISTRIBUTION OF INSHORE AND OFFSHORE COMMERCIAL FISHERIES IN SCOTLAND

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ABSTRACT: Scotland's seas support diverse commercial fisheries, including both inshore and offshore fishing fleets. The offshore fleet (overall vessel length ≥15m) is covered by Vessel Monitoring System (VMS) offering bi-hourly location data which can be linked to landings information. On the other hand, Scottish inshore fishing vessels do not carry VMS, and their activity was recently mapped using an interview based approach with fishery stakeholders (the ScotMap project). Increasing competition over marine space highlighted the need for comprehensive spatial information on fishing activities. Combining commercial and stakeholders' data can provide a Scotland-wide spatial representation of fisheries to assist in marine planning for renewable energy, conservation and fisheries management. VMS data combined with landings were used to describe the spatial patterns of landings of the Scottish offshore fleet. The ScotMap data were analysed to derive monetary value distribution maps for the inshore fleet. ScotMap and VMS layers were added together to produce a combined data set, spatial information for landings value for the whole Scottish commercial fishing fleet. This provides a new perspective which can inform decision making in various policy areas including marine spatial planning, sustainable development of offshore renewable energy, nature conservation and fisheries management.

EIMR2014-259: HUMAN DIMENSIONS RESEARCH ON MARINE HYDROKINETIC ENERGY DEVELOPMENT IN MAINE

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ABSTRACT: Marine hydrokinetic (MHK) energy offers a promising new source of renewable ocean energy. However, regulatory uncertainty and social acceptance may constrain industry development. Our human dimensions research aims to understand the regulatory and permitting process for MHK development and the factors influencing community acceptability. Research has focused on Ocean Renewable Power Company's (ORPC's) Cobscook Bay Tidal Energy Project (CBTEP), the first functioning commercial MHK project in the U.S. Using observations, interviews, and focus groups we identified salient stakeholders and examined community perspectives of the CBTEP. We found an emphasis on direct benefits, indirect benefits, "hopeful" benefits, and potential costs associated with the project. Community stakeholders and fishermen generally perceived ORPC's approach as effective; they noted the company's accessibility and their efforts to engage them early and often. Analysis of a community mail survey administered in two Cobscook Bay communities will be used to support or add to these qualitative findings. Through observations and interviews with regulators and developers we identified institutional factors important for supporting regulatory and permitting decisions including a commitment to interagency coordination, "learning by doing" and an emphasis on early proactive engagement with developers. We also identified institutional challenges that may hamper MHK development. These included knowledge gaps and uncertainties, conflicting agency cultures, and high financial costs and long timeframes associated with baseline data collection. Lessons learned from this study can assist regulators, policymakers, and developers move new renewable ocean energy development forward in a way that is socially acceptable and environmentally responsible.

EIMR2014-293: THE ATTITUDES OF FISHERMEN ON THE ISLAND OF IRELAND TOWARDS THE DEVELOPMENT OF MARINE RENEWABLE ENERGY IN THEIR LOCALITY – PRELIMINARY SURVEY RESULTS

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ABSTRACT: The expansion of marine renewable energy (MRE) will increase pressure on sea space and existing maritime users which represents a challenge for Maritime Spatial Planning (MSP). Commercial fishing has been identified by many as the industry most likely to be affected by the development of MRE. In order to reduce the risk of spatial conflict and to enable decision-making based on the co-existence of the two sectors, it is important to gain a better understanding of the attitudes of fishermen towards the development of MRE in their locality. A survey was designed to provide quantitative information on boat skipper/owner attitudes to the development of MRE projects near their home port. Three MRE developments proposed around the island of Ireland were chosen as case study sites in which to carry out the survey. The sites represent offshore wind, wave and tidal energy respectively and are in differing stages of development. In total, 104 complete surveys were conducted with fishermen located at ports in the vicinity of the case study sites. 40% of those surveyed agreed that it is important to develop MRE in their locality. A further 15% were neutral on this matter. The majority of respondents (70%) were of the opinion that fisheries and MRE projects can co-exist.

EIMR2014-305: 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

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ABSTRACT: It remains unknown how tidal stream turbines could impact deep diving seabird populations such as auks Alcidae sp and cormorants Phalacrocorax sp. Predicting whether and how devices could affect populations is hampered by poor knowledge of what influences seabird foraging distributions in the tidal pass habitats favoured for installations. Here distributions of foraging seabirds are compared with a suite of concurrent environmental variables within the Fall of Warness, Orkney, UK to investigate associations between auks, cormorants and oceanographical processes. Results are presented for Atlantic puffins Fratercula arctica, black guillemots Cepphus grylle, common guillemots Uria algaa and European shags Phalacrocorax aristotelis. These studies provide the information that is needed to predict auk and cormorant distributions within tidal pass over different scenarios, revealing which and when species may interact with devices within these habitats.

EIMR2014-326: SALMON IN SCOTTISH COASTAL WATERS: RECENT ADVANCEMENTS IN KNOWLEDGE IN RELATION TO THEIR INTERACTIONS WITH MARINE RENEWABLE ENERGY INSTALLATIONS

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ABSTRACT: There are concerns about interactions between Marine Renewable Energy (MRE) and migratory fish, in particular Atlantic salmon. Marine Scotland Science (MSS) is attempting to gain information in key areas. Firstly it is necessary to obtain information about which populations of salmon occupy which coastal areas. To this end MSS has been undertaken a programme of genetic characterisation of regional variation in salmon, based on Single Nucleotide Polymorphisms, in order to assign fish intercepted at sea to their likely region of origin. In addition to obtaining geographical distribution of migrating salmon, information about the depths at which they are swimming in coastal waters is vital in the assessment of potential impact

of MRE devices. In May-June 2013 MSS fitted pop-up satellite tags to adult salmon caught on the north coast, recording water depth and temperature at regular intervals, and providing a single geographic location following detachment.

EIMR2014-345: LITTORAL CHARACTERISATION OF WEST MAINLAND ORKNEY: THE RELATIONSHIP BETWEEN WAVE ENERGY, TOPOGRAPHY AND THE BIOLOGICAL COMMUNITY

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ABSTRACT: The rocky coast of West Mainland Orkney (WMO) is characterised by spectacular, sheer cliffs shaped by exposure to extreme wave energy and inhabited by a suite of organisms adapted to this challenging environment. As part of the UK government's commitment towards developing the renewable energy sector, in March 2010, the Crown Estate announced the leasing of several sites within this area for development of wave energy extraction. Owing to difficulties of access, the biological communities of much of this coastline have never been adequately described. As part of a long-term monitoring programme, we have incorporated boat-based field methodologies to complete the first comprehensive baseline assessment of the littoral community along the entire rocky shoreline of WMO, extending northeast to beyond Costa Head. Within this assessment are: the wave energy converter (WEC) testing site for the European Marine Energy Centre, at Billia Croo; rocky shores within leasing sites potentially impacted by large-scale WEC deployment and subsea cable installation; and areas distant from potential impacts which are serving as control sites. Data collected includes species abundance and several quantitative and semi-quantitative topographical indices which may mediate wave exposure including slope, aspect, openness and complexity. Additional data have been collected for barnacles, patellid limpets and high-energy variant fucoid algae. Comparable sites on the west coast of Lewis have been surveyed by the team and are included in analyses for comparison.

EIMR2014-348: RESPONSES OF FREE-LIVING COASTAL PELAGIC FISH TO IMPULSIVE SOUNDS

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ABSTRACT: There are substantial gaps in our understanding of the effects of sounds upon fish. This paper describes experiments on the behaviour of wild, pelagic fish in response to sound playback, observed by means of sonar. Fish, including sprat (Sprattus sprattus) and mackerel (Scomber scombrus) were examined at a sheltered and quiet coastal location. Short bursts of repeated impulsive sounds were presented at different sound pressure levels, simulating the strikes from a pile driver. Behavioural responses included the break up of fish schools and changes in depth. The incidence of responses increased with increasing sound levels. The levels of sound to which the fish schools responded on 50% of presentations were estimated from dose response curves, in terms of the received sound pressure level and the single strike sound exposure level. Observations by means of sonar are especially valuable for examining the behaviour of unrestrained fish exposed to different sound sources. The technique allows testing of the relationship between responsiveness, sound level, and sound characteristics for different types of man-made sound. It is only by examining the responses of wild fish to sound, under natural conditions, that we can fully understand how marine renewable energy and other marine or coastal developments might interact with natural populations of fish.

EIMR2014-357: FISH INTERACTIONS WITH MARINE RENEWABLE DEVICES: LESSONS LEARNED, FROM ECOLOGICAL DESIGN TO IMPROVING COST-EFFECTIVENESS

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ABSTRACT: We are studying fishes associated with a tidal-stream energy project in Cobscook Bay, the north eastern-most bay of the United States, at the entrance to the Bay of Fundy. Tidal energy devices under consideration are Ocean Renewable Power Company's (ORPC) TidGen® and OCGen® systems. Our

research was initiated in 2009 to determine the 'natural' vertical distribution and density of fishes. Baseline data enabled the detection of turbine effects, and will be used to estimate the likelihood that fish encounter a tidal turbine once installed at a fixed height in the water column. Since then, we have built on this research, adding studies of fish behaviour in response to a tidal energy device in the near-field (within 3m) and mid-field (up to 200m away). Approaches at multiple spatial and temporal scales are proving useful in deciphering the previously unknown behaviours of fish in response to marine hydrokinetic (MHK) devices and enabling more focused methods for future monitoring.

EIMR2014-361: ASSESSING THE IMPACT OF MAN-MADE UNDERWATER NOISE FROM MARINE RENEWABLES IN THE OUTER HEBRIDES

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ABSTRACT: Offshore construction developments may lead to the generation of man-made underwater noise as a by-product of the activities followed and this has the potential to impact on marine life. Marine renewables projects, although often cited as "environmentally friendly" are no different in this regard. As part of the consenting process, the regulatory authorities require that such projects undergo a programme of assessment in order to determine the scale and significance of any environmental impact that may occur.

Aquamarine Power Ltd is involved in the development of a site off the west coast of the Isle of Lewis, Outer Hebrides for the installation of a number of their Oyster 800 wave energy converters. During the consenting requirement and as part of the baselining process prior to any development taking place, seagoing surveys were undertaken. The surveys indicated that a number of species of marine mammals, including harbour seal, common dolphin, harbour porpoise and minke whale were often found in and around the project area. It is noted that these are all classified as European Protected Species and are thus legally protected from harassment including that which may arise from man-made underwater noise. Such animals make use of sound to hunt and to communicate and are thus sensitive to disturbance when this capability becomes compromised.

The construction process is likely to involve the drilling of sockets in the seabed in which foundation piles are located while the installation process will require the use of specialist vessels equipped with lifting gear and dredging units in order to prepare the seabed in the project area. In the absence of more relevant data, the operational characteristics of the wave energy devices were based on data extrapolated from other underwater devices of similar power output. This paper outlines the procedures followed by Kongsberg Maritime Ltd when they were tasked to produce an acoustic impact assessment on behalf of the developer. It describes the tasks and equipment used in terms of their likely acoustic source levels and frequency spectra. The paper goes on to show how through the modelling of underwater sound and the application of acoustic impact models, the potential impacts on environmentally sensitive sites close to the wave energy development were quantified. The ensuing analysis indicated that the acoustic impacts likely to occur from the installation and operation of the wave energy development were deemed to be relatively insignificant. As a result, the project received full consent from the Scottish Government in 2013.

EIMR2014-406: INTEGRATED INSTRUMENTATION FOR MARINE ENERGY MONITORING

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ABSTRACT: Integrated instrumentation packages designed for operation at marine renewable energy sites have the potential to reduce the risk uncertainty around high priority interactions between stressors and receptors. Such packages can leverage the competitive strengths of individual instruments and reduce risk in a rapid, cost-effective manner. One emerging example of environmental infrastructure to achieve these objectives, the Adaptable Monitoring Package, is presented and its capabilities described. The development and adoption of such packages requires close coordination between resource managers, technology developers, and researchers.

EIMR2014-463: USING THE FLOWBEC SEABED FRAME TO UNDERSTAND UNDERWATER INTERACTIONS BETWEEN DIVING SEABIRDS, PREY, HYDRODYNAMICS AND TIDAL AND WAVE ENERGY STRUCTURES

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ABSTRACT: The NERC/Defra collaboration FLOWBEC-4D is investigating the environmental and ecological effects of installing and operating arrays of wave and tidal energy devices. The FLOWBEC seabed platform combines a number of instruments to record information at a range of physical and multi-trophic levels at a resolution of several measurements per second, for a duration of 2 weeks to capture an entire spring-neap tidal cycle. An upward-facing multifrequency echosounder is synchronised with an upward-facing multibeam sonar aligned with the tidal flow. An ADV is used for local current measurements and a fluorometer is used to measure chlorophyll (as a proxy for plankton) and turbidity. The platform is self-contained, facilitating rapid deployment and recovery in high-energy sites. Five 2-week deployments have been completed at wave and tidal energy sites at EMEC in Orkney (UK), both in the presence and absence of renewable energy structures. Using multifrequency target identification and multibeam target tracking, the depth preference and interactions of birds, fish schools and marine mammals with renewable energy structures can be tracked. Seabird and mammal dive profiles, predator-prey interactions and the effect of hydrodynamic processes during foraging events throughout the water column can also be analysed. These datasets offer insights into how fish, seabirds and marine mammals successfully forage within dynamic marine habitats and also whether individuals face collision risks with tidal stream turbines. Measurements from the subsea platform are complemented by 3D hydrodynamic model data, concurrent shore-based marine X-band radar and shore-based seabird observations. This range of concurrent fine-scale information across physical and trophic levels will improve our understanding of how the fine-scale physical influence of currents, waves and turbulence at tidal and wave energy sites affect the behaviour of marine wildlife, and how tidal and wave energy devices might alter the behaviour of such wildlife. These results can be used to guide marine spatial planning, device design, licensing and operation, as these individual devices are scaled up to arrays and new sites are considered.

EIMR2014-477: ANALYSIS OF EXPERIENCE FROM ENVIRONMENTAL IMPACT ASSESSMENTS OF WAVE ENERGY TEST CENTRES

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ABSTRACT: The potential environmental impacts of wave energy, and the obligation on developers and regulators to document and assess these, continues to represent a significant barrier to the wave energy industry. As part of the EU IEE-funded SOWFIA project, on streamlining of impact assessment for wave energy farms, an evaluation of experience related to the detection of environmental impacts at wave energy test centres across Europe, coupled with information gained from Environmental Impact Assessments produced for other similar renewable energy developments, has been undertaken. This experience has been examined to understand key receptors of concern and methods used for detecting impacts with the over-arching aim of producing effective methods for communicating the information gathered and to identify, where possible, the type and magnitude of impacts which may be expected in future, larger scale developments. This paper focuses on a selection of these receptors, focusing on the variations found and the implications these variations could have for future assessments.

EIMR2014-488: MARINE MAMMALS AND TIDAL TURBINES: WHAT ARE THE ISSUES OF CONCERN AND HOW ARE THEY BEING RESOLVED?

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ABSTRACT: The potential risks of marine mammals being injured by being hit by tidal-stream turbines, or of vacating significant areas in an attempt to avoid them, are among the most pressing environmental consenting issues facing this emerging family of technologies. Unfortunately, due to the inherent difficulties of studying marine mammal distribution and behaviour underwater, as well as the novelty of the machines themselves, information upon which to base robust impact assessments is extremely limited. Consequently, a variety of research projects in several countries are underway to address these data gaps and investigate different components of these questions. In this presentation we review potential marine mammal-related issues including collision and injury risks, acoustic impacts, displacement, barrier effects and attraction. We then outline what research approaches are being applied and how they relate to one another. The novelty of these challenges, especially working in waters flowing at velocities approaching research vessel speed, has prompted the development of several innovative scientific tools as well as focussing effort onto a previously little studied habitat. These efforts may also tell us much about how marine mammals use such sites, which due to increased density through geographical bottleneck effects, can be perceived as being disproportionately important. There are, however, challenges for the research community to keep pace with the industrial developments themselves, to learn from the many globally dispersed initiatives and to continue research on potential impacts once initial funded consent-to-operate licences have been issued.

EIMR2014-518: IMPACTS OF TIDAL-STREAM ENERGY CONVERTER (TEC) ARRAYS IN RELATION TO THE NATURAL VARIABILITY OF SEDIMENTARY PROCESSES

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ABSTRACT: Tidal-stream Energy Converter (TEC) arrays are expected to reduce tidal current speeds locally, thus impacting sedimentary processes, even when devices are positioned above bedrock. Tidal dissipation can produce high suspended sediment concentrations (turbidity maxima) which are important for biological productivity. Also, devices will potentially impact morphological features further afield, e.g., offshore sand banks and beaches.

Yet few impact assessment studies of potential TEC sites have looked closely at sediment dynamics beyond local scouring issues. It is therefore important to understand to what extent exploitation of the tidal energy resource will affect sedimentary processes, and the aim of this research is to assess the scale of this impact in relation to natural variability, caused by both tidal currents and wave-induced currents.

EIMR2014-524: UNDERSTANDING THE POTENTIAL FOR MARINE MEGAFAUNA ENTANGLEMENT RISK FROM RENEWABLE MARINE ENERGY DEVELOPMENTS

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ABSTRACT: The development of marine renewable energy (MRE; offshore wind, tide and wave energy) in Scottish waters and elsewhere has given rise to concerns about the potential impacts of such technologies on the marine environment. One such potential impact of marine renewable energy development is the risk of whales, basking sharks and other large animals ("marine megafauna") becoming entangled in mooring systems and associated power cables. Similar entanglements in fishing gears have long been recognised as a significant global cause of injury and mortality for many species, and there are concerns that future expansion of the MRE industry may exacerbate the risk.

In the current absence of large numbers of MRE-associated moorings, there are few concrete data on which to base an assessment of entanglement risk. A comprehensive literature review confirmed that the vast majority

of marine megafauna entanglement records worldwide involved fishing gear. There were, however, several reports of large whales interacting with (or becoming entangled in) anchor chains, aquaculture moorings and similar structures, sometimes leading to injury or mortality. This evidence suggests that moorings, such as those proposed for MRE devices, will likely pose a relatively modest risk in terms of entanglement for most marine megafauna, particularly when compared to entanglement rates in fisheries. Nevertheless, some circumstances were identified under which moorings associated with MRE devices could pose a risk to marine megafauna, particularly 1) in cases involving baleen whales and 2) if derelict fishing gears become attached to the mooring and continue to fish, thereby creating an entanglement risk for a wide range of species (including fish and diving seabirds).

EIMR2014-560: AN OVERVIEW OF A SIMULATION APPROACH TO ASSESSING ENVIRONMENTAL RISK OF SOUND EXPOSURE TO MARINE MAMMALS

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ABSTRACT: Underwater sounds caused by military sonar, seismic surveys and marine renewable construction/operational activities can harm/disturb acoustically sensitive marine mammals, and many jurisdictions require such activities to undergo environmental impact assessments to guide mitigation. The ability to assess impacts in a rigorous, quantitative way is hindered by large knowledge gaps on hearing ability, sensitivity and responses to noise. We will describe an analytical framework, called SAFESIMM (Statistical Algorithms For Estimating the Sonar Influence on Marine Megafauna) which partitions our knowledge of noise impacts into linked modules that collectively calculate the numbers of animals likely to be affected by noise. The simulation framework will be illustrated using two species that are relevant to marine renewable assessments in the UK, namely grey seal (Halichoerus grypus) and harbour porpoise (Phocoena phocoena). We have run a suite of simulations which consider sensitivity to uncertainty in three areas: how sound energy is perceived by animals with differing hearing apparatuses; how animals move in response to disturbance (i.e., the strength and directionality of evasive tactics); and the level of site fidelity effects. In particular we consider sensitivities over exposure scenarios of differing lengths. We will describe the main outcomes of these simulations and place the results in the context of the decisions that developers and regulators are faced with. Simulation frameworks offer a powerful way to explore, understand and estimate effects of cumulative sound exposure on marine mammals, but they can act as black boxes that hide important, but subjective, decisions. For example, we have found that the estimate of received sound exposure level (SEL) is influenced most strongly by the weighting function used to account for the species' presumed hearing ability and therefore tools that make different assumptions about auditory weighting will give contradictory recommendations to managers about sound exposure relative to allowable harm limits.

EIMR2014-573: A REVIEW OF MARINE BIRD DIVING BEHAVIOUR: ASSESSING UNDERWATER COLLISION RISK WITH TIDAL TURBINES

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ABSTRACT: Tidal turbines have the potential to impact diving birds, primarily through collision with turbine blades. There is a legal requirement to assess these impacts. Collision risk modelling has been used widely to quantify collision risk to birds flying through wind farms. Intuitively, the same approach can be taken when assessing risk of underwater turbines to diving birds. Such models require data on a bird's foraging and diving behaviour to calculate their likely exposure to a tidal turbine array while foraging underwater. Accordingly, we

have reviewed studies from peer-reviewed literature that present estimates for diving parameters for diving marine birds that occur in UK waters. These values can be used within underwater collision risk models. This work will provide a key resource to the consenting process as it can be used in the assessment of environmental impacts of marine renewable developments.

