EIMR International Conference

The International Conference on

The Environmental Interactions of Marine Renewable Energy Technologies

Orkney Scotland I 30 April to 4 May 2012


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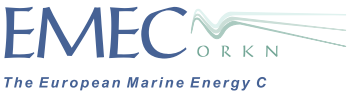
EMEC
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The European Marine Energy C


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SCOTTISH
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SCIENCE


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agus nan Eilean
Colaisde a' Chaisteil

CONTENTS

Energy of ORKNEY

With some of the greatest wind, wave and tidal resources in the world, the leading wave and tidal test facilities at the European Marine Energy Centre, a local skills base, a developing supply chain and infrastructure, including three major pier developments and two Scottish Government Enterprise Areas, Orkney is uniquely placed to lead the development of marine energy and has rightfully earned the title of the **'Energy Islands'**.

Visit the Orkney stands at All Energy 2012 in Aberdeen AECC 23rd/24th May or contact energy@orkney.com

© Scotrenewables Tidal Power Ltd. Photo: Mike Brookes-Roper

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European Marine Energy Centre

Based in Orkney, the European Marine Energy Centre (EMEC) Ltd is the world's only accredited, grid-connected test facility for full-scale wave and tidal energy converters. With 14 full-scale test berths, it is home to some of the most innovative marine energy devices currently in development and to date more devices have been tested at EMEC than at any other single site in the world.

Scapa Flow

Fifty square miles of sheltered, deep water anchorage with locally based marine services, knowledge and skills.

©Mike Brookes-Roper

Established supply chain

A globally recognised community of academic, commercial and technical expertise complements the supportive environment for business development and inward investment.

Infrastructure

Orkney Islands Council, with support from the European Regional Development Fund, Highlands and Islands Enterprise and the Scottish Government, is undertaking a major infrastructure programme which includes three major new pier developments with additional shoreside improvements. These developments have been supplemented by two recently nominated Scottish Government Low Carbon and Renewables Industry Enterprise Areas on Orkney.

www.orkneymarinerenewables.com **www.orkney.gov.uk**

ORKNEY ISLANDS COUNCIL

WELCOME

Dr Mike Weston, Head of Energy Research, University of the Highlands and Islands

As an island nation we have always maintained a close relationship with the sea and it seems fitting that something so important in shaping our past should now be so vital to building our future.

Operating in these environmental extremes while maintaining the delicate social and ecological balance is no small challenge and will require global vision and collaboration.

I hope this event will allow these challenges to be addressed openly and facilitate the sharing of experiences which will help us take this sector into the next stage of development.

In this spirit of collaboration and endeavour, I would like to offer a personal welcome to EIMR 2012.

Prof Steve Chapman, Principal of Heriot-Watt University

Renewable energy technologies have a major role to play in our energy future due to the limited supply of fossil fuels and need to mitigate the effects of the global warming. Renewable energy research has become increasingly important since the signing of the Kyoto Protocol, with marine, solar and wind industries growing rapidly.

This conference brings together expertise from across the globe to discuss the energy challenges we all face and pool our expertise in an effort to provide solutions to these challenges.

I am delighted to be involved with the Environmental Interactions of Marine Renewable Energy Technologies Conference. As a university at the forefront of providing solutions across the energy agenda, the issue of marine renewable energy is of considerable importance to Heriot-Watt University and our involvement and contribution to this conference once again demonstrates our commitment to the field of renewable energy technologies.

Heriot-Watt is investing significant resources into the areas of Marine and Climate Change research, through its multidisciplinary Environment and Climate Change Theme and its leading role in the Scottish Marine Pooling Initiative, Marine Alliance for Science & Technology, Scotland. (MASTS.) Forward-looking consideration of the energy system is required to drive the agenda forward and bring together world class expertise that spans exploration to conservation. Our interaction with the international agenda of climate change, sustainability and security of supply at conferences such as this allows us the opportunity on how best to match our skills-base to the emerging research challenges.

I hope you find the conference to be interesting and stimulating and I welcome you all to Orkney.

James Fraser, Principal and Vice-Chancellor, University of the Highlands and Islands

We are all aware of the increasingly important part marine renewable sources will play in securing our energy supply over the coming decades, and alongside that goes the need to consider how commercial installations will sit among offshore ecosystems and the human communities which will service this emergent industry. Here in the Highlands and Islands of Scotland, we are very proud of the organisations from across our region that have taken a lead with research into many of the key disciplines relevant to this subject, and with this in mind, on behalf of the University of the Highlands and Islands may I wish you all a warm welcome to Orkney. Thank you for choosing to join this EIMR conference and making it possible by your attendance.