EIMR2014-575: EXPLORING THE MOVEMENTS OF ATLANTIC SALMON AROUND SCOTTISH COASTS, USING HISTORICAL TAGGING DATA AND A SIMPLE AGENT-BASED MODELLING APPROACH

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ABSTRACT: Meeting targets for green energy generation will involve marine renewables. To ensure that this development is environmentally sustainable, it is necessary to assess potential interactions between renewable energy arrays and marine organisms.

One species that may be affected is the Atlantic salmon (Salmo salar). Salmon undertake extensive migrations which pass through Scottish coastal waters, where they may encounter renewable energy developments. To assess possible risks to migrating salmon, it is important to understand how many fish may encounter devices. This requires knowledge of how many migrating salmon pass through areas where renewables development is taking place, but there are few data available.

One potential resource in Scotland is a historical archive of tagging study data. We use these data, in conjunction with an agent-based modelling approach, to simulate movements of fish around Scotland. This approach works by representing the coastal seas as a linear series of 'cells' corresponding to salmon fishery districts, and a parallel series of cells representing the salmon home rivers. At each time step, fish can migrate along the coast, or move into their home rivers. This model can be parameterised using data on coastal fishing effort, productivity of home rivers, and other factors, in order to explore potential influences on patterns of recaptures, and to test hypotheses about coastal movements of salmon.

EIMR2014-586: A TOOL TO PREDICT THE IMPACT OF ANTHROPOGENIC NOISE ON FISH

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ABSTRACT: Anthropogenic (man-made) noise is a global problem in aquatic and terrestrial environments. In the shallow seas around many countries, including the UK, large windfarms are being constructed using pile driving to create a solid base for the turbines. Offshore pile driving creates pulsating noises and vibrations of very high intensities, which has been shown to be deleterious to a variety of aquatic species.

Using a hydrodynamic model that predicts the propagation of underwater noise while taking into account bathymetry, tidal movements and currents, we integrated a numerical behavioural tool that models fish behaviour in response to noise. Using agent based modelling, scientifically published data and parameters obtained from carefully controlled experiments, we modelled the impact of noise on European sea bass (Dicentrarchus labrax) as they encountered pile driving during migration from the ocean to a spawning site close to the shore. Taking our empirical experiments into account which showed a negative impact of noise on feeding behaviour and increased oxygen consumption the model predicts that the fish took significantly longer to arrive at the spawning site.

This effect could have important implications at a population level, as fish would use more energy to reach the site and might desynchronize spawning behaviour, which in turn would influence larval survival and life history processes that reduce fitness. This tool not only shows the value of using numerical models to predict animal behaviour in a complex environment, but also highlights the merit of using such models to predict anthropogenic impacts that would otherwise be difficult or too costly to obtain.

EIMR2014-596: MODELLING IMPACT ASSESSMENT IN RENEWABLES DEVELOPMENT AREAS USING THE NEW R PACKAGE, MRSea v0.1.1

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ABSTRACT: For both developers and government licensing organisations it is important to have the ability to quantify spatially explicit change in the density and/or distribution of animals in and around marine renewables sites and, in particular, to identify if change occurs near renewables devices[1]. The publicly available MRSea package (Marine Renewable Strategic environmental assessment)[2] has recently been developed for analysing data collected for assessing potential impacts of renewable developments on marine wildlife, although the methods contained in this package have wide applicability.

As a part of work commissioned by Marine Scotland, a number of candidate modelling methods were critically compared and the Complex REgion Spatial Smoother (CReSS)[3] with spatially adaptive knot placement using SALSA[4] was the recommended approach due to its success at locating spatially explicit impact-related change. The CReSS/SALSA approach was coupled with Generalised Estimating Equations (GEEs), which accommodate the spatial and temporal correlation that is generally inherent in baseline monitoring and impact assessment data.

We present the capabilities of MRSea using an example data set from the package, which is based on offshore data collected from an existing renewables development. Specifically, we analyse a scenario where the animals have re-distributed across the study area between two time points, before and after construction of an offshore wind farm. We begin with correcting the observed counts from the survey data for imperfect detection, fit a spatial model with environmental covariates to the corrected counts, assess the fit of the model, run model diagnostics, make predictions and calculate uncertainty about these predictions. Most importantly for these applications, we identify spatially explicit significant differences in animal density before and after the construction.

EIMR2014-598: USE OF POPULATION VIABILITY ANALYSIS (PVA) TO ASSESS THE POTENTIAL FOR LONG TERM IMPACTS FROM PILING NOISE ON MARINE MAMMAL POPULATIONS – A CASE STUDY FROM THE SCOTTISH EAST COAST

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ABSTRACT: The greatest impact on marine mammals from offshore wind is widely considered to occur primarily during the construction phase when turbine foundations are being driven into the seabed. Marine mammals rely heavily on sound to navigate, feed and conduct social interactions, and are sensitive to increased underwater noise. Potential effects (of piling noise on marine mammals) include lethal effects and physical injury, auditory injury and behavioural displacement. Standard mitigation should be effective in negating or significantly reducing the potential for lethal effects and physical injury, but even with mitigation, PTS onset and behavioural displacement may occur. Because the majority of the currently proposed offshore wind farms consist of several hundred rather than tens of turbines, pile driving may be carried out over a period of years rather than months, and therefore the potential for longer term effects on marine mammals may exist. The consideration of long term impacts is important for both EIA and HRA, where an assessment against a designated site's conservation objectives 'in the long term' is required.

We used data from a proposed UK offshore wind farm – Inch Cape (Scottish east coast) – to investigate the potential for long term effects of noise from piling on bottlenose dolphins and harbour seals (SACs have been designated locally for both species). Noise impact contours were modelled by Subacoustech Environmental Ltd using their INSPIRE model. The harbour seal density surface was produced by SMRU using their telemetry and haul out count data while the bottlenose dolphin density surface was inferred

using the most appropriate information available. The numbers of animals predicted to be affected by PTS onset and behavioural displacement were then estimated using a dose-response approach. Because the consequences of PTS onset and behavioural displacement were unknown, assumptions had to be made (about how exposure to piling noise might influence demographic parameters) in order to model potential impacts on population dynamics. We assumed that the mortality risk of PTS onset was likely to be similar to that of old age (and 'harvested' 25% of the animals estimated to be exposed to SELs sufficient to induce PTS onset in each year in the PVA). Behavioural displacement was assumed to result in breeding failure due to a reduction in condition of breeding females (and a reduction in reproduction proportional to the percentage of the population that had the potential to be displaced in each year was modelled in the PVA). All assumptions were conservative and the magnitude of impact considered was always worst case.

PVA modelling indicates that worst case scenarios could lead to short term impacts upon population size, but not to longer term impacts on population viability. Application of PVA to inform EIAs and HRA has proved useful and may be further enhanced through development of clear guidance to aid interpretation of the modelled outputs by the SNCBs.

EIMR2014-614: TIDAL ENERGY, UNDERWATER NOISE AND MARINE MAMMALS

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ABSTRACT: Obtaining energy from renewable sources is currently a key theme in modern society. Consequently, the pace of development of these emerging technologies is likely to increase in the near future, particularly in marine renewables. However, the environmental and ecological impact of many of these new developments in the marine environment is largely unknown. This PhD project[1] focused on one unknown area of interaction; the potential effect of tidal-stream devices on marine mammals. Two commonly cited concerns with respect to marine renewable devices are collision risk and noise impact[2]. Currently, there is very little information available to quantify collision risk, especially when marine mammal behavioural reactions to anthropogenic stimuli are variable and may depend on context[3].

It is well understood that marine mammals use sound and hearing as their primary sense for communication, foraging, navigation and predator avoidance[4], so it is highly likely that the primary cue for device detection will be acoustic. However, it is not known how operational marine renewable devices might modify the acoustic landscape in these areas, or whether they will be audible to marine mammals in time to alert them to the presence of devices. It has been suggested that the high level of natural and anthropogenic background noise in tidal-stream areas may mask (drown out) the signal of the tidal devices. The acoustic characteristics of underwater noise in shallow coastal waters are also currently not well known.

EIMR2014-622: ENVIRONMENTAL IMPACTS OVER THE SEABED AND BENTHIC COMMUNITIES OF SUBMARINE CABLE INSTALLATION IN THE BISCAY MARINE ENERGY PLATFORM (BIMEP)

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ABSTRACT: On the 1st of June 2009, the General Council on Environmental Quality Assessment of the Ministry of Rural, Marine and Natural Environment of the Spanish Government, on the light of the Environmental Impact Study (EIS) of the Biscay Marine Energy Platform (BIMEP) project carried out by AZTI-Tecnalia, decided that whole Environmental Impact Assessment (EIA) process was not required. Nevertheless, the Environmental Impact Statement (EISt) of the above mentioned Ministry, taking into account the great uncertainties about some predicted environmental impacts, underlined the need to implement the Environmental Monitoring Program (EMP) proposed in the EIS. Among other environmental factors, substratum alteration was foreseen to occur during the commissioning stage of the submarine cables and consequently, may affect benthic habitats and species. Funded by BIMEP S.A. (www.bimep.com) and carried out by the Marine Research

Division of AZTI-Tecnalia (www.azti.es), the EMP of the submarine cables installation in BIMEP showed that the observed impacts were in the range of those predicted in the EIS an assessed as non-significant.

EIMR2014-629: TRACKING PORPOISE UNDERWATER MOVEMENTS IN TIDAL RAPIDS USING DRIFTING HYDROPHONE ARRAYS. FILLING A KEY INFORMATION GAP FOR ASSESSING COLLISION RISK

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ABSTRACT: The growing interest in generating electrical power from tidal currents using tidal turbine generators raises a number of environmental concerns, including the risk that cetaceans might be injured or killed through collision with rotating turbine blades. To understand this risk we need better information on how cetaceans use tidal rapid habitats and in particular their underwater movements and dive behaviour. Porpoises, which are the most abundant small cetacean at most European tidal sites and we have developed an approach which uses time of arrival differences of narrow band high frequency (NBHF) porpoise clicks at hydrophones in an array drifting in tidal rapids, to accurately track their fine scale movements underwater. Extensive ground-truthing and calibration trials have been carried out that show that the system can provide depth and location data with sub meter errors and also indicate array configurations likely to provide the best balance of accuracy and practicality. Field data from porpoises apparently foraging in strong tidal current areas reveal contrasting behaviours at different locations. A recent surprising observation has been of porpoises diving to ~100m in the Corryvreckan/Great Race.

EIMR2014-662: LISTENING FOR CANARIES IN A TORNADO: ACOUSTIC MONITORING FOR HARBOUR PORPOISE AT THE FORCE SITE

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ABSTRACT: The FORCE site in Minas Passage, Bay of Fundy, has tidal ranges of over 13m and current velocities that regularly exceed 3m/s. This makes it an attractive site for generating electricity from tidal turbine devices, but also a very challenging site from both an engineering and environmental monitoring perspective. However, with proper study design and analytical techniques, environmental monitoring can be successfully achieved. The aim of this study was to determine baseline Harbour porpoise habitat use in Minas Passage.

EIMR2014-681: MONITORING BENTHIC HABITATS AND BIODIVERSITY AT THE TIDAL ENERGY SITE OF PAIMPOLBREHAT (BRITTANY, FRANCE)

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ABSTRACT: Marine tidal energy technology is still in its infancy in France and potential environmental impacts on the seabed are virtually unknown. The first French pilot project is currently launched close to Paimpol and the Bréhat Island (Brittany). Environmental monitoring has started in 2012 to assess the baseline of benthic compartment before deployment and the grid-connections of the 4 turbines. The Paimpol-Bréhat tidal site is located on a hard rocky bottom where conventional benthic survey techniques are unsuitable. This paper describes the methodology used to assess the initial state of benthic communities on the turbines

and cable deployment area and presents the first results of the mapping and monitoring of the targeted benthic ecosystem.

EIMR2014-683: MOVEMENT PATTERNS OF SEALS IN TIDALLY ENERGETIC SITES: IMPLICATIONS FOR RENEWABLE ENERGY DEVELOPMENT

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ABSTRACT: Proposed sites for tidal stream renewable energy extraction tend to occur in discrete locations, usually between islands, around headlands or at the narrow mouths of inlets. Such areas are also frequently used by marine mammals such that the overlap is one of the most pressing issues facing this emerging sector. This paper reports on a tagging study of harbour seals in a tidal channel on the west coast of Scotland and discusses the implications of the movements for tidal energy in such tidal channels.

EIMR2014-713: THE ROLE OF TIDAL ASYMMETRY IN CHARACTERISING THE TIDAL ENERGY RESOURCE OF ORKNEY

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ABSTRACT: When selecting sites for marine renewable energy projects, there are a wide range of economical and practical constraints to be considered, from the magnitude of the resource through to proximity of grid connections. One factor that is not routinely considered in tidal energy site selection, yet which has an important role in quantifying the resource, is tidal asymmetry, i.e. variations between the flood and ebb phases of the tidal cycle. Here, we present theory and develop a high-resolution three-dimensional ROMS tidal model of Orkney to examine net power output for a range of sites along an energetic channel with varying degrees of tidal asymmetry. Since power output is related to velocity cubed, even small asymmetries in velocity lead to substantial asymmetries in power output. We also use the 3D model to assess how tidal asymmetry changes with height above the bed, i.e. representing different device hub heights, how asymmetry affects turbulence properties, and how asymmetry is influenced by wind-driven currents. Finally, although there is minimal potential for tidal phasing over our study site, we demonstrate that regions of opposing flood- versus ebb-dominant asymmetry occurring over short spatial scales can be aggregated to provide balanced power generation over the tidal cycle.

EIMR2014-723: THE HEBRIDEAN WAVE MODEL

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ABSTRACT: Any investigation of the interaction between marine renewables and their physical environment requires detailed information about the baseline wave resource. Hebridean Marine Energy Futures (HebMarine) have been conducting a high resolution spectral wave model of the Outer Hebrides of Scotland, site of several planned wave energy deployments. The simulation, performed using DHI Mike 21 spectral wave software, was fully calibrated and validated with data from three wavebuoys and two acoustic devices. Estimating energy loss due to bottom friction, wavebreaking and whitecapping involves optimisation over a four dimensional space of calibration parameters, to ensure the model reproduces measured behaviour over a suitably representative time period. We believe that the temporal and spatial variation of wave height, period and power will be of local interest to stakeholders while the methodology and software tools will be of interest to the wider wave resource modelling community.

EIMR2014-770: BETTER TOGETHER: THE IMPLICATIONS OF TIDAL RESOURCE INTERACTIONS FROM RESOURCE CALCULATION TO POLICY AND GOVERNANCE

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ABSTRACT: Tidal energy extraction at one location affects the strength and timing (phase) of tidal elevation and currents elsewhere, with immediate implications for the resource and the environment. More holistically, it is apparent that the entire approach to tidal energy and related marine and energy policy should be informed by understanding of this interaction. We examine first the physical phenomena of interaction using a range of models and then consider the broader implications.

Studies using 2-dimensional or 3-dimensional hydrodynamic models and precise environmental and tidal stream array characteristics provide specific case studies of the effects of tidal stream arrays. These studies are reviewed here, but we demonstrate that a simpler "wiring diagram" approach gives more generic results and insights.

Previous studies have categorised effects of renewable energy extraction on the flow as near-field (<1km), far-field (1-10km) and regional (>10km). Here, we concentrate on interactions spanning far-field and regional (>1km) and introduce the alternative categories of "systemic", "inter-channel" and "intra-channel". We show that in the case of both inter-channel and intra-channel interactions that "parallel is good, serial is bad". Policy and governance should address this fundamental truth, encouraging the positive interactions associated with parallel developments.

EIMR2014-776: MONITORING SPATIAL VARIABILITY FOR MARINE ENERGY SITES

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ABSTRACT: The successful implementation of marine renewable energy requires complex engineering projects to interact with difficult environmental conditions. Technological advances of environmental monitoring systems, supported by detailed analysis of environmental data sets are supporting the ongoing development of best practice for this industry. This paper describes detailed analysis from marine energy sites to demonstrate spatial variability in marine conditions. Specific case studies from a tidal energy site and a wave energy site are used to demonstrate how increased environmental monitoring can improve marine operations and resource assessment procedures. In particular, the outcomes demonstrate areas in which real time measurements can increase working limits for marine operations, and spatial data sets can improve both baseline and monitoring of environmental impacts. Applying the methods described here has the potential to reduce costs for marine operations, increase the accuracy of resource assessments and associated site design, and support more sensitive methods for environmental assessment. These are measures that would reduce uncertainty, and increase stakeholder confidence in the adequate environmental monitoring of marine energy projects.

EIMR2014-780: THE IMPLICATIONS OF WAVE-TIDE INTERACTIONS IN MARINE RENEWABLES WITHIN THE UK SHELF SEAS

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ABSTRACT: There are many regions throughout the world which concurrently experience a high wave and a high tidal energy resource. These regions include the northwest European shelf seas, the Gulf of Alaska, New Zealand, northwest Australia, and the Atlantic seaboard of Argentina. Due to wave-tidal interactions, special consideration needs to be given to energy schemes developed in such regions. In particular, resource

assessments of such regions should account for the way that one marine resource (e.g. waves) modulates other marine resources (e.g. tides) at a variety of timescales.

In the present research, a coupled wave-tide model of the NW European shelf seas has been developed using SWAN-ROMS. After model validation at a number of tidal gauges and wave buoys the effect of tides on the wave resource assessment is presented. Results of analysis based on linear wave theory, and the application of a non-linear coupled wave-tide model, suggest that the impact of tides on waves can be significant in site assessment, and can exceed 10% in some regions. We also conclude that it is the tidal currents, rather than tidal depth variations, that are the main factor at this scale. While a coupled model can theoretically implement many wave-tide interaction processes, the application of the model at shelf scale is highly constrained by computational cost, model resolution and data availability.

EIMR2014-839: ADVANCES IN RESEARCH TO UNDERSTAND THE IMPACTS OF WAVE AND TIDAL ENERGY DEVICES IN THE UNITED STATES

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ABSTRACT: The United States Department of Energy's Wind and Water Power Technologies Office (WWPTO) funds a research portfolio aimed at strategically filling knowledge gaps in the understanding of environmental impacts of wave and tidal energy devices. This portfolio includes research, monitoring, and modelling efforts to assess the impacts of marine energy devices; work to advance environmental monitoring instrumentation; and initiatives to aggregate, analyse, and disseminate the results of marine energy environmental research occurring around the world. This paper explores the approach that the WWPTO has taken to addressing two potential issues of concern regarding possible effects of wave and tidal devices on marine life, with an emphasis on recent results from this portfolio of work and research funded since the publication of the Annex IV report. Specifically, it focuses on the potential effects of device-generated noise on local marine organism behaviour, movement, and habitat use patterns and the potential for blade strike from tidal devices to cause harm to marine animals. For both these interactions, a combination of WWPTO-funded laboratory research, field monitoring, and modelling efforts have helped bound the understanding of the level of potential environmental effects of these technologies. As a whole, the U.S. Department of Energy research program seeks to provide data which can be used to inform the consenting process for future projects, reduce environmental uncertainty, inform the design of effective monitoring regimes, and identify potential mitigation strategies where necessary.

EIMR2014-846: ESTIMATING DISTRIBUTION OF SEDIMENTARY BENTHIC HABITATS AND SPECIES ON THE EASTERN PACIFIC SHELF AND DETECTING EFFECTS OF DEVICE DEPLOYMENT

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ABSTRACT: The Northwest National Marine Renewable Energy Centre at Oregon State University aims to close key gaps in understanding the technical, ecological, and human dimensions of wave and wind energy development. The Henkel lab investigates benthic conditions and biological communities on the shelf in order to establish an understanding of baseline habitat characteristics, species distributions and abundances against which potential project-induced changes may be assessed. We also aim to develop an understanding of temporal and spatial variability in benthic conditions and species to inform the intensity of sampling needed for future studies. Under baseline conditions, infaunal invertebrates showed little temporal variability but had high spatial heterogeneity related to grain size and depth. Conversely, fish exhibited little spatial variability across the limited depth ranges of the study; however, strong seasonal and interannual trends were detected. Thus, different sampling regimes will be required to adequately assess the range of what is 'normal' for each group before potential impacts can be assessed.

EIMR2014-885: FLOW AND BENTHIC ECOLOGY 4D – FLOWBEC – AN OVERVIEW

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ABSTRACT: FLOWBEC is a three year NERC & DEFRA funded project that aims to identify the physical conditions influencing the behaviour of fish, their predators, and benthic communities using developments in high resolution physical modelling and state of the art observation systems. The development of an understanding of these linkages and the potential changes to hydrodynamics that marine renewable energy devices might cause will provide a logical pathway to assess the environmental interaction of marine renewable energy devices and the environment.

EIMR2014-887: MARINE RADAR DERIVED CURRENT VECTOR MAPPING AT A PLANNED COMMERCIAL TIDAL STREAM TURBINE ARRAY IN THE PENTLAND FIRTH

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ABSTRACT: A marine radar was deployed on a remote clifftop overlooking a 4.8km radius area of the Inner Sound of Stroma in the Pentland Firth for 3 months during spring 2013. The area viewed by the radar includes the Crown Estate lease areas for MeyGen Ltd (Inner Sound of Stroma) and Scottish Power Renewables (Ness of Duncansby), although the data analysis has focussed solely on the MeyGen area. Data were post processed to extract current vector maps based on determining the Doppler shift of sea surface waves by the tidal current. Comparisons between current time series from the ADCP and the radar derived data are presented and show excellent correlation. The quality of the data has enabled tidal analyses to be performed and spatial variations in tidal current constituents to be mapped.

EIMR2014-2120: HISTORIC ENVIRONMENT GUIDANCE FOR WAVE AND TIDAL RENEWABLE ENERGY

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ABSTRACT: In 2012, English Heritage commissioned Fjordr Ltd to prepare guidance on the interaction between wave and tidal energy generation and the historic environment[1]. Partnership funding from Historic Scotland and Cadw enabled the guidance to encompass Scotland and Wales.

This paper describes the key findings that emerged from a programme of extensive preparatory research and discussions with developers, regulators and archaeologists across Great Britain. It describes some effects of wave and tidal energy on the historic environment, with a particular focus on Scotland, and identifies options and best practice for ensuring that such development is undertaken sustainably.

EIMR2014-4121: MULTI-DISCIPLINARY RISK IDENTIFICATION AND EVALUATION FOR THE TIDAL INDUSTRY

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ABSTRACT: With tidal industry still having not achieved high Technology Readiness Levels (TRL), it becomes a pertinent task for developers, investors and operators to develop a widely agreed risk register in order to efficiently control residual risks towards further development. Scarcity and sensitivity of available data and limited synergy between industry agents constitute the task of stakeholder and risk identification quite difficult with relevant studies performed so far focusing specifically on individual sectors of the industry. This paper adopts a PESTLE approach to categorise the different sectors of the tidal industry, identifying key stakeholders and listing the risks considered most relevant. Outputs of this analysis stand as a basis for a targeted survey among stakeholders highlight the most critical risks through multi-criteria assessment in order to establish effective mitigation strategies that allow focus to be placed upon the most critical risks as perceived by the industry cumulatively.

EIMR2014-4123: SEABIRD SURVEYS IN HIGH ENERGY MARINE SITES; MARRYING BEST PRACTICE AND GUIDANCE

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ABSTRACT: This paper examines current seabird survey guidance and norms for wet renewable projects against practical experience and survey results gained by Natural Research Projects Ltd (NRP) during surveys at seven 'wet renewable' sites around Scotland over the past five years. Marine renewable energy projects by their very nature are targeted at sites that have high energy environments and consequently commonly present challenging conditions for boat-based and shore-based survey methods. The first part of the paper aims to serve as a reality check on undertaking visual surveys for seabirds at wet renewable sites. The second part goes on to consider in more detail how the practical constraints can be taken into account during the survey design and execution.

NRP's experience is that poor or unfavourable sea conditions are a significant constraint to undertaking surveys at most wet renewable sites. The practical realities of undertaking surveys in high energy sites are described and the implications of this for complying with survey guidance are examined. A key aspect of managing these constraints is consideration of the data quality and survey frequency requirements. The current norm for EIA studies is to undertake a two-year programme of monthly survey work. Results from the sites surveyed by NRP are briefly examined to see how well such a generic approach is appropriate for a range of seabird species.

It is concluded that the appropriate amount of survey effort and quality of data required vary between species, sites and the type of technology to be deployed, and these factors should be taken into account at the survey design stage. It is further concluded that survey guidance and monitoring will need to be updated and revised as knowledge of the impacts of wet renewables on marine wildlife improves. In the same way that has occurred for terrestrial wind farms, there is likely to be a shift away from generic surveys aimed at all species towards surveys that focus on priority species and issues and conducted only at the times of year when significant impacts are plausible.

EIMR2014-6115: MARINE MAMMALS AND TIDAL TURBINES: UNDERSTANDING TRUE COLLISION RISK

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ABSTRACT: Understanding how animals may be able to avoid collisions is crucial in determining the true risk of collision between marine mammals and tidal turbines. SMRU Marine and the Sea Mammal Research Unit (SMRU) are driving the development of innovative monitoring techniques on several tidal energy projects to collect data on near-field behavioural responses and to determine true encounter rates. One of these projects is at Marine Current Turbines' (MCT) SeaGen tidal turbine in Strangford Lough, NI. MCT have secured a license to operate the turbine without the precautionary marine mammal shutdown mitigation that was originally implemented to protect the Strangford Lough harbour seal population (a qualifying feature of the Strangford Lough SAC designation). This paper presents an update on the latest studies currently planned around the UK and highlights how data will be collected to provide evidence for evasion or avoidance capabilities of marine mammals; currently a key barrier to unlocking the future potential of marine energy.

EIMR2014-7105: MODELLING CHANGES TO PHYSICAL ENVIRONMENTAL IMPACTS DUE TO WAVE ENERGY ARRAY LAYOUTS

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ABSTRACT: This paper describes the first stage of an approach developed through the NERC/Defra EBAO (Optimising Array Form for Energy Extraction and Environmental Benefit) project to model the potential environmental impacts of a range of wave farm designs. The eventual aim of the methodology is to inform array design in order to minimise negative environmental impacts or even produce benefits. The modelling study considers differing array sizes and layouts, allowing issues such as the most appropriate device spacing, or the need for a 'corridor' between clusters of devices, to be assessed from an environmental perspective. The results presented in this paper focus on the physical wave climate, using the EMEC test site as a case study. The modelling uses the SWAN spectral wave model to assess the potential far-field change in the wave climate due to different array layouts and spacing. Preliminary results indicate that although designing arrays as sub-array clusters with corridors between them will have a notable effect on the wave climate impact in the immediate wake of the array, at far-field distances (>5km), differences in the impacts when compared with regularly-spaced arrays are negligible. These results are discussed in the context of other physical impacts including acoustic noise, and conclusions drawn regarding the overall impact of array design on the marine environment.

EIMR2014-7118: THE MODELLING OF TIDAL TURBINE FARMS USING MULTI-SCALE, UNSTRUCTURED MESH MODELS

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ABSTRACT: A model intercomparison study is presented between MIKE 21 and Fluidity for the modelling of tidal turbine farms. Close agreement is observed in the outcomes of both models. An important aspect is the parameterisation of turbines in tidal models that typically do not resolve the individual turbine scale. Here we present a correction to the applied drag force to ensure results that are less mesh resolution dependent.

EIMR2014-8111: WHAT'S NEXT AND WHY? A LOOK AHEAD AT STRATEGIC ECOLOGICAL RESEARCH DIRECTION

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ABSTRACT: In the marine environment we are about to move from an era of testing and single devices or relatively small areas of wind farms to very large arrays of offshore energy development for wind, wave and tidal energy extraction. As we are moving to the use of substantial amounts of our most productive oceanic areas to be harnessed for the 'greater good' of supplying the urgent need for lowcarbon energy we must understand, at a fundamental level, the ecological impact of this activity at the ecosystem level. In our world, with an increasing population, we need to be smarter in encouraging anthropological activity at sea than we were on land over the last few centuries – where globally our biggest cites are also generally over running on top of very fertile soils, situated in large deltas of the major maritime trading ports of the past.

So far the understanding of possible environmental interactions has been somewhat limited by the lack of even the most basic of baseline data. Therefore some years and a lot of money has now been spent just in starting to determine the answers to question such as: what species are present, how many and where are they? A resounding answer to all questions has been – YES, there are a lot of species which use these high energy areas for foraging and migration routes between feeding grounds and sites used for reproduction. There are also some specialist species which may use these high energy sites almost exclusively for foraging.

Therefore we need to do much more than just document what organisms are present and if their distributions are changing. We need to understand what happens across trophic levels at these high energy sites and what the effects of extracting a proportion of wind, wave and tidal energy, or just the deployment of man-made structures, will have on the behaviour of foraging and migrating animals.

An understanding of cumulative effects, in their widest sense, ranging from the production levels of primary produces to the reproductive output of marine mammals, needs to be progressed such that a more accurate prediction of the scale and intensity of effects in 'downstream' regions can be considered. We do have a good enough understanding at both small and large scale spatial and temporal levels to be able to make predictions of at least what will change physically within our marine environment when many hundreds to thousands of marine renewable devices are operating. We need to match that knowledge with a rapid increase in our understanding of how a range of animals from the benthos, through to fish, seabirds and mammals will react to those changes in order to make well informed, lower risk and ecologically sustainable choices in the approved locations, density and detailed array design of renewable developments.

EIMR2014-8114: USE OF ANIMAL TRACKING TECHNOLOGY TO ASSESS POTENTIAL RISKS OF TIDAL TURBINE INTERACTIONS WITH FISH

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ABSTRACT: Fish utilization of high flow environments and the associated risks of fish-turbine interactions at tidal energy development sites are little understood. The Fundy Ocean Research Centre for Energy (FORCE) in the upper Bay of Fundy is a tidal energy test facility that has been the focus of a multi-year fish tracking study (2010-2013) to address questions related to the potential risks of turbine operation to migratory species "at risk" – Atlantic salmon, Atlantic sturgeon, American eel and striped bass. Tagged fish of all 4 species were detected on receiver "listening gates" in the Minas Passage and FORCE test area. Travel speeds through the Minas Passage often exceeding 3m/s. Swimming depth in Minas Passage was variable for eels, sturgeon and striped bass and largely within the top 40m in and near the FORCE test area. Of the four species, striped bass was most commonly detected in the Minas Passage, with many being detected during summer, fall and winter. The ability of striped bass (and other fish species) to detect and avoid tidal turbines when travelling at very high speed (>3m/s) remains unknown. The main challenge faced in detecting acoustically tagged fish in Minas Passage is poor receiver efficiency due to excessive noise interference when current speeds exceed 2m/s.

Poster Presentations

Abstracts for poster presentations accepted for the conference are arranged numerically according to submitting Author's ID

EIMR2014-91: OFFSHORE WIND IN THE BELGIAN PART OF THE NORTH SEA: UNDERSTANDING ENVIRONMENTAL IMPACTS

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ABSTRACT: Belgium has allocated a 238km^2 zone in the Belgian part of the North Sea (BPNS) to offshore renewable energy production, for example offshore wind farms. The first wind turbines were built in 2008. At present (March 2014), 153 turbines are operational in the BPNS. The installed wind turbines differ in foundation type and generated power: while the first six wind turbines have gravity based foundations (GBF), the majority are monopiles (98) followed by jacket foundations (49). The power that can be generated ranges between 3 and 6.15 megawatt (MW) per wind turbine. In the next few years, several hundreds of turbines will be up and running. The offshore wind farms are expected to contribute for about 43% of the Belgian 2020 targets for renewable energy.

EIMR2014-93: FROM NATIONAL TO REGIONAL LOCATIONAL GUIDANCE FOR RENEWABLES

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ABSTRACT: The recently published Regional Locational Guidance for Wave and Tidal Devices in the Shetland Islands (RLG) arose as a first step in identifying opportunities for future renewable developments. Although marine renewables offer potential economic and environmental benefits, there is a need to ensure that the growth of this emergent industry considers existing features and users of the marine environment, and there is a clear role for marine spatial planning to guide its spatial development. In response to this, the Scottish government has produced Sectoral Marine Plans for offshore wind, wave and tidal energy. However, although these provide strategic direction for the marine renewables industry at a national, societal level, they do not represent the local cultural values of those potentially impacted by siting decisions. The Shetland RLG is a complementary, sensitivity led approach to identifying the suitability of areas around the Shetland Islands for renewable energy development. It has been successfully translated into policy within the Shetland Islands Marine Spatial Plan, which will form supplementary guidance to the Shetland Islands Council's forthcoming Local Development Plan. Working closely with local stakeholders was key to this process, which incorporates economic, environmental, social and cultural constraints into one constraint model; constraint levels are set by local and societal values, rather than monetary equivalences. Here we present a comparison of this local plan to the national Sectoral Marine Plans, and provide insights on the process of developing local scale Guidance.

EIMR2014-98: CHANGES TO EDDY PROPAGATION DUE TO TIDAL ARRAY AT RAMSEY SOUND

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ABSTRACT: This paper details a depth averaged finite element model of the Pembrokeshire coast. The influence of a 10MW tidal array at St David's Head is modelled as an extra sink in the momentum equations solved by the hydrodynamic software Telemac. Initial results show that, at St David's Head during a peak spring flood (2.74m/s), the wake of the array extends ~4km. Ramsey Sound is very turbulent environment producing large eddies. The changes to the hydrodynamics, by the array, directly influence the creation and propagation of these eddies. Initial investigations suggest the influence of these eddies propagations may extend as far 35km away.

EIMR2014-911: ADVANCING SOCIAL STUDIES OF MARINE ENERGY

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ABSTRACT: Marine spatial planning (MSP) is a social and political construct requiring deep understanding of human behaviours and attitudes to marine development. The UNESCO definition of MSP concludes with the words "…objectives that are usually specified through a political process". To date, academic research relating to Marine Renewable Energy (MRE) has largely focused on resource assessment, technical viability and environmental impact. Experiences from onshore renewable energy tell us that social acceptability is also critical to project success. However, experiences from onshore may not be directly applicable to MRE and the specific nature of marine resource distribution and governance. ISSMER (International Network for Social Studies of Marine Energy) is an international network formed of social scientists, environmental economists and anthropologists with an interest in marine (ocean) energy. Working through a NERC funded programme, a team from ISSMER has researched the need for social studies of MRE. The research addressed the major headings of economic impacts; wealth distribution and community benefits; communication and knowledge flow; consultation; future uncertainty; public attitudes; planning processes; and comparative studies[1]. Drawing on this research, this paper advances an agenda for social science research into MRE. The study on which the agenda is based adopted a novel approach allowing local experts to have the main voice giving academic researchers the opportunity to learn directly from real-world experiences. The study was conducted in Orkney which is home to the most intense cluster of MRE research, development and deployment activity in the world today. At a workshop 12 guest experts (drawn from MRE promoters, developers, government and local planners, local industries and the arts/cultural community) entered separately into conversation with 25 invited ISSMER academics from 10 countries. The paper concludes that understanding of social interactions is vital to the successful assimilation of large scale MRE development into the marine environment. As new energy landscapes begin to involve the sea and coast as well as the land, collaborative and future-oriented social science research has an essential role to play. Future development of the ISSMER network and a research agenda are identified.

EIMR2014-915: THE MORPHODYNAMICS OF A BEACH IN THE LEE OF WAVE ENERGY CONVERTER ARRAYS

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ABSTRACT: A fully coupled 3D spectral wave, hydrodynamic and sand transport model is used to investigate the impact of wave energy converters on the Bay of Skaill, Orkney. Cross-shore intertidal beach profiles were measured over a short term experiment to provide calibration data for the numerical model. The model failed to correctly predict the measured intertidal change. Tests with wave energy converters in place did show differences in beach response but confidence in results is low due to poor predictability of the natural condition.

EIMR2014-916: IDENTIFYING GAPS RELATED TO POTENTIAL IMPACTS OF OFFSHORE RENEWABLE ENERGY DEVICES

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ABSTRACT: Technologies to extract renewable energy from marine waves and tidal streams are developing rapidly. However, one constraint to their implementation remains a lack of scientific data and knowledge with which to make confident assessments about the potential impacts of these new technologies on certain ecological receptors.

ABP Marine Environmental Research (ABPmer) Ltd has undertaken research to identify evidence gaps regarding the potential impacts of offshore wind, wave and tidal energy devices in order to determine where we are in terms of providing the industry with the tools needed to make an informed assessment. The research has mainly been done to inform the Habitats Regulations Appraisals (HRAs) for marine renewable energy plans and has involved exploring how the industry tackles these issues on the ground before then providing recommendations for the next steps.

EIMR2014-917: LINKING FORAGING THEORY AND BEHAVIOURAL DATA: UNDERSTANDING FORAGING BEHAVIOUR AND THE IMPACT OF TIDAL RENEWABLE DEVICES

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ABSTRACT: The potential impact that the development of renewable resources may have on habitat characteristics, availability and distribution of the resources and the behaviour of different species is still unknown. Diving marine predators, such as seabirds, forage at depths at which tidal turbines are likely to be located. The difficulty in observing seabird's underwater movements, where and when they search for the resources, their prey capture rates and their foraging strategies generates a lack of data and also a lack of general theory that can inform the development of behavioural models.

Motivated by these issues, we first developed a theoretical 2-Dimensional model to gain understanding of the potential differences in foraging efficiency of diving predators characterised by contrasting foraging strategies in complex landscapes. Animal movements, intervals between prey captures and foraging efficiency are likely to critically depend on species' foraging strategies, size of devices and their effect on prey distribution.

However, diving animals move and forage in complex and highly variable 3-Dimensional environments. Our 3-Dimensional model aims to simulate predator and prey behaviour, starting from statistical parameters extracted from biologging behavioural data and multifrequency instruments. This modelling framework aims to provide a better understanding of the mechanisms and consequences of movements and subsurface predator behaviour under different complex scenarios. This clearer analysis will then be used to assess likely impacts of alternative future development scenarios.

EIMR2014-919: TIDAL ENERGY RESOURCE ASSESSMENT INCLUDING THE LOCAL WAVE CLIMATE

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ABSTRACT: Surface waves will influence fatigue loading estimates and array optimization, as well as resource and environmental impact assessments; yet wave climates at tidal stream energy sites are poorly understood. Although much research has been focused on the influence of surface waves upon tidal turbine performance, a major limitation within such research appears to be the direction of wave propagation. Previous studies assume "waves following" or "waves opposing" to the tidal current. The wave climate of

the Northwest European shelf was simulated over the 7 years (2005-2012), and compared to tidal currents simulated with a 3-dimensional ROMS tidal model. A significant wave climate oblique (i.e. out-of-line) to the rectilinear tidal flow was found. Therefore, waves may not always "follow" or "oppose" the tidal current, but propagate at angle to the flow. Furthermore, the oblique wave climate was found to be bigger than the inline wave climate, both in magnitude and frequency. Hence, wave angle should be considered in future research of tidal turbine interaction with ocean conditions.

EIMR2014-921: BENTHIC INTERACTIONS WITH RENEWABLE ENERGY INSTALLATIONS IN A TEMPERATE ECOSYSTEM

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ABSTRACT: Wave Hub is a Marine Renewable Energy Installation (MREI) off the southwest peninsular of the UK. Wave Hub's seabed infrastructure, including the main connection unit and 18km of seabed cable were deployed in 2010. To enhance knowledge on the potential future impacts of MREI, this study assesses the effect of the power cable, with its associated 80,000 tonnes of rock armoring. Species assemblages were compared between rock armored and control sites two years after installation.

EIMR2014-927: UNDERWATER SOUND LEVELS AT A WAVE ENERGY DEVICE TESTING FACILITY IN FALMOUTH BAY, UK

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ABSTRACT: There is a paucity of evidence on the noise produced from in situ wave energy converters (WECs) during all stages of their deployment, operation and decommissioning. Research in this area is needed to inform the consenting process. The aim of this research is to gather empirical data to address this knowledge gap. A WEC has been trialled at the Falmouth Bay Test Site (FaBTest), in Cornwall, UK since March 2012.

The area supports considerable commercial shipping and recreational boating along with diverse marine fauna, including bottlenose dolphins, harbour porpoises and fish. A passive acoustic monitoring device, recording broadband sound in the effective frequency range 10 Hz to 32 or 48 kHz, for half an hour in every hour, has been deployed at the FaBTest site since March 2012. Underwater sound monitoring covered a two week baseline period, a five day installation period, testing periods when the WEC was producing power and when the device was not producing power but was in situ. The median sound level during the baseline period ranged from 60-80 dB re 1 μPa in the frequency range 0.01-10 kHz, then decreasing to ~45 dB re 1 μPa at 48 kHz. It is likely that the considerable shipping present at the site affects the sound levels. Sound levels were, on average, higher during installation activity compared to periods of no installation activity in the frequency range 10-5000 Hz with a median increase of 8.2 dB re 1 μPa (interquartile range=6.7 dB re 1 μPa). Average sound levels were found to be louder at times when the WEC was producing power compared to times when the device was in situ and not producing power in the frequency range 10-1000 Hz with a prominent peak in the frequency range 57-63 Hz. From the long term monitoring of the site it has been identified that the sound levels are highly variable, and it is difficult to determine the effect of the wave energy converter in such a variable ambient noise environment. The paper will summarise the sound level findings and estimated source levels of installation and operational sounds, which will be combined with hearing sensitivity information from the literature to estimate the effect on local species.