Over the next few days, we will be privileged to hear presentations and contributions from across the world, and many thanks must go to all those who have submitted presentations for this event. There are so many demands on researchers' time, and many of you lead such busy professional lives, that we sincerely appreciate the time and effort you have taken to prepare contributions to share with your peers.

I hope all of you will discover many useful and worthwhile insights during your time together, as well as establishing new contacts and renewing old friendships; and that this gathering will serve to broaden your knowledge. Furthermore, I hope you will enjoy your participation in every aspect of what has been planned: not just the plenary sessions, but also the more informal parts of the week – meeting and debating issues with colleagues, and seeing some of Orkney and the commercially important areas in the surrounding waters. Finally, I hope that you will round off each of the days of the conference by enjoying the hospitality that Orkney is renowned for during our social programme.

Dr Roland Cormier

Dr Roland Cormier holds an MSc in Biology from the “Université de Moncton” (Canada). He has more than 30 years experience in crustacean stock assessment, shellfish sanitation, fish inspection and environmental assessment. He originally started to work for Fisheries and Oceans Canada doing research and conducting fisheries stock assessments. At the Canadian Food Inspection Agency, he developed and implemented bio-toxin monitoring programs and auditing of HACCP programs. At the Food and Agriculture Organization of the United Nations, he developed an aquatic food program knowledge base and conducted capacity building initiatives in developing countries.

He is currently the Regional Director for Ecosystems Management at Fisheries and Oceans Canada in Moncton. His present focus is on the development and implementation of ecosystem–based risk management frameworks, DPSIR pathways analysis, environmental policy gap analysis and environmental regulatory verification and auditing. He is also a member of the International Council for the Exploration of Sea working group on spatial planning and integrated coastal zone management.

Dr Scott Couch

Dr Scott Couch is a Senior Research Fellow at the University of Edinburgh’s Institute for Energy Systems (IES). Scott leads activity on several of IES’s key marine renewable energy research focus areas, including resource characterisation and appraisal, device performance assessment, and assessing potential (physical) environmental impact of array-scale projects. His research has attracted funding from EPSRC, NERC, the Energy Technologies Institute, Sustainable Development Commission, Scottish Enterprise, UK Department of Trade & Industry and the Carbon Trust. Scott also provides consultancy services to a wide range of marine renewable technology and project development companies as well as government agencies in the United Kingdom and internationally. He additionally acts as the UK nominated expert on the ‘tidal energy resource characterisation’ standard development panel, a component part of the International Electrotechnical Commission TC114 activity. Prior to joining the University of Edinburgh, Scott held research positions at The Robert Gordon University and Oregon State University. He received both his Master’s degree in Civil Engineering in 1996 and PhD with a research focus on coastal engineering and physical oceanography in 2001 from the University of Strathclyde.

Dr Sarah Henkel

Dr Sarah Henkel is a benthic ecologist at the Hatfield Marine Science Center and investigator with the Northwest National Marine Renewable Energy Center at Oregon State University. Her research investigates potential ecological effects of wave energy development on bottom-associated fish and invertebrates. This involves fieldwork from the nearshore to the outer continental shelf from northern California to Washington, USA. She received her B.S. from the College of William and Mary, her master's degree from California State University, Fullerton, and her PhD from the University of California, Santa Barbara. Before moving to OSU, Sarah worked at the California Ocean Science Trust working on projects related to invasive species, oil platform decommissioning, and marine protected areas.

Dr John Huckerby

Dr John Huckerby is the current Chairman of the Executive of the International Energy Agency's Ocean Energy Systems Implementing Agreement (OES). He was appointed as New Zealand representative in 2008 and has been Chairman since January 2009. OES has just published its "International Vision for Ocean Energy", a document setting out its expectation of the development of ocean energy to 2050. From 2009 – 2011 John was a Lead Author of the Intergovernmental Panel on Climate Change's (IPCC) "Special Report on Renewable Energy Resources and Climate Change Mitigation", published in June 2011. Formerly he was a member of the Royal Society of New Zealand's President's Panel for Energy. In New Zealand he is the founder and current Executive Officer of the Aotearoa Wave and Tidal Energy Association (AWATEA), a marine energy industry association formed in April 2006. He is also the director of Power Projects Limited, an energy industry consultancy. Since 2004, Power Projects has been involved in the Wave Energy Technology – New Zealand (WET-NZ) R & D programme, which is developing a point-absorber wave energy converter.

John has a Ph.D. from Imperial College in London and an MBA from Henley Management College. He is a Chartered Engineer and a member of the Energy Institute in London, the Royal Society of New Zealand and the Institute of Directors in New Zealand.