EIMR2014-928: IMPROVED ARRAYS FOR TOWED HYDROPHONE SURVEYS OF SMALL CETACEANS AT OFFSHORE MARINE ENERGY SITES

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ABSTRACT: Planned developments of marine renewables in areas which are important habitats for small cetaceans is providing an increased requirement for quantitative surveys in areas which are often physically challenging to work in. Towed passive acoustic surveys can be a cost effective method of providing abundance estimates over extended areas. There are some short comings with existing methods, especially in reliably measuring range from a track line for distance sampling analysis. We built, tested and compared the performance of three different arrays. All provided measures of range to sound sources that would be useful in Distance analysis. A long baseline planar array provided the lowest % error for target motion analysis (11%) and using newly developed code it was possible to calculate "instantaneous" locations for short vocalisation bursts using data from this array. An array with a tetrahedral configuration of hydrophones within an acoustically transparent "torpedo" housing showed promise as it provided unambiguous 3D bearings while being easy to deploy and retrieve at sea. We are encouraged by these early results and suggest some obvious next steps to achieve further improvements.

EIMR2014-931: A 3D FAR-FIELD MODEL FOR PREDICTING THE HYDRODYNAMIC IMPACTS OF TIDAL TURBINE ARRAYS

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ABSTRACT: Tidal current energy resources have the ability to provide a sizable proportion of our future energy requirements. However, to date there have been relatively few deployments of commercial-scale tidal turbines and, as a result, field data relating to hydro-environmental impacts is severely lacking. It is therefore necessary, to utilise numerical models to determine the likely impacts of deployments of turbine arrays on the surrounding environment. For the purposes of this research, an existing three-dimensional (3D) model was modified to incorporate the mechanics of energy extraction by a tidal turbine. The tidal turbine is simulated as a porous disc and energy is extracted from the flow by incorporating the turbine thrust as a retarding force. The 3D model developed was validated against previously published one dimensional (1D) results and applied to an idealised channel to simulate the effects of both floating and bed mounted turbines. As expected, attenuation of current was found to occur within the extraction layers. However, currents above and below the extraction layers were also found to be accelerated above ambient levels. The turbines' deployment depth was also found to significantly alter the effect of energy extraction on the vertical velocity profile. These effects can only be observed using a 3D model, thereby demonstrating the benefit of utilising 3D over 2D models.

EIMR2014-932: A FREQUENCY DEPENDANT METHOD FOR THE SIMULATION OF DISTURBANCES AROUND A SMALL SCALE WARE FARM USING A BOUSSINESQ SIMULATION

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ABSTRACT: A Boussinesq model has been created to simulate the presence of an array of shallow water wave surge oscillator devices using DHI's MIKE21 Boussinesq wave (BW) model suite. The simulation uses a regular grid domain with a constant depth of 10m and a grid spacing of 2m in the x and y dimension.

This new method provides a crucial enhancement of including a frequency dependant absorption, where the devices reflected, absorbed and transmitted characteristics are shown using a realistic power transfer function. The frequency spectrum as a set of n monochromatic waves at frequency intervals with a proportional energy scaled wave height. A simulation is then run for each frequency where the porosity value is dependent on the WEC's absorption spectrum. The results of each simulation are then summed to form overall wave energy.

The results demonstrate the application of this new method and provide a detailed map of the spatial change in wave energy around devices, highlighting the regions of importance.

EIMR2014-933: HAS THE DEPLOYMENT OF MARINE ENERGY CONVERSION SYSTEMS AT EMEC'S FULL-SCALE TEST SITES CAUSED ANY DISCERNIBLE DISPLACEMENT OF KEY WILDLIFE SPECIES?

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ABSTRACT: This first-of-its-kind project will answer one of the most pressing questions facing decision-makers in the industry today: Can the presence of Marine Energy Conversion Systems (MECS) cause displacement of marine wildlife? Specifically, the project will utilise unique long-running wildlife observations and MECS operational status datasets collected at the EMEC full-scale grid-connected test sites to determine whether the presence and operation of MECS can cause discernible spatial displacement or redistribution effects on birds and marine mammals at test site scale. The study will also examine whether associated vessel activities have had any discernible effect on marine wildlife at the test sites.

EIMR2014-934: SYNCHRONISATION OF ENVIRONMENTAL MONITORING ACROSS EUROPEAN WAVE AND TIDAL TEST CENTRES (PART OF THE FP7 MARINET PROJECT)

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ABSTRACT: The immediate focus of the wave and tidal energy industry over the next 3 to 5 years will be on test centres, with the first commercial scale devices currently under test at a few high-energy sites across Europe. At this early stage of the industry the extent to which these technologies interact with the surrounding environment is largely unknown, and understanding these interactions will be essential to the acceptance and commercial development of these technologies. Test centres therefore have an instrumental role to play in making sure that environmental monitoring is targeted and effective, allowing the industry to progress beyond this crucial pre-commercial stage. This study looks at the need for environmental monitoring at marine renewable energy test centres across Europe, describing the key environmental uncertainties surrounding marine renewable energy developments, and strategies, protocols, equipment and techniques being developed to address them.

EIMR2014-935: FURTHER DEVELOPMENT AND TESTING OF THE EMEC INTEGRATED ENVIRONMENTAL MONITORING PLATFORM

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ABSTRACT: Under the UK Energy Technologies Institute funded ReDAPT project, EMEC designed, built and operated a cabled integrated environmental monitoring platform for use at tidal test sites.

The main purpose of this integrated monitoring unit is to undertake behavioural monitoring of marine mammals and diving birds in the close vicinity of operating marine turbines, in order to assess the risk of harm to these species due to potential collision with devices. This is still a key area of concern for regulators It also facilitates environmental characterisation and gathering of acoustic output data from devices in operation.

A cabled system has been developed in order to facilitate long-term 24/7 real-time data collection. The unit was successfully commissioned and operated for an initial six months and is now undergoing some design improvement, being scheduled for redeployment at the EMEC tidal site (thanks to MRCF funding) in summer 2014.

EIMR2014-936: THE ROLE OF THE SEABED COMPOSITION IN THE PLACEMENT OF TIDAL TURBINES – SEDIMENT MOTION IN A TURBINE WAKE

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ABSTRACT: The placement of tidal turbines has been investigated previously in the context of maximizing their power output, but without necessarily considering the local impact of the devices on sediment motion. This paper presents the results of an investigation, through high-resolution three-dimensional computational simulations of the hydrodynamics of a horizontal-axis tidal turbine and the motion of sediment in the turbine wake, into the role of the seabed composition in the interactions between the rotor wake and the seabed.

EIMR 2014-938: SECTORAL PLANNING FOR MARINE RENEWABLE ENERGY DEVELOPMENT IN SCOTTISH WATERS

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ABSTRACT: Marine Scotland is the marine planning authority in Scottish waters. Planning for marine renewables is being addressed through a sectoral planning process, and the Draft Sectoral Marine Plans are being progressed within the broader context of the Draft National Marine Plan for Scotland. Sectoral Plans are intended to complement both the National and future Regional Marine Plans through the provision of relevant information and assessment on strategic spatial locations considered suitable for the development of commercial scale offshore renewable energy. The primary purpose of Sectoral Plans is to ensure compliance with EU and domestic legislation, and in doing so provide a spatial basis for licensing and for any future leasing rounds.

The Draft Plans identify 8 potential options (zones) for wave and 10 options for tidal energy potentially suitable for commercial scale offshore renewable energy developments. The Draft Plans are supported by Regional Locational Guidance documents which provide a wide range of detailed information on environmental characteristics, current uses and socio-cultural factors in the Plan Options and surrounding areas to assist stakeholders in their assessments of the Draft Plans. The Draft Plans have been subject to Sustainability Appraisal, comprising Strategic Environmental Assessment, a socio-economic assessment and a Habitats Regulations Appraisal (HRA) to identify the potential for effects on designated European nature conservation sites. The Sustainability Appraisal identifies the potential key sectoral impacts for developments at a regional level, such as fishing and shipping. This is based on an assessment of the existing sea usage and environmental attributes within each plan option. A Sustainability Appraisal Report also accompanies the Draft Plans to explain the combined outcomes of the socio-economic and environmental assessments.

The Draft Plans were subject to public consultation during the summer of 2013, and the consultation analysis will be taken into account in developing the final Plans. The Regional Locational Guidance will be revised once the final Plans have been prepared.

EIMR2014-942: THE USE OF BREEDING SEABIRD FORAGING RANGES FOR ASSESSING IMPACTS TO SPECIAL PROTECTION AREAS (SPA's) FROM WAVE AND TIDAL RENEWABLE ENERGY PROPOSALS

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ABSTRACT: Wave and tidal renewable energy devices have the potential to impact diving birds through collision, disturbance and habitat loss. EU and UK legislation requires that these impacts are assessed through an Environmental Impact Assessment (EIA) and Habitats Regulations Appraisal (HRA). Under HRA, seabirds which are qualifying features of SPAs are protected both within and outwith the SPA and, therefore, potential impacts to breeding seabirds both within and outwith the SPA require assessment. During the breeding

season, seabirds are known as central-place foragers, as they are fixed to a single geographical breeding location with a foraging range extending out to sea. The use of breeding season foraging ranges provides a suitable method for assessing geographical overlap, and thus connectivity, between SPA breeding seabird colonies and proposed wave and tidal renewable energy development sites. If connectivity is established, the next stage involves consideration of site characterisation survey results, information on impact pathways, and the sensitivity of the species to potential impacts. SPA breeding seabird populations are protected at all times and not just the breeding season. As such, any HRA will require assessment of SPA populations both during the breeding and non-breeding season. During the non-breeding season, however, most seabird species tend to range more widely and are not fixed to a single geographical location. We provide details of a GIS based analysis of breeding seabird foraging ranges to assess connectivity of SPAs with wave and tidal Areas for Lease. This method may also be used to assess connectivity for other protected seabird colonies, such as Sites of Special Scientific Interest (SSSIs), Marine Protected Areas, and for regionally important colonies, for assessment under the EIA. It may also be used to inform impact assessments for other marine developments, such as off-shore wind farms. This work provides a key resource to the consenting process and can be used by developers, consultants, government and their advisors in the assessment of environmental impacts of marine renewable developments.

EIMR2014-943: STICKING TOGETHER: MOVEMENT OF MARINE MAMMALS AND RESPONSE TO UNDERWATER NOISE

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ABSTRACT: Marine mammals use vocalisations for a number of purposes: in locating food and underwater obstacles, and to maintain contact with members of their family group. These sounds are loud in comparison with the ambient background, but are subject to masking due to underwater noise sources such as tidal turbines.

We developed a model of animal movement which implements simple behavioural rules to allow group cohesion. We discuss some general features of group behaviour, and approaches to validation of the model using empirical data. Including external sources of noise can lead to loss of contact between group members. However, animals can take various measures to deal with these effects, such as more frequent vocalisation or "panic" swimming in response to sounds.

EIMR2014-944: EXPLORING THE INTERACTIONS BETWEEN WAVE ENERGY EXTRACTION AND KELP COMMUNITIES IN SCOTLAND

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ABSTRACT: Marine renewable energy is a rapidly growing sector in Scotland, with wave devices forming part of the design mix. The cover of kelp (specifically Laminaria hyperborea) is a major driver of subtidal biodiversity in the UK. The development of a wave energy industry in high energy regions of sea may coincide with areas known to support important kelp habitats. To facilitate progress of the sector, it is necessary to consider the risks to environmental features to understand impacts and mitigate at a planning and project level. Work commissioned by Scottish Natural Heritage assessed in detail the likely interactions between kelp habitats and activities associated with the developing wave energy industry. An assessment of the features of wave energy devices that are likely to cause changes in kelp communities and their 'functioning' was made. Using key features of each device, including the method of attachment to the seabed and the depth of deployment, made it possible to group different approaches to extracting wave energy in order to evaluate their potential impact on kelp communities. This revealed that shallow seabed mounted structures were the most likely to have significant impacts on the functioning of local kelp communities as these technologies are placed directly within the kelp zone and are associated with an extensive infrastructure of cables (and in some

cases high pressure water pipes). After disturbance, kelp communities will largely recover within 5-6 years. Assuming that the large majority of areas disturbed in shallow subtidal areas will be replaced with suitable hard substrata, communities will likely recover within the lifespan of projects (approximately 20 years). However, the response of ecosystems to disturbances, whether natural or anthropogenic, is scale-dependent, and it is important to identify the scale(s) at which kelp communities are most strongly impacted by disturbances. Kelp forests are dynamic systems that undergo significant interannual and seasonal fluctuations in biomass which can occur over tens to hundreds of kilometres in a year. In Scotland, winter storms physically remove approximately 34% of the kelp canopy biomass from the rocks each year. This review of the ecological implications of kelp community disturbance will allow for such changes to kelp communities to be detailed in context with natural processes of succession and disturbance. Such information will aid the wave energy community (developers, regulators, etc.) to more accurately determine their impact on kelp communities whilst identifying opportunities for mitigation.

EIMR2014-949: MODELLING OFFSHORE WIND FARMS OFF THE EAST COAST OF SCOTLAND USING THE FINITE-VOLUME COASTAL OCEAN MODEL (FVCOM)

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ABSTRACT: There is considerable interest in Scotland in the expansion of renewable energy production. In particular, significant offshore wind energy developments are already planned in coastal waters to the east of the Forth and Tay estuaries. It is important to understand the local and cumulative environmental impact of such developments within this region, to aid licensing decisions but also to inform marine spatial planning in general. Offshore wind farms have the potential to interact with physical marine and coastal process in numerous ways, such as tidal, wind, and wave driven circulation, as well as coastal sediment transport and estuarine dynamics. These interactions can provide further feedbacks with ecological systems, which could ultimately have socio-economic consequences. The Firth of Forth and Tay areas both exhibit complex estuarine characteristics due to fresh water input, intricate bathymetry and coastline, and tidal mixing. An unstructured grid hydrodynamic model of the Firth of Forth and Tay region is being developed using the Finite-Volume Coastal Ocean Model. Our goal is to resolve the estuarine hydrography of the area, and simulate the presence of wind farms by considering the potential wind speed deficit due to the wind farms and by representing the wind turbine foundations within the model. In this study the potential for large wind farms to influence the physical processes in the area is investigated. It is anticipated that this work will help provide an accurate baseline of the hydrography in this region, and the means for the assessment of the potential consequences of multiple wind farm development scenarios.

EIMR2014-951: COMPARISON OF TWO TYPES OF HYDRODYNAMIC MODEL FOR INVESTIGATING THE ENVIRONMENTAL IMPACTS OF ENERGY EXTRACTION FROM TIDAL FLOWS

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ABSTRACT: Two commercial suites, MIKE3 by DHI and TideModeller by Ansys, are used to simulate energy extraction by an array of tidal turbines in Lashy Sound, Orkney. We compare the predictions of the two models for the effects of energy extraction on flow speed and water level, and consider the advantages and disadvantages of the two modelling approaches for various environmental impact applications.

EIMR2014-952: DETECTING ONSHORE IMPACTS OF WAVE POWER DEVICES: MAPPING INTERTIDAL ROCKY SHORES WITH REMOTELY PILOTED AIRCRAFT

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ABSTRACT: The basic methods for sampling rocky shore communities have not changed for many decades. Most surveys are variations on transect-based and/or stratified random sampling of quadrats whose scales and spatial arrangement are determined by the capabilities of the observer. The primary goal is to provide estimates of abundance of assessed species that are representative of the whole shore, based on statistical assumptions. Here I present the results of an alternative approach using multiple images taken by a camera mounted on a low-flying remotely piloted aircraft, flying a pre-programmed flight path. Three locations in the Outer Hebrides were surveyed in June 2013 as part of the pre-deployment phase of a study to assess the effects of an array of nearshore wave-energy extraction devices. Ground-based low-tide surveys were made using categorical abundance and quadrat-based estimation of abundance of conspicuous cover-forming species. Overflights were made at the same time using a 1.5m-wingspan Quest 200 UAV at 30m altitude, equipped with a Panasonic LX5 camera taking images every 2s. Flights lasted up to 25 minutes and returned 150-200 overlapping GPS-located images of the target area. Photogrammetry software allowed the production of ortho-photographs and digital elevation models (DEMs) of areas extending 400-700m along the coast and 70-100m from low to high shore. The orthophotos and DEMs had resolution of 1.5cm and 5cm respectively. This resolution showed individual fucoid plants and other macroalgae, notably Enteromorpha intestinalis, and the quality of the images permitted the distinction between areas dominated by newly settled and older barnacles (mostly Semibalanus balanoides). Supervised pixel classification on downscaled (5-cm) images gave moderately successful recognition of six types of substratum cover. The results of the aerial and ground-based surveys were compared, and the relative merits of each were assessed. Aerial methods are not likely to replace ground surveys soon, but they allow scaling up from quadrat-based estimates with an unprecedented level of confidence, and are likely to play an increasingly important role in the development of rocky shore ecology in the 21st century.

EIMR2014-953: MODELLING AND COMPARING THE SEASONAL AND DIURNAL COMPONENTS OF ELECTRICITY DEMAND, WIND SPEED, WAVE HEIGHT AND WAVE PERIOD; FOR THE ISLES OF LEWIS AND HARRIS

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ABSTRACT: The location of the Isles of Lewis and Harris, off the west coast of mainland Scotland (Figure 1), is favourable for the generation of renewable electricity from both the wind and ocean waves. However the islands' position on the UK electrical grid's periphery, with restricted local network capacity and only a limited connection to the mainland, makes it more challenging to capitalise on this advantage. This study sought to explore the relationship between the local wind and wave resources and consider how they track the islands' indigenous demand for electricity.

This was accomplished by using a mixture of Fourier analysis and auto-regressive techniques to model and de-trend local electricity demand data gathered over a 365 day period; and similarly process the wave and wind parameters associated with renewable generation, obtained from Hebridean metrological measurements recorded over the same interval.

Results confirm that due to the partially complimentary relationship between wind and wave power, balancing generation across these sources is more likely to be efficient at matching customer demand, rather than a reliance on electricity from wind power alone. This would seem particularly significant for relatively isolated networks with only limited local network capacity and modest quantities of conventional generation available to balance any fluctuations in renewable supply.

In conclusion, for the Isles of Lewis and Harris over the 365 day period studied, where grid capacity is restricted and such resources are available, it appears advantageous in terms of network efficiency to combine generation from wind and wave sources.

EIMR2014-954: MODELLING THE IMPACT OF TIDAL FARMS ON FLOOD RISK IN THE SOLWAY FIRTH ESTUARY

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ABSTRACT: The available tidal energy resource within estuaries is quite significant in the UK but these areas are usually prone to flooding. The objective of this study is the assessment of flood risk due to tidal farms in estuaries through its application to a real case, the Solway Firth.

A numerical model has been developed to represent the hydrodynamic conditions of the estuary during an extreme event. The results from this model for the maximum velocities indicate the suitable locations for the tidal farms. Two different cases with parallel and staggered configurations of tidal farms have been introduced. The comparison of the results for the maximum water levels between the situations with and without the farms allow us to draw conclusions about changes of flood risk due to the farm and contrast the impact of two different arrangements of turbines. The values of the energy extracted in both configurations will also be investigated.

EIMR2014-955: INTRODUCING NOVEL USES OF MULTIBEAM SONAR TO STUDY BASKING SHARKS IN THE LIGHT OF MARINE RENEWABLE ENERGY EXTRACTION

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ABSTRACT: Reaching over 12m in length, basking sharks (Cetorhinus maximus) are the largest fish in the Northeast Atlantic and seasonally aggregate in UK coastal waters. Little is known about their behaviour during aggregations and as the rate of marine renewable energy development increases, there is an urgent need to develop resource-efficient platforms for monitoring basking sharks. Despite their size, quantifying their natural behaviour in plankton-rich waters remains a major challenge. Here, we present the successful application of a Teledyne RESON (Seabat 7128) multibeam sonar to track basking sharks at a key aggregation site on the West Coast of Scotland. First results of individual fine-scale tracking indicate that multibeam sonar is a promising tool for acoustic detection and tracking from a safe distance to the target species.

EIMR2014-956: A QUALITATIVE, MIXED METHODS APPROACH TO FINDING THE ROLE OF AGENTS FOR CHANGE IN THE DEVELOPMENT OF MARINE RENEWABLE ENERGY IN ISLAND REGIONS

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ABSTRACT: This study uses a qualitative, mixed methods technique to explore the concept of agents for change in the context of community within the case study of wave energy development on the Isle of Lewis and on Orkney, in the Highlands and Islands region of Scotland. It gives a summary of the developed methods and why they were chosen and briefly discusses the role of agents for change and the issues that they face.

EIMR 2014-958: NO TITLE

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ABSTRACT: The planned construction of increasingly large marine renewable energy installations around the UK could substantially increase the availability of hard habitat in many coastal locations. Many authors have suggested that once colonised, these structures are likely to act as stepping-stones for the spread of both native and non-native species. Stepping-stone connectivity between structures may be of growing concern as marine renewable energy developments begin to transition from single devices to increasingly large arrays. Current marine renewable energy environmental impact assessment (EIA) regulations state

that cumulative effects must be addressed in any EIA; modelling studies of connectivity could be useful when identifying the scales of concern for relevant environmental effects (e.g. spread of non-native species, enhancement or detraction from commercial species stocks).

We aimed to assess the characteristics of dispersing organisms which might enhance their ability to colonise offshore structures and spread via stepping-stones. These characteristics included larval behaviour in the form of vertical distribution routines, spawning habitat depth and location, and pelagic larval duration. We coupled a hydrodynamic model of the Firth of Lorn region, Scotland, to realistic biological models of the larval behaviour of three species of barnacle. These biological models were developed from field surveys of horizontal and vertical zooplankton distributions and available literature data on seabed habitat. Modelled dispersal distances ranged between 17.5 and 74 km, and particles could be effectively dispersed throughout the model domain. Vertical positioning in the modelled flow fields strongly influenced the dispersal paths and transport distances of particles. Where spawning habitat was located several kilometres offshore, horizontal transport and dispersal were enhanced.

We suggest a sound understanding of species biology, including habitat preferences, larval vertical distributions, and pelagic larval duration, is essential when assessing the stepping-stone connectivity of biofouling species on marine renewable energy developments. Furthermore, populations formed at renewable energy structures may experience greater transport and dispersal, as larvae may be more quickly swept into directional flows and away from natal habitat. This could increase downstream connectivity for these populations, and amplify the effects and population impacts of successful settlers on offshore renewable energy devices, despite the small habitat surface area they offer. Where these developments span biogeographic barriers, unprecedented dispersal to further habitat could become a possibility for some organisms including climate migrants and/or non-native species.

EIMR2014-964: ASSESSING EFFECTS OF INCREASED NOISE LEVELS ON FISH BEHAVIOUR

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ABSTRACT: Man-made noise can affect physiology and behaviour of animals of all taxa, including fish. However, there is not much known about effects of increased noise levels on anti-predator and foraging behaviour, which are both essential for survival and reproduction. In our laboratory study, we investigated effects of increased noise levels on these behaviours in two sympatric fish species, three-spined sticklebacks (Gasterosteus aculeatus) and European minnows (Phoxinus phoxinus), which differ in their anti-predator defences and likely in their hearing capabilities. Our study indicated that both behavioural contexts were affected by increased noise levels, but effects differed between species. Sticklebacks responded to a visual predatory stimulus sooner when exposed to additional noise playbacks than in control conditions, whereas minnows were not affected by the noise treatments. In foraging experiments, both fish species consumed fewer water fleas, but the reasons fish decreased food consumption seemed species specific: sticklebacks increased the number of foraging errors, whereas minnows tended to decrease their foraging effort by interacting socially more often and more individuals were inactive during increased noise level conditions. To allow for controlled comparative experiments, our studies were conducted in the laboratory. Complementary field experiments ensuring natural acoustic conditions will be necessary to investigate whether species differences can translate into community effects and whether these effects differ between different kinds of noise, such as drilling, pile driving and energy device operation noise. Expanding research to commercially important fish and quantification of particle motion in addition to sound pressure as most fish, and likely invertebrate species, perceive particle motion rather than sound pressure, would further deliver valuable knowledge for industry, policy makers and fisheries managers about how marine renewable energy devices may interfere with the marine environment.

EIMR2014-966: BENTHIC PRODUCTIVITY ON ARTIFICIAL STRUCTURES

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ABSTRACT: The infrastructure deployed in association with marine renewable energy devices may act as artificial reefs. At present, there is little understanding of the factors dictating the production of biomass productivity on such structures, and how this might vary according to prevailing environmental conditions. This is partly because existing techniques for measuring productivity, and its drivers, are not suitable for use in close proximity to the seabed, or over large spatial scales. Using clones of the bioindicator bryozoan Flustra foliacea, benthic productivity on the Loch Linnhe Artificial Reef Complex was quantified. Productivity varied according to exposure to tidal currents and location on/within a single reef unit. Productivity appears to be related to the mass of sediment reaching the reef surface. Such an understanding may be used to better predict the environmental consequences of the scale-up of renewable technology for commercial production.

EIMR2014-967: EFFECTS OF MAN-MADE STRUCTURES ON SEDIMENTARY OXYGENATION: EXTENT, SEASONALITY AND IMPLICATIONS FOR OFFSHORE RENEWABLES

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ABSTRACT: The number of man-made structures to be placed in the marine environment is set to increase massively in the near future as a consequence of the wide-scale adoption and commercialisation of offshore electricity generation. Marine renewable energy devices (MREDs) interact with their receiving environment and are de-facto artificial reefs. The Loch Linnhe Artificial Reef (LLR) complex is a large-scale experimental facility, with the main matrix consisting of 30 separate reef modules deployed in 10-30m depth and over a gradient of hydrographic and sedimentological conditions. The LLR offers potential to examine impacts that are analogous to those likely to occur around MREDs. The aim was to assess changes associated with reef-proximity to inform us about the likely extent and nature of the impacts that are likely to occur around offshore structures that are placed in similar environments.

EIMR2014-968: MODELLING WAVE ENERGY IN ARCHIPELAGOS – CASE OF NORTHERN SCOTLAND

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ABSTRACT: Scotland has a complex coastline that includes hundreds of islands and three major archipelagos, Hebrides, Orkneys and Shetlands. In order to predict the wave resources, the spectral wind wave SWAN was designed on an unstructured grid over the Scottish shelf sea. The grid provides a good resolution in nearshore areas and allows long fetched wind waves.

In spite of the domain size, previous simulations suggested that the boundary conditions could have a significant impact on wave predictions. The implementation of boundary conditions derived from 1D spectral data significantly improved the model predictions. A comparison of the wave energy estimated from wave buoy records and model predictions shows only an under-prediction of 3%.

EIMR2014-969: RESEARCH NEEDS TO REDUCE ENVIRONMENTAL, SOCIAL AND ECONOMIC IMPACTS OF MARINE RENEWABLE ENERGY DEVELOMENT AND STREAMLINE THE CONSENTING PROCESS: AN INDUSTRY PERSPECTIVE

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ABSTRACT: Ensuring novel research and existing best practice are applied to environmental and socio economic consenting issues for marine renewable energy developments provides a possible win-win.

Consenting can be streamlined to increase investor's confidence in developments whilst environmental and socio-economic issues can be identified, assessed and mitigated at the earliest possible stage. To identify priority research topics that have been encountered by the marine renewable energy industry a questionnaire based survey was developed and conducted with industry, regulatory and relevant consultancy personnel. Of the priority research topics identified the existing research and planned projects that were relevant to those topics were summarised following review of existing research activity and discussions with researchers. Following the review of existing research key evidence gaps were identified at the time of the study. These included; development of a knowledge base and planning processes to allow identification of key scoping factors at a site, development of best practice methods for socio economic assessments and stakeholder engagement, evidence on the response and movement patterns of marine mammals encountering tidal turbines and development of effective means to share data from each demonstration array.

EIMR2014-972: DIVING AND FORAGING BEHAVIOUR OF SEABIRDS IN A HIGH-ENERGY TIDAL STREAM: IMPLICATIONS FOR ENCOUNTERING TIDAL-STREAM DEVICES

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ABSTRACT: Diving seabirds may encounter and collide with tidal turbine installations while foraging underwater. Some may be killed or injured. Others may avoid the devices, or even harness prey associated with them, with implications for their foraging efficiency. These consequences have the potential to impact on seabird populations. There is a legal requirement to assess any impacts of marine renewable energy developments through an Environmental Impact Assessment (EIA) and Habitats Regulations Appraisal (HRA).

High energy tidal stream devices are being developed, and this is challenging our understanding of impacts on seabirds. For birds with foraging and diving preferences within high energy tidal streams the devices may have important behavioural and ecological implications. However, our knowledge base on this is very limited. Our study seeks to develop our understanding of seabird foraging and diving behaviour under different tidal conditions within a high energy tidal stream. Focal observations were undertaken from six vantage points along the length of Bluemull Sound, Shetland, prior to the deployment of a tidal stream device. Data were collected during the 2011 and 2012 breeding seasons, and January 2012. During each observation the location and duration of behaviours were recorded, including foraging behaviours and the direction the bird was facing and moving within the tidal stream. Observations were undertaken across a range of tidal conditions. Diving species observed included European shag (Phalacrocorax aristotelis), northern gannet (Morus bassanus), black guillemot (Cepphus grylle), common guillemot (Uria aalge) and Atlantic puffin (Fratercula arctica), with European shag and black guillemot being the most frequently observed species in both breeding and non-breeding seasons.

We present results on diving frequency under these different tidal conditions, and also determine any relationships between dive frequency/direction and tidal speed at different depths. This study is identifying under which tidal conditions species may be more likely to encounter tidal turbines. This should lead to a more accurate assessment of the impacts of marine renewable energy developments.

EIMR2014-978: LEARNING FROM TEST CENTRE EXPERIENCE TO IMPROVE CONSENTING FOR LARGER, COMMERCIAL SCALE WAVE ENERGY DEVELOPMENT

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ABSTRACT: Consenting is an often cited non-technological barrier to progress of marine renewables, and ocean energy in particular. Few large-scale commercial wave energy developments are currently operational yet lessons for consenting processes can be learned from the experience gained by those involved in the

development and management of operational test centres. As part of the SOWFIA project, on streamlining impact assessments for wave farms, six wave energy test centres in Ireland, France, Portugal, Spain, Sweden and the United Kingdom were studied. This paper documents the existing context for development in each country, the consenting process applicable, the environmental monitoring which is ongoing at these sites and the lessons learned to date, with a view to informing the development of more suitable consenting processes for larger, commercial-scale wave energy developments.

In general, strategic plans like Maritime Spatial Planning (MSP) and Strategic Environmental Assessment (SEA) aimed at maximising and managing the sustainable use of maritime areas are not yet fully implemented. Dedicated wave energy consenting processes did not exist in most of the countries analysed, although some countries have recently amended existing legislation to be more reflective of the needs of the wave energy industry. There are some incidences of wave energy EIAs but reliable baseline and long-term impact data are not yet available, partly because the industry is still relatively new. Such knowledge gaps hinder transfer of knowledge and consequent improvement of the environmental assessment process for projects. Consultation is sometimes perceived by stakeholders as a "tick-box" exercise and there is a prevalent view that developers do not really take stakeholders' concerns and opinions into account.

Despite these seemingly negative observations, most stakeholders in the vicinity of the test centres are generally supportive of marine renewables, particularly wave energy, which is viewed as having lower visual and other impacts than some other marine renewable technologies, particularly offshore wind. Whilst consenting processes and environmental monitoring will always be site specific to an extent, it is contended that greater consistency can be achieved across the EU with respect to certain fundamental elements. Based on the experiences to date, a number of strategic and operational recommendations were developed under four main themes namely integrated planning; administrative procedures; Environmental Impact Assessment (EIA); and public consultation. These recommendations were then further tailored to the needs and realities of the individual countries in the hope that they could be put into practice by the relevant actors (regulators, industry and/or stakeholders).

EIMR2014-979: MAKING LANDFALL: THE IMPORTANCE OF THE INTERTIDAL AND COASTAL ZONES TO MARINE RENEWABLE ENERGY DEVELOPMENT

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ABSTRACT: This poster draws on data from several projects completed in recent years to demonstrate the range of maritime archaeological heritage that could be present on the coastal and inter-tidal zones. It will detail why the identification and recording of these remains should be an important consideration in proposals for the development of coastal infrastructure associated with future marine renewables activities.

EIMR2014-984: THE PENTLAND SALMON INITIATIVE: A NEW RESEARCH PARTNERSHIP EXPLORING THE POTENTIAL INTERACTIONS BETWEEN MIGRATORY FISH AND MARINE RENEWABLES

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ABSTRACT: Atlantic salmon (Salmo salar) are iconic and economically important fish, but their migratory behaviour during passage through Scottish coastal seas is not well understood, and there are several key questions which need to be answered in order to predict possible interactions with marine renewable energy arrays. Do migrating salmon (adults and post-smolts) travel through marine renewable energy development areas? Will migrating fish actually encounter arrays of devices as they pass through these areas? What effects might these encounters have on migrating salmon, and what might be the consequences of these interactions for fish populations?

In response to these questions, the Environmental Research Institute has established the Pentland Salmon Initiative – a new partnership which aims to engage a growing number of organisations with interests or

experience relevant to marine renewables and salmon migration, with a particular focus on the Pentland Firth. This site represents not only a potential bottleneck for migrating salmon but also a key site for the developing marine energy sector.

EIMR2014-990: WAVE ACTION MEASUREMENTS OF THE INTERTIDAL ZONE TO ENABLE LONG-TERM ENVIRONMENTAL MONITORING AND PREDICTIONS OF ECOLOGICAL IMPACT DUE TO WAVE ENERGY CONVERTER ARRAYS

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ABSTRACT: Future installations of utility scale wave energy converter (WEC) arrays have the potential to affect both the annual and seasonal wave energy levels on adjacent shorelines while the potential modification of these intertidal habitats and their associated biological assemblages, due to their proximity to such developments, are not well understood.

Unfortunately we currently lack the ability to make accurate predictions of possible impact, particularly to existing vulnerable species that may be under protection by legislation; due to ecological classification systems featuring qualitative energy levels based on physically defined characteristics and not in-situ measured wave energy levels. This situation has been due to the historically reported difficulty of working in such a highly energetic environment especially when long-term monitoring is required. Hydrodynamic models have been used for investigating wave propagation in and around wave devices, but their use is limited by grid resolution and the availability of suitable bathymetric data. A new low-cost device, positioned within biotopes of interest, together with a practical methodology are presented which have been specifically developed to provide a safe and reliable long-term quantitative proxy measurement of wave action on high energy shorelines, thus enabling the discrimination of wave energy levels within a relevant spatial scale of rocky shore biota. Research has been carried out at two replicate intertidal sites, 14km apart, on the west coast of Orkney and both have been able to provide a two year continuous data set of wave action results.

The results presented in this work highlight significant seasonal difference in the average energy levels associated with biotopes that are currently classed as having equivalent levels in the European Nature Information System (EUNIS) classification system. They also support the conclusion that the use of the existing energy classes in classification systems are poorly suited for this field of research and highlights the requirement for quantitative values to be produced.

EIMR2014-992: UNDERWATER NOISE EMISSION FROM THE NOAH'S DRILLING OPERATION AT THE NAREC SITE, BLYTH, UK

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ABSTRACT: In November 2011, the National Renewable Energy Center (Narec) launched their offshore wind demonstrator project 'round 3'. Narec commissioned SeaRoc to undertake the deployment and drilling operation of the Narec Offshore Anemometry Hub (NOAH). On this occasion, the Bio-Acoustic Research Consortium combining university and industry researchers conducted a study on noise and marine mammal occurrence before, during and after installation of the Noah platform. This paper describes the noise emission from the installation of the NOAH's jacket.

The team preliminary undertook underwater ambient noise measurements at different seasons, and locations at the site. The results of these measurements are discussed in this paper.

The pin pile drilling itself occurred at 3 nautical miles offshore Blyth and at a 40m depth. The Newcastle research vessel Princess Royal was positioned at 500m and 3 nautical miles from the NOAH's drilling. The

engine and all electronic equipment on board, such as sonar and depth sensors were switched off during the pin pile drilling noise monitoring. At each position, a self-recorder hydrophone was deployed from a semi-submersible drifting buoy to reduce the effect of the swell (sea state 3), which could have affected the quality of the recordings. The deployment from a drifting buoy also has the advantage of reducing mechanical noise from the boat as the buoy drifts freely away from the vessel. Each recording lasted between 5 and 10 minutes and the buoy was then retrieved for another deployment at the next position. Sample measurements were taken at approximately 10m depth and at a sampling rate of 312 kHz and 24 bits resolution.

Matlab was used as a post-processing tool to analyse the data. Each file was processed on a 2 min average using a FFT of 216 points. The in-house code displays Sound Pressure Level (dB re1μParms) and Pressure Spectral Density (dB re1μParms2/Hz) with a 1Hz resolution.

The results demonstrate that the noise coming from the pin pile drilling was relatively low in comparison to the background noise. At 500m from the drilling, the noise appears to be only 10 to 20 dB higher than the background noise over the frequency band 10 Hz to 50 kHz. Higher energy was concentrated between 100 Hz and 600 Hz reaching up to 100 dB re1μParms.

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EIMR2014-995: ENERGY EXTRACTION IN AN IDEALISED TIDAL CHANNEL: A COMPARISON OF THREE-DIMENSIONAL AND ONE-DIMENSIONAL MODELS

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ABSTRACT: Theoretical estimates of the tidal stream energy resource in a channel may be obtained by modelling the channel mathematically as a one-dimensional system. More reliable estimates of the actual power available for a particular array configuration require more realistic two-dimensional or three-dimensional models that can better resolve the local flow field in the vicinity of, and at the scale of, an individual turbine. Similarly, an assessment of the potential environmental impacts of an array of turbines requires more detailed knowledge of the flow field at a range of scales. Smaller-scale flow phenomena may play an important role in the transport of nutrients and sediments for example.

In this paper we consider the correspondence between one-dimensional and three-dimensional models. In particular, the one-dimensional channel flow equations are derived by integrating the three-dimensional continuum equations, subject to the hydrostatic approximation. This facilitates a mathematical comparison of the two sets of equations, taking explicit account of the simplifying assumptions.

The poster presentation shows results of the computational modelling of an idealised tidal channel using the Finite-Volume Coastal Ocean Model (FVCOM). The hydrodynamic effects of a tidal turbine are simulated by means of a frictional resistance term in the momentum balance equation at the appropriate location in the channel. The results are compared with those obtained from simpler, one-dimensional models. Comparisons are performed both for the baseline case and for an idealised energy extraction scenario.

The wider aim of the study is to explore the limits of one-dimensional models, and to help understand how, and upon what basis, outputs from different mathematical and computational models may be interpreted and compared.

EIMR2014-999: A TIDAL ENERGY LAGOON IN SWANSEA BAY: OPTIMISING ITS VALUE FOR BIODIVERSITY BY CREATING AN ARTIFICIAL REEF

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ABSTRACT: Tidal Lagoon Swansea Bay plc (TLSB) proposes to construct a tidal energy lagoon. The structure will enclose an 11.5km^2 tidal area. The lagoon wall will stretch for 9.5km and incorporate up to 16 underwater

turbines which produce 400GWh on a net annual output basis. The nature of the project requires the building of rock armour protected seawalls which will be placed on top of the soft substratum in Swansea Bay. It will hence add to the existing rocky intertidal and subtidal habitat in the area. The company aspires to optimise the design of the wall to promote biodiversity and create an artificial reef. TLSB collaborates with the SEACAMS project at Swansea University to explore options that would benefit the ecological value of the lagoon. The EU project SEACAMS (Sustainable Expansion of the Applied Coastal and Marine Sectors in Wales) is a strategic development project to integrate research and business opportunities around the coast of Wales.

Recommendations for the project were guided by the latest research on eco-engineering of coastal defence structures in the coastal and marine environment (URBANE project, 2013). They can be broadly separated into hard engineering solutions, which affect the nature and texture of the building materials, and soft engineering, referring to the creation of biogenic habitat features.

EIMR2014-9100: DELIVERING OCEAN ENERGY IN THE CONTEXT OF INCREASING MARITIME USES: THE NEED FOR A COHERENT AND INTEGRATED POLICY AND PLANNING FRAMEWORK

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ABSTRACT: Growing global food and energy demands along with commitments to reduce greenhouse gas emissions will put additional spatial pressure on European coastal and marine environments. The long term growth and development of maritime activities, including marine renewable energy, aquaculture, tourism, shipping and transport, are supported by over-arching EU policies such as the Integrated Maritime Policy, Blue Growth and Sea Basin strategies. These objectives influence national policies of Member States and inform their respective national development plans. Across Europe, management frameworks for maritime activities have traditionally been fragmented and sectoral in approach. The realities of increasing use and spatial pressure require the implementation of an appropriate integrated management solution though this is not yet apparent in many EU countries. The European Commission's proposal for a Directive on Maritime Spatial Planning (MSP) and Integrated Coastal Management (ICM) last year was divisive at both EU and Member State level and its future remains uncertain. Requirements to continue to conserve biodiversity, and protect the marine environment, through relevant EU legislation also influence the management framework.

This paper traces maritime policy developments in Ireland in the context of recent EU law and policy developments. The Irish Government published its first integrated marine plan, Our Ocean Wealth, in 2012. This aims to double the value of Ireland's ocean wealth to 2.4% of GDP by 2030 and to increase the turnover from Ireland's ocean economy to more than €6.4 billion by 2020. Separately Government departments have set independent but associated objectives: Food Harvest 2020 aims to increase the volume of production from aquaculture by 78% by 2020; under the National Ports Policy 2013, four of the country's largest ports have lodged expansion plans; and, Ireland's forthcoming Offshore Renewable Energy Development Plan will provide a vision and actions for the future development of marine renewables. Despite these aspirations, the reality of delivering a marine project in Ireland is notoriously difficult with different consenting systems applicable to each sector and a process that is largely based on legislation that is over 80 years old. Acknowledging the latter legislative problem, the responsible department published a consultation document on "A New Planning and Consent Architecture for Development in the Maritime Area" in March 2013 followed by the associated Bill in October 2013. Paradoxically the Bill primarily covers developments relating only to energy infrastructure and its single sector approach thus fails to capture the multi-sector stakeholder buy-in generally acknowledged as a requirement for successful development. This is further compounded by the lack of a clear stakeholder consultation requirement in the operation of the Bill.

This paper will argue that the fledgling marine development and management framework in Ireland appears to defy the principles of integrated maritime governance advocated by the EU. It will highlight the frailties of what is currently being proposed and will demonstrate that any spatially based management system which seeks to deliver sustainable development of maritime resources will require input from all relevant stakeholders through a transparent, inclusive and flexible process.

EIMR2014-9101: ADVANCES IN STUDYING VOCALISING CETACEANS IN ENERGETIC COASTAL SITES USING MOORED AND DRIFTING PASSIVE ACOUSTIC DETECTORS

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ABSTRACT: Dynamic coastal waters present considerable difficulties for the study of cetacean distribution, abundance and habitat use, due to diverse bathymetry, exposed coastlines and the variable impact of tides and waves. With these areas showing increased interest for wave and tidal developments, detailed information on cetacean activity and their use of these areas is important information for consenting.

Vessel-mounted surveys of these sites are often negatively impacted by unsettled weather patterns and localised tidal conditions, and can offer only snapshots of cetacean distribution. Conversely, moored passive acoustic monitoring (e.g. C-PODs) allows for continuous data acquisition, although moorings can be costly to deploy and run the risk of equipment loss from trawlers or strong tidal flows. For the last three years, our research group has specialised in developing and testing low-cost, lightweight mooring designs for tidal and wave energy sites off Scotland. Autonomous porpoise click detectors (C-PODs) and sub-surface acoustic releases were included within linear moorings of rope, chain and ballast, and deployed from commercial vessels with modest winch specifications.

Our methods have evolved following positive and negative experiences, resulting in recent successes in tidal (click detectors deployed in 100m with 5m/s current for 5 days) and wave energy test sites (click detectors deployed over 250m in 60m of water over 2 months). Previous losses were due to: a) delayed retrieval, b) unknown fishing activity or c) poor buoyancy design. New techniques have utilised moored and drifting click detectors to assess variability in temporal-spatial distribution of harbour porpoise (Phocoena phocoena). Recent trials have shown that 1) basic mooring designs can be efficiently deployed from low-cost platforms, 2) lack of surface expression greatly reduces consenting requirements and risks, 3) moored passive acoustic methods can, as a result, be successfully used to study odontocete cetaceans in tidal streams, and 4) drifting detectors are easy and cost-effective to deploy; 5) they provide wider spatial coverage albeit without standardised effort coverage, 6) the combination of moored and drifting devices can provide more detailed information about how porpoises use the site.

EIMR2014-9102: TIME SERIES ANALYSIS OF DISPLACEMENT DATA WITH RESPECT TO SENSOR ARTIFACTS

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ABSTRACT: Wave buoy sensors can return erroneously high values in certain situations. This is due to the occasional extreme nature of the conditions the device is exposed to and limitations of the sampling rate of the sensor. The values recorded can lead to overestimation of resource during extreme conditions or an underestimation where data is unnecessarily discarded.

This study looks at developing and applying a statistical approach to identify these potentially erroneously high values for a Datawell Waverider MKII/MKIII wave buoy. Identifying when and how often these occur, the effect of removing or masking these events has on statistics for that time series and the effect they have on the spectral output.

The main output of this study is a set of software tools which can be applied to existing Waverider datasets. These tools perform statistical analysis using with a range of options for filtering suspect values.

EIMR2014-9103: THE USE OF ADAPTIVE MANAGEMENT IN ADDRESSING RISK AND UNCERTAINTY IN THE POTENTIAL IMPACTS ON MARINE MAMMALS FROM TIDAL ENERGY DEVELOPMENTS: LESSONS LEARNED FROM SEAGEN

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ABSTRACT: The SeaGen S tidal energy device is located in a narrow channel at the entrance to Strangford Lough, Northern Ireland. The Environmental Impact Assessment (EIA) identified uncertainties regarding some potential impacts on key marine species, including harbour seal (Phoca vitulina). Harbour seal are a qualifying feature of the Strangford Lough Special Area of Conservation (SAC), a sensitive site, and operation was only permitted within the constraints of careful license conditions and an Environmental Monitoring Programme (EMP). The EMP was closely linked to a series of agreed mitigation procedures, with the management of that mitigation and the EMP, all falling within an adaptive management strategy. In May 2013 a revised assessment of collision risk and population level risk was undertaken which provided a framework through which the regulator to permit periods of unmitigated operation. During unmitigated operation, further data gathering will continue to inform our understanding of risk. This project has shown how risks to the developer, Regulator and to marine mammals can be managed and mitigated. Both the developer and Regulator need to be prepared to agree on an adaptive approach to management where uncertainty exists as it may be the only way to move forward for total developments when uncertainty about the true risk is high.

EIMR2014-9104: ALTERED SEDIMENTATION: GRADUAL BURIAL OF TWO SPECIES OF BIOGENIC REEF-FORMING MUSSELS

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ABSTRACT: Alterations in sediment uplift, transportation and deposition are expected as a result of energy extraction from the sea. Such alterations are expected to be applicable locally to the installation and further afield particularly as the industry advances and cumulative effects of multiple arrays become evident. It is important that the biological and ecological consequences of such physical changes are assessed. We address the behavioural response of two biogenic reef forming mussels, Mytilus edulis and Modiolus modiolus, to gradual burial.

EIMR2014-9106: BIOSECURITY PLANNING FOR THE WAVE AND TIDAL STREAM ENERGY INDUSTRY

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ABSTRACT: Wave and tidal stream energy production is likely to have some environmental impacts. One impact which has received limited attention is the introduction, establishment and spread of non-native species. This may occur as a result of increased vector activity and the addition of large amounts of artificial habitat in areas with a low number of non-native species. Non-native species can pose a severe threat to economic activity and to the marine environment; and the wave and tidal stream energy industry has a responsibility to minimise its contribution to the introduction and spread of non-native species. This project aims to identify potential introduction pathways that will be present in the renewable industry when it is commercially operational. The project will also qualitatively evaluate these risks and suggest realistic control measures that can be implemented to reduce the risk of non-native species introduction, establishment and spread.

EIMR2014-9107: SPATIAL ANALYSIS OF FISH DISTRIBUTION IN RELATION TO A MARINE RENEWABLE ENERGY DEVELOPMENT

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ABSTRACT: The study presents an effective analysis technique that could be used to evaluate the potential changes to species distribution that may result from an offshore renewable energy development based on its environmental footprint and existing (pre-construction) monitoring data on species that may be affected. Though monitoring techniques have been established by offshore energy developers, such methods currently tend to evaluate animal distribution trends in the short term from pre to post construction. One main aspect that is often not taken into account is the baseline historical distribution trends over the longer term and how they can help determine whether changes that may occur may be deemed different to what has occurred previously (i.e. a kind of calibration of the data). Also, the probability of presence of species in an area will be a function of the current species distribution. In this study spatio-temporal analysis of CPUE data of areas where an offshore wind farm was to be developed (the London Array) was undertaken utilizing geostatistical kriging methods to enable long term trends to be evaluated of four elasmobranch species common to the North Sea over the 1990-2011 survey period. Overall, the mean CPUE was found to remain stable for all species. However, distribution trends were found to vary throughout the periods examined and the confidence in the estimated distribution depended on the number of sampling sites used to estimate the distribution of the species. Such trends were often correlated to the potential for overlap between surveys and mating seasons, as well as the habitat preferences for each species.

As elasmobranchs are relatively long-lived they are particularly vulnerable to overfishing, habitat disruption, and anthropogenic disturbance, hence consistent monitoring periods and survey locations are essential to their conservation and protection. It is therefore unlikely short monitoring periods will provide appropriate information on the potential impacts offshore energy developments may have on elasmobranch populations. The approach used is generic enough to provide a basis on which to analyse spatial distribution of animals in relation to other sources of anthropogenic influence, and environmental parameters.

EIMR2014-9110: TURBULENCE, TROPHIC INTERACTIONS, AND SUSTAINABLE ENERGY EXTRACTION

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ABSTRACT: This interdisciplinary study seeks to investigate the poorly understood role of turbulence in sites appropriate for tidal energy extraction, drawing on expertise from ecology and engineering. These highly energetic environments represent a challenge in data collection and analysis. Variable surface wind/wave interactions, extreme tidal friction effects and intense shear in the wake of obstacles lead to the vertical advection of bubbles and deep turbulent circulations. The resulting complex flow environments are a challenge for the design of devices and arrays, as well important ecologically as foraging habitats of many mobile species. This project utilises a variety of acoustic instruments to provide new information on the physical properties and ecological implications of turbulence in these environments. This study will lead to a better understanding of the scale and significance of the impacts of marine energy extraction.

EIMR2014-9113: RIDING THE WAVES: USE OF THE PELAMIS DEVICE BY SEABIRDS

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ABSTRACT: Seabirds are important marine predators that may be influenced by developments in marine renewable energy. To explore how seabirds might exploit novel floating structures at sea, an autonomous

camera system was used to record attendance of seabirds on a Pelamis wave-energy device. Numbers and identities of seabirds on the machine were explored in relation to a set of metocean variables. Use of the machine was most affected by time of day, but less so by state of the tide. Birds did not use the machine during strong winds or when waves were large. Cameras can provide an effective, low-cost way to collect data about seabirds over weeks or months in inaccessible locations and under inclement metocean conditions.

EIMR2014-9116: INFLUENCE OF TURBULENT FLOW ON THE ENVIRONMENTAL NOISE OF TIDAL TURBINE ARRAYS

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ABSTRACT: The turbulence of the onset flow will determine the fluid generated sound levels for a given tidal turbine design and hence the potential for underwater environmental noise. A combination of an analytical model for sound propagation in a fixed channel and large eddy simulation of a representative turbulent inflow have been used to evaluate the magnitude of the blade sound sources as they rotate. The calculations use Openfoam with a mesh that resolves 80% of the turbulent inflow kinetic energy. Selection of the correct rotational speed is seen as critical to the likely noise levels and with a potential benefit of variable speed devices to reduce noise levels at lower tidal speeds.

EIMR2014-9117: EFFECTS OF OFFHORE WIND FARMS (OWFS) ON FISHING ACTIVITY AND LANDINGS

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ABSTRACT: The development of offshore wind farms (OWFs) and other marine renewable energy technologies and the designation of marine protected areas will place pressure on existing economic activities. Marine spatial planning opportunities for habitat enhancement and co-location may also be provided. Spatial fishing effort for two fishing gear categories, mobile and static gear, was analysed for pre and post construction periods at three separate UK OWF sites. Fishermen were also interviewed on their experiences of the effects of OWFs, existing pressures prior to OWF development and perceptions of the best planning scenarios to accommodate OWFs, marine protected areas (MPAs) and economically viable fisheries in each region. Mobile fishing activity displayed the greatest displacement of fishing effort from OWF sites. Fishermen using static gears identified potential benefits to stocks and fisheries if reef material was deployed within OWFs. Benefits from co-location of OWFs and MPAs were raised by fishermen. Mobile gear fishermen identified a benefit if fishing grounds remained open elsewhere. Static gear fishermen identified a benefit from co-location if they retained access but mobile vessels were prohibited.

EIMR2014-9119: CHANGING THE TIDES

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ABSTRACT: Tidal energy has become a focus of interest in recent years due to a need to generate more electricity from renewable sources. As a part of this tidal barrages and lagoons have been re-examined with particular attention paid to the Bristol Channel. It is known that the Bristol Channel is a highly sensitive region for the tides and the impact on the tides, through the introduction of a barrage, is examined through the use of modelling in this paper. The effects are shown to be significant close to the barrage and generally very small elsewhere. However this is not true everywhere with small but noticeable changes in tidal amplitude shown off the coast of Ireland, Belgium, Canada and the USA.

EIMR2014-9125: THE MULTIPURPOSE OFFSHORE TROPOS PLATFORM: ENVIRONMENTAL AND SOCIETAL ISSUES

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ABSTRACT: The key objective of the on-going TROPOS project is the development of a floating modular multi-use platform system for use in deep waters with an initial geographic focus on locations of Crete (Greece), Gran Canaria and Taiwan. The TROPOS multi-use platform system will be able to integrate a range of functions from the Transport, Energy, Aquaculture and Leisure sectors. A core part of the project addresses Environmental and Socio-Economic Impact Assessment (EIA, SIA) from the construction and operation of the platform, that are assessed through common schemes for all locations (European/international regulations), and then adapted to the pending national and local regulations. The conference presentation describes the procedures and some results from these assessments.

EIMR2014-9126: EXPOSURE TIME MODELLING FOR TIDAL TURBINES AND DIVING BIRDS

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ABSTRACT: The main approach taken to predicting collision risk for birds interacting with wind turbines in onshore and offshore environments in the UK has been based upon using a strike model that requires estimation of the avoidance rate of birds to the wind turbines (e.g. Band *et al.* 2007). Estimating avoidance by birds in flight can be problematic, whilst model predictions are highly sensitive to variation in the avoidance rate (Chamberlain *et al.* 2006). Our understanding of the movement and behaviour of birds underwater is considerably poorer than for birds in flight, so that there are even greater challenges in measuring the behavioural response of diving birds to underwater devices, and in applying models that are dependent upon estimation of avoidance rates to predict collision risk from tidal turbines. Therefore, there is merit in investigating alternative approaches to assessing the collision risk to diving birds from tidal turbines.

In this paper an approach is proposed that first uses population modelling to estimate an 'acceptable' additional mortality threshold within the population of interest. From this, the collision rate that is required to obtain this level of additional mortality can be calculated if the size of the population of interest and the time that individuals from the population are exposed to the tidal devices are also known. Thus, the approach proposed here requires estimation of the exposure time, which is undertaken by using data on the frequency of foraging trips, the extent to which birds from the population use the development site, diving behaviour (e.g. number of dives per foraging trip and mean duration of dives) and the proportion of the water volume within the development site that is occupied by the turbines. The resulting collision rate (i.e. that required to obtain the mortality threshold for the given exposure time and population size) is assessed subjectively in terms of whether this is a likely event or not.

The paper presents an outline of the exposure time modelling approach, detailing how the required data can be sourced, and illustrates this with an example bird population and tidal turbine development site. The sensitivity of the estimated exposure time to variation in the different constituent parameters is investigated, as is variation in the estimate of the required collision rate. The advantages and disadvantages of this approach compared to one that provides a more direct estimate of collision rate are considered.

EIMR2014-9127: FLOWBEC: ASSESSING SPATIAL VARIATION IN EPIFAUNAL COMMUNITIES IN RESPONSE TO FLOW MODIFICATION BY A TIDAL STREAM TURBINE

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ABSTRACT: The advent of marine renewable energy devices brings with it the need for new methods of assessing the associated impacts of energy extraction from the marine environment. This study covers the benthic section of FLOWBEC, a NERC and DEFRA funded project.

Strangford Lough Narrows is an ideal location for a tidal stream turbine due to the funnelling of its high velocity tidal amplitudes through the Narrows twice daily. The floor of the Narrows is dominated by a sub-tidal boulder field with highly diverse epifaunal communities which conform to a distinct biotope under the EUNIS habitat classification scheme (CR.HCR.FaT Very tide-swept faunal communities). To assess variability in the spatial structure of the ambient epifaunal communities in relation to flow modification by the turbine, a multidisciplinary approach was taken. High resolution drop-down video footage was taken along transects within a 150m x 300m grid surrounding the turbine using a state of the art camera system. Epifaunal communities and substrate type distributions were analysed by video still analysis. The wake of the turbine was modelled using a very high resolution computational fluid dynamics (CFD) model which allows for the numerical study of the turbulent wake produced by the turbine. This study is aimed at testing whether the CFD model can predict detrimental effects that may be imposed on epifaunal communities by the wake of the turbine. Pending the results of the CFD model, the next stage includes the use of an artificial neural network to develop a predictive model for change in benthic community structure in relation to velocity and turbulence change caused by the presence of the turbine. The results will be an important addition to baseline data for the tidal industry.

Other Presentations

Abstracts for other papers to be presented to the conference are arranged numerically according to the unique identifier number

EIMR2014-A10: BEST PRACTICE IN MRE RISK ASSESSMENT: EXPERIENCE FROM THE BAY OF FUNDY

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ABSTRACT: Determining the acceptability of marine renewable energy is a ballet with three Acts: I – Context and Problem Definition; II – Project Definition and Risk Assessment; and III – Adaptive Management. Increasingly, there are calls for a statement of best practices to guide developers, regulators and communities in determining the acceptability of energy development proposals, but the best practices need to cover a bewildering and diverse spectrum of activities and contexts. Nova Scotia – which generated nearly 90% of its electricity from fossil fuels in 2007 – established a target of >40% of its electricity to come from renewable energy such as wind and tidal power by 2020. The environmental and socio-economic trade-offs required for a rapid transition to renewable energy necessitates an aggressive but adaptive strategy based upon the best scientific and socio-economic information, cross-sectoral cooperation, extensive public engagement, and a sophisticated process of risk evaluation.

EIMR2014-A12: CONSOLIDATION OF WAVE AND TIDAL EIA/HRA ISSUES AND RESEARCH PRIORITIES

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ABSTRACT: Aquatera was commissioned by The Crown Estate to identify priority research projects that should form the principal/initial focus of any coordinated research programme that is established for the wave and tidal energy sectors in the UK.

A consolidated list of EIA/HRA issues facing the wave and tidal sectors was produced through extensive consultation with regulators, advisors, industry and researchers. Following identification of the EIA/HRA issues and a detailed gap analysis, five priority research projects were identified that could form the focus of any coordinated research programme. Additional research priorities that would best be coordinated by regulators, statutory nature conservation bodies, developers and researchers were also identified. Priority projects that were considered most suitable for a coordinated research programme to focus upon were; behavioural monitoring around wave and tidal developments, investigation into the possible consequences of collisions with tidal current turbines, further development of instrumentation for monitoring behaviour around wave and tidal energy developments, development of an approach for assessing the effects of displacement and the establishment of an evidence base for operational device acoustic data.

EIMR2014-A20: UNCERTAINTY IN THE ASSESSMENT OF CUMULATIVE IMPACTS: THE CASE OF MARINE RENEWABLE ENERGY IN THE UK

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ABSTRACT: Cumulative impacts and their assessments are receiving more attention in the UK as marine renewable energy applications are increasing with an unprecedented industrialisation of the marine environment. The uncertainty surrounding cumulative impacts however remains high and is becoming a cause of delay in the consenting process. Using the example of birds and wind farms, this study examines the types and sources of uncertainty in cumulative impact assessments and provides recommendations as to how these may be reduced. To reduce uncertainty in the cumulative impact assessment process,

adequately assess cumulative impacts and streamline the consenting process for marine renewable energy applications, all sources of uncertainty must be addressed.

EIMR2014-A65: OFFSHORE RENEWABLES AND IMPACTS: WHO CARES, HOW MUCH AND WHY?

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ABSTRACT: Background: The number of man-made structures to be placed in the marine environment is set to increase massively in the near future as a consequence of the wide-scale adoption and commercialisation of offshore electricity generation. Marine renewable energy devices (MREDs) interact with their receiving environment at a number of levels. Environmental monitoring in relation to these interactions has focussed on the top-predators (cetaceans, pinnipids and birds), commercially relevant groups such as fish and seabed organisms.

Aim: 1. To review the basis of current monitoring programmes from a European planning perspective. 2. Comment on the likely scale of MRED-environment interactions and consider how these differ between different receptors (from mammals to benthic infauna). 3. Suggest ways of developing proportionate monitoring programmes that are relevant, in space and time, and cost-effective. 4. Show how regulators will need to make 'value-judgements' in relation to receptor-type and receptor-risk and prioritise limited monitoring funds appropriately.

Review contents: Monitoring programmes should start with a clear understanding/statement of the questions being addressed and these should be considered within the likely cumulative and ecosystem consequences of the proposed development. In order to assist this process the following aspects will be addressed:

1. the difference between 'impact monitoring' and 'environmental research'.
2. the need to clearly specify what it is that we actually care about – what is our metric/ response variable?
3. that tests of null hypotheses of 'no impact' are of limited value
4. the need for effect sizes, not null hypotheses.
5. the need for spatially and temporally defined effect sizes
6. the need for affordability – how to we maximise overall monitoring efficacy?

Conclusions: Monitoring and research usually have quite different objectives (e.g. in the spatial domain) and, consequently, monitoring programmes are not necessarily helpful in understanding processes relevant to their proper design. Through environmental research we need to predict/identify and understand processes and interactions, occurring around offshore structures, which are of a relevant scale and involve societally-relevant processes. Ecosystem models, with relevantly-scaled domains (e.g. the North Sea), supported by hydrographic models, would be useful in identifying potential factors and processes that are relevant to a wide-range of receptors and ecosystem services. Considerable thought should be given to how limited resources be allocated, to maximise cost-benefit, and monitor only those aspects of environment that are considered at most risk. Decisions should be made in relation to the efficacy of monitoring ecosystem components that are considered at low-risk.

EIMR2014-A74: QUANTIFYING ENVIRONMENTAL IMPACTS FOR TWO DANISH OFF-SHORE WIND FARMS USING THE COMPLEX REGION SPATIAL SMOOTHER (CReSS)

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ABSTRACT: Animal numbers collected as a part of baseline monitoring and impact assessment studies are typically highly uneven across the survey area. Animal distribution data can also be patchy in terms of the temporal survey effort in the area, particularly when weather/logistics preclude servicing the experimental design originally planned. Some of these renewables sites can also have complex topography which excludes

animals from particular areas (e.g. marine mammals and islands) or may contain areas which the animals avoid (e.g. sea birds and large areas of land). Data of this sort also typically contain complex (e.g. highly nonlinear) relationships with the environmental covariates and across the spatial area. Additionally these data are typically correlated along transects (or within grid cells from vantage point studies) and the models fitted typically fall short in explaining this correlation due to lack of at least one of the important (dynamic) drivers of animal abundance (e.g. prey distribution). For this reason some of the pattern in the data remains unexplained by the model and this violates the critical 'independent errors' assumption of standard modelling techniques (e.g. Generalized Additive Models). For all of these reasons, any modelling methods used for such data ought to be able to accommodate all of these features in order to make reliable predictions and inference.

The complex region spatial smoother (CReSS) is a recently developed spatially adaptive smoothing technique which is designed to model highly uneven distributions while respecting natural boundaries (e.g. land) relevant for the species of interest and can also deal with complex relationships between density and environmental covariates. Coupled with SALSA2D and Generalized Estimating Equations (GEEs), this approach tackles model selection and spatio-temporal auto-correlation (e.g. along transects) which is invariably present in model residuals. Addressing this aspect of the modelling is crucial if any confidence intervals about differences pre/post installation(s) are to be believed and used for decision making.

This methodology provides accurate predictions for species' distributions across the surveyed area but as importantly, returns defensible predictions about any spatially explicit differences across the area pre/post installation(s).

We present this methodology and its application to bird abundance and distribution for two large scale offshore wind farm examples in Denmark: Nysted and Rødsand II (using Long-tailed Duck Clangula hyemalis) and the Horns Rev 2 windfarm (using Common Scoter Melanitta nigra and Red-throated/Black-throated Diver Gavia stellate/arctica). The results clearly indicate significant decreases in bird numbers in and around the footprints of each wind farm and some redistribution within the survey area. These analyses were carried out using the recently developed, and now publicly available, MRSea package in R.

EIMR2014-A108: DEVELOPMENT OF A SPATIO-TEMPORAL RISK ASSESSMENT METHODOLOGY APPLICABLE TO THE MARINE ENVIRONMENT

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ABSTRACT: Risk and uncertainty in environmental policy, regulation and consenting is a priority area for the marine renewable energy (MRE) sector and significant in decision making. The research presents a spatio-temporal analysis based method for assessing environmental risks within the marine environment for target species distribution in relation to local environmental change, such as that associated with marine renewable energy developments. The method focusses on data commonly used by decision-makers, but importantly includes consideration of the uncertainties associated with understanding the changes to a given environmental effector and species distribution.

To set the scene an overview of the current state of risk within the MRE sector will be presented which identifies the methods used and highlights the knowledge limitations and gaps in understanding and applying risk assessment often encountered by practitioners regarding risk and uncertainty. An integrated and adaptive environmental risk assessment framework is put forward to improve understanding of risk and uncertainty across the UK MRE sector. To provide some of the necessary data to input into such a framework the proposed spatio-temporal risk assessment method for MRE development was developed which evolved from a project that applied climate change scenarios to the distribution of priority species. Within the climate change project a two-dimensional geospatial model was developed for species that are functionally important for demersal/benthic ecosystems and have fisheries importance. The approach started through the climate change study

and further developed for MRE represents a step towards a cumulative risk assessment methodology, which includes level of certainty.

We envisage that future research will take forward this work to further incorporate different levels and type of impact and the associated change to the environmental risks. These issues also affect wider risk assessment and decision-making processes in the marine environment and as such the outputs may be applicable to a wider marine planning process.

EIMR2014-A112: PREDICTING RISK OF CATASTROPHIC EVENTS AT MARINE RENEWABLE ENERGY SITES

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ABSTRACT: Marine Renewable Energy (MRE) projects involve risk. An important risk factor is the potential for interactions between marine mammals or fish aggregations and devices (e.g. tidal turbines, wave energy convertors) that may lead to a catastrophic impact. Objectives of operation and environmental monitoring plans all include preventing catastrophic impacts between organisms and devices. Ideally, there would be analytic techniques that, based on local data, predict temporal windows when catastrophic impacts (i.e. extreme events) are likely to occur. These model predictions could then be used to define conditions of operating licenses, increase monitoring vigilance, modify operations, or curtail operations during high risk periods. We use a suite of methods to define thresholds of extreme events and then use Extreme Value Analysis (EVA) to model the periodicity of extreme events.

Before the probability of an interaction can be calculated, it is imperative to determine the threshold of an extreme event. Conceptually this is a deviance from a measure of location or trend in an empirical data set or theoretical model. Three methods were applied to a baseline acoustic data set characterizing density of fish and macrozooplankton in Admiralty Inlet, Washington, USA to identify extreme events: Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models, Scale-Averaged Wavelets (SAW), and Mean Residual Life (MRL) functions. GARCH models and SAW use peaks in temporal variability to identify extreme data points. We assume that high densities relative to the variability in series are associated with extreme biological interactions at MRE sites. Statistically significant deviations from GARCH models, which quantify localized variability as a function of the variability in the time series, are extreme events where the monitored variable(s) deviate from the variance structure of the series in the recent past. SAW also identify extreme events as significant deviations of localized variability, but uses localized deviations from the variability in the series, averaged across temporal scales. In a MRL function, if a Generalized Pareto Distribution (GPD) is assumed for extreme events and that mean values above a threshold are linearly related to the threshold, then discontinuities from linearity can be used to identify a threshold.

Having identified thresholds using MRL, shape and scale parameters of the GPD for fish density were estimated by maximizing the log likelihood of the acoustic data. By using the GPD to model the probability of events beyond the threshold, the return period (i.e. mean time until an event at least as strong) of each observed value can be inferred. The GPD can also be used to extrapolate the return period for events more extreme than what was observed, analogous to predicting the amplitude of the “100 year flood.”

From an MRE perspective, this approach can be applied to any environmental monitoring variable and when designing MRE components to predict the periodicity of catastrophic events.

EIMR2014-HMEF02: HEBRIDEAN WAVE DATA

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ABSTRACT: The Hebridean Marine Energy Futures (HebMEF) project's overarching aim is to accelerate the commercialisation of wave energy converter (WEC) projects. To support the investment case a reliable yield forecast of planned developments is essential. High resolution spectral wave models are an important part in energy forecasting, either by providing direct information on the wave resource at a given site, or by providing detailed boundary data for small scale nested simulations using Boussinesq or CFD applications.

During the setup, and also to prove the accuracy, of numerical wave resource models, measured wave data is used for calibration and validation. Good practice requires the use of different measured data sets from varying geographical locations for validation, than what was used for calibration of the models.

This paper gives an overview of the wave data acquisition activities undertaken under the HebMEF programme between 2011 and 2014 at the north-west coast of the Isle of Lewis of the Outer Hebrides of Scotland. A data acquisition array of three floating wave measurement buoys and two submerged acoustic sensors was commissioned in intermediate and shallow water depths to successfully obtain time series displacement data together with fully directionally resolved spectral information for deployment periods of more than 12 consecutive months at a coastline with one of the most energetic wave power resources globally.

EIMR2014-HMEF04: INVESTIGATING THE POTENTIAL EFFECTS OF WAVE RENEWABLE ENERGY DEVICES ON SEABIRDS

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ABSTRACT: The Pentland Firth and Orkney waters is the first region to contain commercial-scale marine renewable energy sites in the UK, with a potential capacity to generate up to 1,600 MW. Breeding seabirds are central-place foragers and Scotland has many internationally important colonies. Wave and tidal technology is still in its infancy and with few opportunities to directly observe interactions between seabirds and devices in the field, the number of peer-reviewed papers assessing their impacts remains small. The Hebridean Marine Energy Futures project has provided a unique opportunity to monitor seabird interactions with the Pelamis wave energy converter (WEC) at the EMEC test facility off the West coast of Orkney. By combining spatially-explicit observational data with information on the marine environment and the location of devices at the EMEC test facility we explored the potential consequences of WECs for seabirds at both the individual and population level.

General Information

Conference Venue:

An Lanntair Arts Centre will play host to the EIMR2014 international conference with supplementary workshops taking place in Stornoway Town Hall, only 60 metres from An Lanntair and situated in the middle of town, offering the chance to explore the culture and history of Stornoway.

Registration and Information Desk:

The area opposite the reception desk, outside the gallery in An Lanntair Arts Centre will be used for registration and conference office during the week. Speakers are requested to hand in their presentation here on a memory stick to conference staff on the day before their talk.

Badges:

Delegates name badges will be issued on registration. Name badges serve as an admission pass to all sessions and social events. Delegates are asked to ensure they wear their name badges at all times.

Poster Exhibition:

The Poster Exhibition will be held in the gallery and additional space on the 2nd floor and basement. EIMR2014 and its partners cannot be responsible for posters that are not removed on time. Posters should not be removed prior to 6pm on Thursday 1st May.

Car Parking:

Free parking is available at the South Beach car park opposite An Lanntair and at No.1 pier.

Cloakroom Facilities:

There are no secure cloakroom facilities at An Lanntair Arts Centre. Please ensure you keep any valuable belongings with you. Toilet facilities are located on the ground, first and second floors accessible through the stairwell or at the end of the restaurant.

Conference Secretariat:

Monique Watt and Arne Vögler, Lews Castle College, Stornoway, 01851 770235 or 07880 607202.

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General Information

Dress Code:

The dress code during the conference sessions is casual and comfortable. The conference dinner on the Wednesday evening is casual but smart, while the ceilidh on Thursday evening is informal.

Internet Services:

Wireless broadband is available at An Lanntair Arts Centre. It is also available in most hotels.

Lost Property:

Enquiries regarding items lost or found can be made at the reception desk in An Lanntair. To minimise losses, please ensure your delegate bag is labelled and that your name is written inside your copy of this handbook.

Lunches and Refreshments:

Coffee, tea and lunches will be served throughout the conference in An Lanntair.

Medical Information:

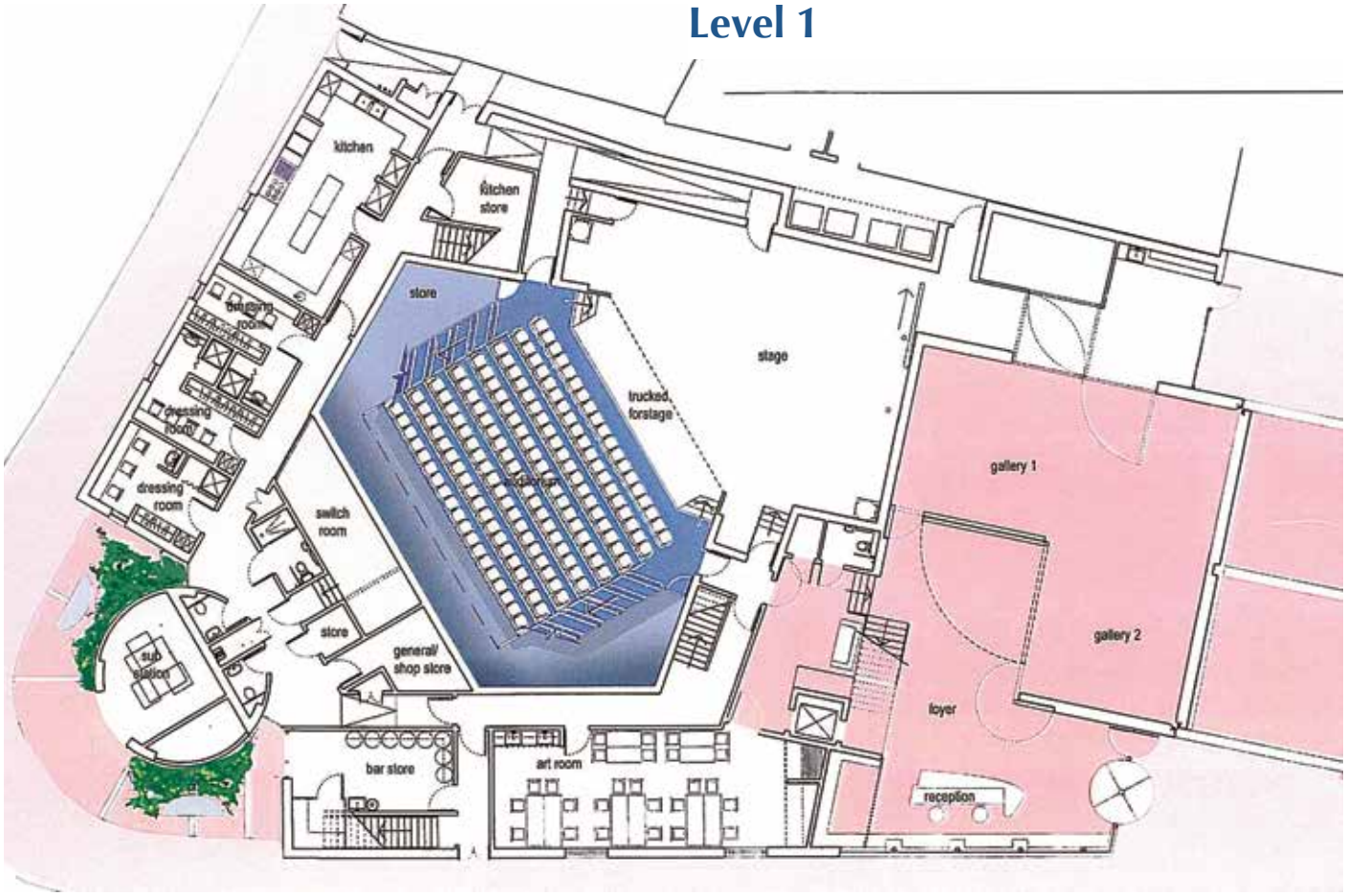
There are dedicated first aid trained staff within An Lanntair to assist delegates if required. In the event of an emergency, please contact a member of staff at the centre.

NHS 24: 08454 242424, *www.nhs24.com*
Boots UK: 52 Point Street, Stornoway, 01851 701769
KJ Macdonald Ltd Pharmacy, 29-31 Cromwell Street, Stornoway, 01851 703131
NHS Western Isles Hospital, Macaulay Road, Stornoway, 01851 704704

Mobile Phones:

Please switch off mobile phones during conference sessions.

Level 1



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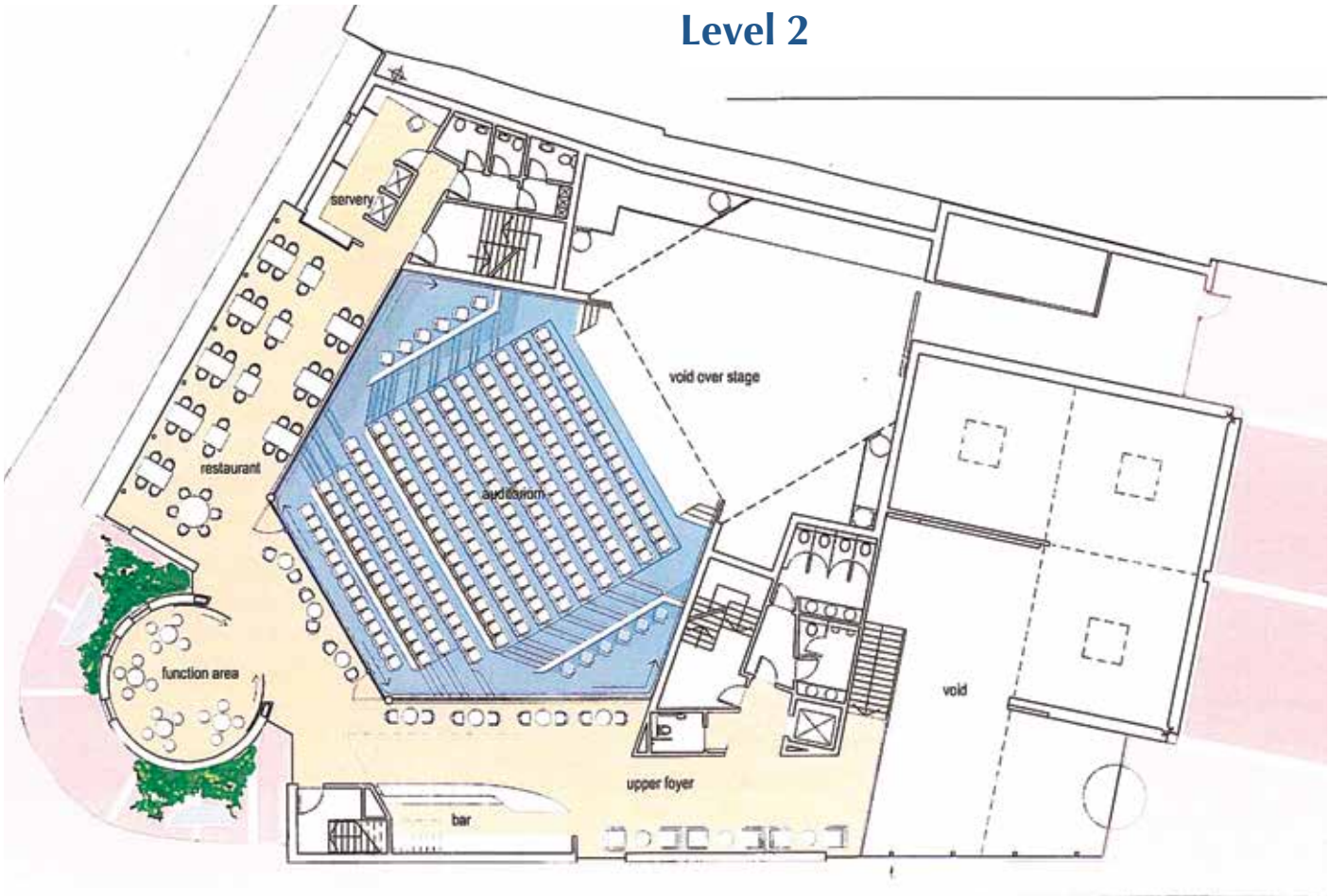

General Information

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ATM Cash Machines in Stornoway nearest to An Lanntair:

Royal Bank of Scotland, Tesco, Ferry Bank Road and 17 North Beach
Bank of Scotland, 45-47 Cromwell Street
TSB, 18 Francis Street
Clydesdale Bank plc, 23 South Beach Street

Taxis in Stornoway:

Stornoway Taxi & Courier Services: 01851 704444
Quickcab: 01851 701234
Hebridean Taxis: 01851 702708

Useful Contact Details:

VisitScotland, Stornoway Information Centre, 26 Cromwell Street
Calmac, Ferry Terminal, Shell Street, Stornoway, 0800 066 5000, *www.calmac.co.uk*
Police: Telephone number 101

Airline Reservations and Enquiries:

Stornoway Airport: 01851 707400, *www.hial.co.uk/stornoway-airport/*
British Airways: 0844 493 0787, *www.britishairways.com*
Eastern Airways: 0870 366 9100, *www.easternairways.com*
Flybe: 0871 700 2000, *www.flybe.com*

Scotland

Electricity:

The voltage in the UK is 220-240V.

Telephone:

The International dialling code for Scotland is +44.

Scottish Bank Notes:

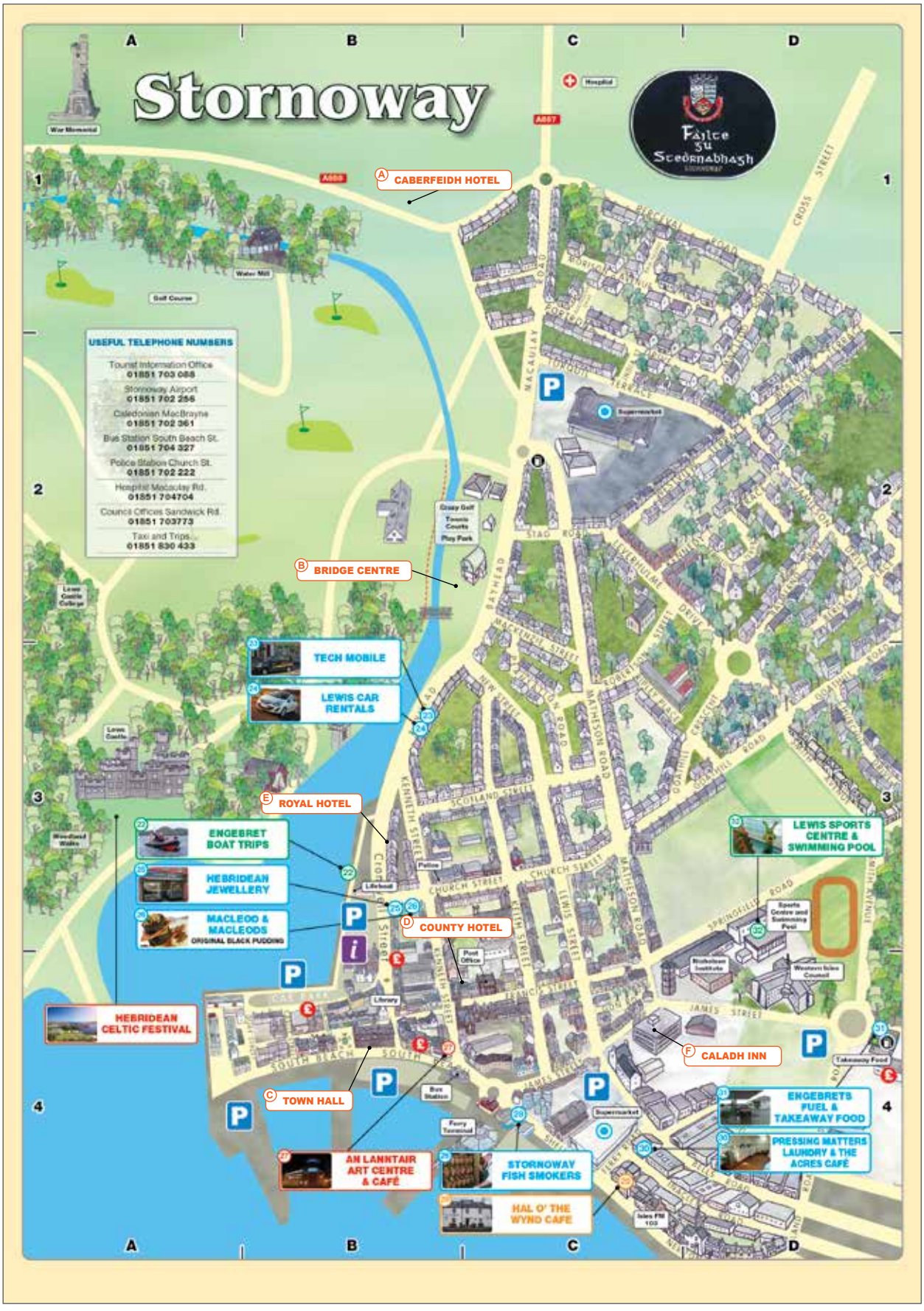
Scottish banks issue their own bank notes for all denominations. The appearance differs from English bank notes, but they are of the same value and generally accepted elsewhere in the UK. English bank notes are freely accepted in Scotland.

Smoking Policy:

Please note that smoking is banned inside all public buildings and on public transport in Scotland. Delegates will generally find designated areas outside the venues.

VAT-free Shopping:

Visitors from non-European Union countries can reclaim UK sales tax on certain purchases. This Value-added Tax (VAT) is applied at 20% to most goods and services except food, books and children's clothing. Please enquire about this at individual retailers, particularly if they display a Tax Free Shopping Scheme sticker.



Credit: Explore Outer Hebrides Guide *www.isle-of-lewis.com*

General Information

Credit: Explore Outer Hebrides Guide *www.isle-of-lewis.com*

The Outer Hebrides – A Brief History and Description

The Outer Hebrides, which lie off the north-west of the Scottish mainland, includes the Isles of Lewis, Harris, North & South Uist, Benbecula and Barra. The archipelago measures some 200km from the Butt of Lewis in the north to Barra Head in the south, and is separated from Skye and the Scottish mainland by the Minch, a sea strait between 30 and 70km wide.

To the west lies St Kilda, the remote outpost famously evacuated in 1931, the Atlantic Ocean, and the enormous potential for harnessing marine energy.

Geologically the Outer Hebrides have more in common with Iceland than the Scottish mainland. Lewisian Gneiss is the bedrock of these islands, amongst Europe's oldest rocks. The landscape is both stunning and spectacular, including mountainous regions in Harris and South Uist, extensive freshwater systems, peat moorland and fertile machair – low lying areas on the western coastal fringes – particularly in the north of Lewis. The Outer Hebrides have been continuously inhabited since Neolithic times, and are rich in history and culture. Erosion to the machair land continues to uncover significant prehistoric sites, like the Iron Age house in Bosta on Bernera.

The Callanish Standing Stones dating from around 3000BC are the best known of a series of megaliths and stone circles throughout the islands. Other well known prehistoric sites include the massive chambered cairn in Bharpa Langais, North Uist and the Carloway Broch on Lewis. Other historic sites include Teampull na Trianaid in North Uist, a monastery and place of learning dating from the 12th century, Kisimul Castle, seat to the Chief of the MacNeils of Barra, and St Clements Church at Rodel on Harris built for Macleods of Dunvegan and Harris, both dating from the 16th century.

The famous Lewis Chessmen were discovered in Uig on the west coast of Lewis in 1831. The popular story is that local man Malcolm Macleod had gone in search of cattle that had strayed from the herd and were grazing on the sand dunes at Ardroil. Mr Macleod stumbled across an ancient stone casket that had been exposed in the shifting sands.

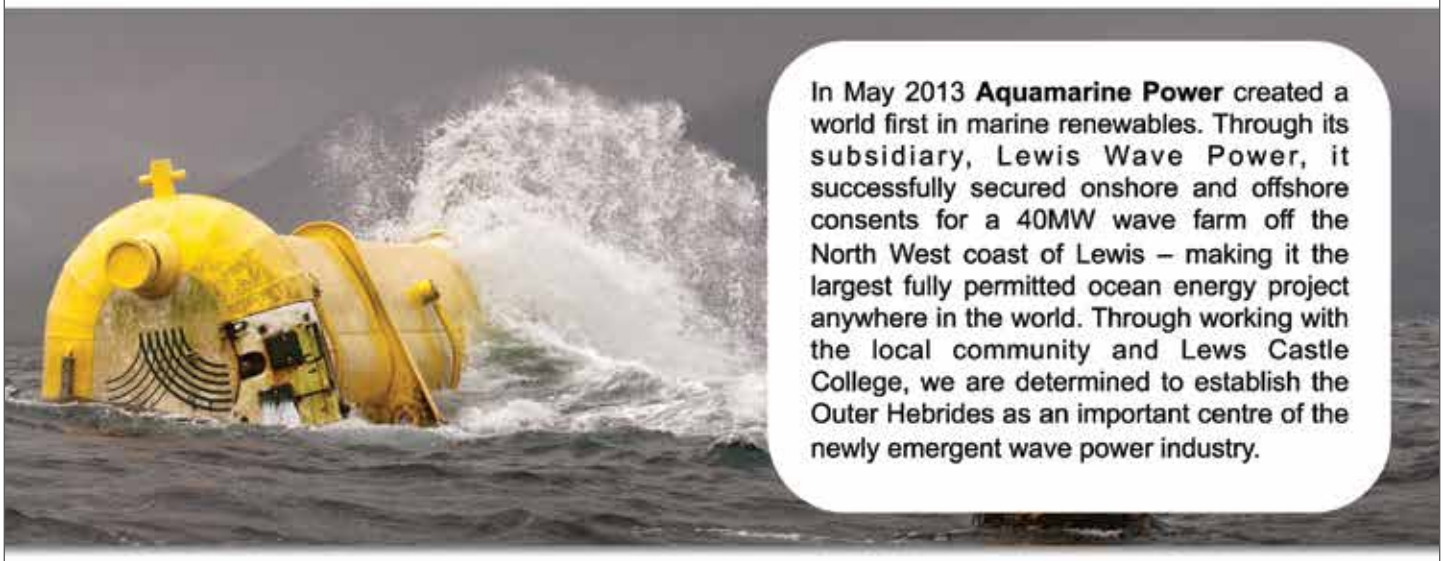
The casket contained eighty Norse chess pieces, now known as the Lewis Chessmen. The pieces are believed to date from the 12th century, a time when the Outer Hebrides was under Norse control. The collection is currently held in the British Museum in London and the Museum of Scotland in Edinburgh.

Six of the Lewis Chessmen will be on permanent display from 2015 in the new Museum nan Eilean, to be housed in Sir James Matheson's Lews Castle, dating from the mid 19th century and currently undergoing major refurbishment. The museum will also focus on the strong Gaelic culture. The Outer Hebrides is one of the strongholds of the Scots Gaelic language, which is still widely spoken.

Powering the Scottish Islands

Supporting research in wave resource and environmental monitoring

In 2014, **Pelamis Wave Power** continues to address knowledge gaps surrounding the potential interactions of Pelamis technology with local environment. We are combining desk based reviews and evaluation with real observations of interactions at sea, working directly with a number of leading academic institutions including the Environmental Research Institute (ERI), International Centre for Island Technology (ICIT), part of Heriot Watt University, and the Scottish Association for Marine Science (SAMS).



In May 2013 **Aquamarine Power** created a world first in marine renewables. Through its subsidiary, Lewis Wave Power, it successfully secured onshore and offshore consents for a 40MW wave farm off the North West coast of Lewis – making it the largest fully permitted ocean energy project anywhere in the world. Through working with the local community and Lews Castle College, we are determined to establish the Outer Hebrides as an important centre of the newly emergent wave power industry.

Both Aquamarine Power and Pelamis Wave Power are part of the 'Hebridean Marine Energy Futures' project, a consortium, funded by the Scottish Funding Council and led by Lews Castle College. The consortium, which includes academia, technology developers and project partners and is also backed by HIE, is aimed at developing and exchanging skills, models, data and strategies which can help the Scottish marine energy industry move to commercial scale in the Hebrides, and from there to global markets.

marinescotland

The Scottish Government
Riaghaltas na h-Alba

Marine Scotland is the directorate of Scottish Government (SG responsible for the integrated management of Scotland's seas)

Our mission, purpose and vision

Our mission is to manage Scotland's seas for prosperity and environmental sustainability. This contributes to the Scottish Government's overall purpose of sustainable economic growth and achievement of a shared vision of clean, healthy, safe, productive, biologically diverse marine and coastal environments, managed to meet the long term needs of people and nature

Find out more about Marine Scotland at:
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Visit the Marine Scotland Renewables blog at:
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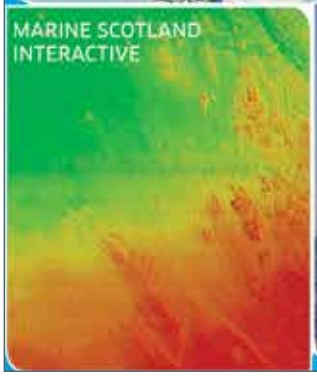

SuLA is a two year project funded by the Northern Periphery Programme and European Regional Development Fund. The SuLA project is the vision of a home supervising service which will enable house-owners and social housing providers to provide a service that will reduce energy use in homes and save on energy costs for space heating.

Each of the three partners (Oulu University, Finland; Lews Castle College UHI, Scotland and The University of Ulster, Northern Ireland) has at least 10 pilot sites monitoring a variety of building types. A variety of sensors in each pilot house monitors heating energy, indoor temperature and weather station data. This data is then logged in two databases, one in Finland and another in Scotland.

Work Package 3 is concerned with the collection of sensor data in Finland and the development of a smart decision system, which uses dynamic threshold limits and prediction models to form an overall view of household heating and energy consumption. The smart system uses groups of sensors to estimate data trends and forecast future sensor values. In addition, the smart system will send email and SMS alerts if it detects problems with heating systems.

Major challenges for the smart system:

- Statistical methods for predictions adapt too quickly for sudden changes;
- Unexpected heating behaviour is very difficult to predict;
- The completion of various tests is a slow process.

This intelligent software will be a key SuLA service helping identify faults, breakdowns or inappropriately configured setups in heating, ventilation and air conditioning systems. Partners are located in sparsely populated regions so this service concept will help people overcome distance through the means of new technology. The ultimate goal is to save energy.

SuLA's Progress – The core homes that would be used to validate the intelligent system have all been established and significant challenges overcome, for example, server routines had to be optimised to manage the huge volume of raw data flowing to the server and to ensure that even minor heating system problems are not missed. As with all new technology there were unexpected problems, for example, mains voltage variations throughout the trial area affected logging equipment. This was overcome by installing a local backup power supply.

Hebridean Housing Partnership, a social housing organisation in the Western Isles has six homes included in the trial by Lews Castle College UHI. These properties are very similar and are being used to compare the effectiveness of air source heat pumps and further, to make a comparison with storage heaters. The monitoring hardware was rationalised and components eliminated where possible in an attempt to reduce product cost and make it affordable for all domestic energy monitoring applications.

In tandem with SuLA's technical advances a Market Survey and Feasibility Study are also underway. The University of Ulster is carrying out a detailed review of the products and services available and relevant to SuLA. The main areas of interest are:

- Smart Meters and Energy Monitors
- Home Automation and Control
- Home Energy Management

The complete Market Survey and Feasibility Study will be available shortly via the project website.

Northern Periphery Programme

University of the Highlands and Islands Lews Castle College

University of ULSTER

OULU UNIVERSITY OF APPLIED SCIENCES

SuLA

For more news and updates visit our website **www.oamk.fi/sula**
Or check out our social media sites **www.facebook.com/SuLANPP** or **www.twitter.com/SuLANPP**

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Tethys is an online knowledge management system that provides access to over 1200 scientific papers and other documents on environmental effects of marine energy development.

Annex IV is an international collaborative project among member nations of the IEA Ocean Energy Systems that collects metadata on marine energy projects and research studies, provides analyses of key environmental interactions, and brings together the international community. Annex IV material is hosted on ***Tethys***.

Environmental Science and Marine Renewable Energy

NERC SCIENCE OF THE ENVIRONMENT


Attendees at a programme workshop during EIMR 2012 pictured with anti-fouling coatings test rig.

Did you know..?
The Natural Environment Research Council funds a knowledge exchange programme which acts as a catalyst for the uptake of scientific research by the marine renewable energy sector. It fosters partnership working between the academic research base, regulators and policy-makers within the sector, and runs a number of initiatives designed to tackle challenges for the industry in the following areas:

- Uncertainty and risk
- Cumulative impact assessment
- Underwater noise
- Cost-effective monitoring
- Data access and management

Guidance notes and position papers resulting from programme knowledge exchange activities.

The programme works toward a sustainable future for the renewable energy sector, through the application of environmental science which improves our shared understanding of the potential effects of wave and tidal devices and offshore wind farms on the ecology and hydrodynamics of the marine system.

It contributes to economic growth by delivering highly skilled people across a range of relevant and excellent UK environmental science; it improves policy and service delivery; enhances performance in existing business and contributes to attracting global investment in research and development.

You can find out more at **www.mrekep.net**, on twitter from **@MREKEP**, by email at **mrekep@nerc.ac.uk**, or by talking to one of the programme team here at EIMR 2014.

NERC SCIENCE OF THE ENVIRONMENT

Marine Renewable Energy
Knowledge Exchange Programme

Outer Hebrides

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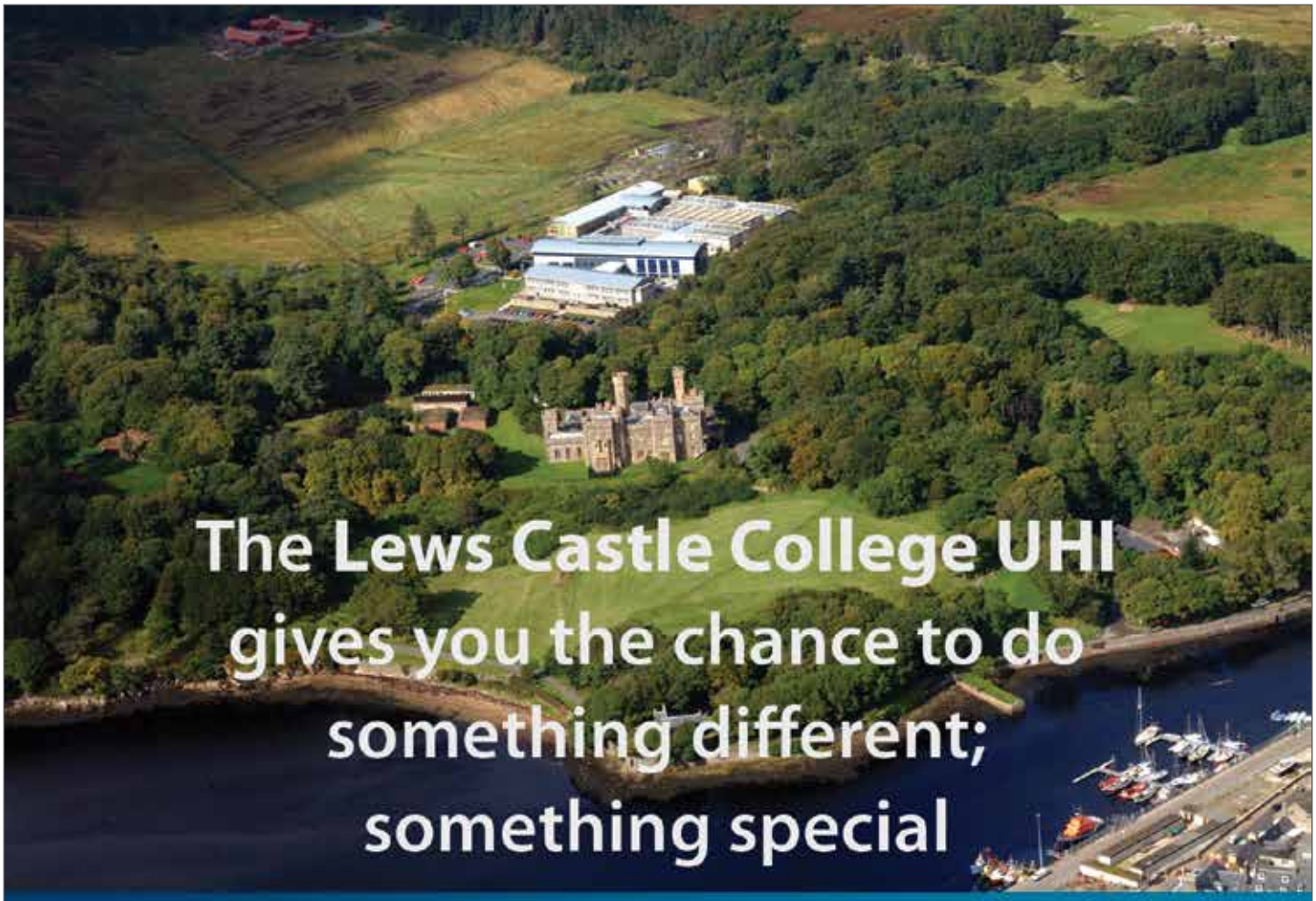

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- Efficient Deck Hand
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- PDA Renewable Energy Systems
- The Hydrogen laboratory (combustion engine and fuel cell technology)
- Energy Engineering Research

For further information on the wide range of opportunities available locally at
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Please phone 01851 770000 or visit www.lews.uhi.ac.uk

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