Neil Kermode

Neil was appointed in 2005 as Managing Director of EMEC, Orkney. From the original 4-berth wave test site, Neil has overseen considerable growth throughout the company, which now features 6 wave berths, an 8-berth tidal energy test site, and two nursery sites for smaller scale device testing. In addition, staffing has increased from 4 to 21 people.

Before EMEC, Neil worked as a project developer of a potential tidal scheme to use the Churchill Barriers in Orkney. This followed 6 years at the Environment Agency dealing with regulation and development issues, particularly relating to public participation in decisions on flooding, waste and water resources. He is a Chartered Engineer and Chartered Environmentalist.

Neil has spoken on marine energy extensively in the UK and internationally. He is an active member of assorted advisory groups on the subject and passionate advocate for a sustainable energy future.

Prof Catherine Mitchell

Prof Catherine Mitchell is Professor of Energy Policy at the University of Exeter. Previous to that, she worked at the Universities of Warwick, Sussex and California, Berkeley. Her undergraduate degree was in History from London University; her Masters was in Energy and Environmental Studies from Boston University, USA and her PhD was from Sussex University in Technology and Innovation policy. Catherine is a Lead Author in the IPCC's Fifth Assessment Report in the Policy and Institutions Chapter of WG3; she was also a Co-ordinating Lead Author of the Policy, Financing and Implementation Chapter of IPCC's Special Report on Renewable Energy and Climate Change Mitigation (published 2011); and she is also a Lead Analyst of sub-Chapter 13 (Policy) of Chapter 11 (Renewable Energy) of the Global Energy Assessment undertaken through the International Institute for Applied Systems Analysis (IIASA) due to be published in 2012. She is PI of an ESRC/EPSRC interdisciplinary research cluster into Energy Security in a Multi-Polar World; and is PI responsible for policy and regulation within the supply theme of UKERC Phase 1 and 2. She was a member of the UK Government's Energy Advisory Panel (1998-2003); a Member of the DTI/DEFRA/Ofgem Embedded Generation Working Group 2000-1; Member of the UK Cabinet Office's Energy Review in 2001-2; Member, Scientific Advisory Panel, Towards a Sustainable Energy Future, Research Councils UK, 2003-2006; International Advisor to New Zealand Government Energy Review, October 2006-March 2007; a Member of the Balancing and Settlement Code Panel, 2008-2010; and Chair of the BIEE, 2009-2010. She has also advised numerous national and international companies, NGOs and institutions on various aspects of the transition to a sustainable energy system.

Dr Dan Wilhelmsson

Dr Dan Wilhelmsson is Scientific Advisor at the Swedish Secretariat for Environmental Earth System Sciences (SSEESS), dealing with a broad set of global environmental change issues, including research capacity building and collaboration with decision makers. Dan, a marine ecologist by training, has been working with issues around sustainable resource use (e.g. fisheries, alternative livelihoods for fisher families), conservation, and monitoring of coastal natural resources, including policy advice for the past 14 years. Starting in 2003, he has been working on the environmental risks and opportunities of offshore renewable energy (primarily wind and wave energy). The research focus has been on fish, crustaceans and benthos inside wind and wave farms, including artificial reefs effect, as well as on synthesizing research on positive and negative effects on the marine environment as a whole. Within this field, Dan Wilhelmsson was Scientific Coordinator at IUCN Global Marine Programme, and he has also functioned as advisor in permitting processes for offshore wind farms.

Scientific Steering Committee

Dr Mike Bell, Post-doctoral Research Associate,
International Centre for Island Technology, Heriot-Watt University, Stromness, Orkney KW16 3AW

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Dr Ben Wilson, Principal Investigator in Mammalogy and Marine Renewables,
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PROGRAMME **Tuesday, 1 May 2012**

08.00 Registration opens

08.30 Conference opens

Welcome Address by **Dr Mike Weston**
Head of Energy Research – University of the Highlands and Islands

08.45 – 10.25 **Marine Renewable Energy Resources**
Session Chair: **Arne Vögler**

Keynote Speaker: **Dr Scott Couch**, University of Edinburgh

Mitsuhiro Kawase, University of Washington
Effects of localised energy extraction in an idealized, energetically complete numerical model of an ocean-estuary tidal system

James McNaughton, University of Manchester
CFD study on the influence of the turbulent environment on tidal turbines

Giacomo Marchi, Environmental Research Institute, UHI
Tide gauge data for the testing of tide and surge models in the Pentland Firth

Dr Michael Hartnett, National University of Ireland, Galway
Quantification of tidal power in a highly dynamic estuary

Poster elevator pitches

10.25 – 10.55 Coffee

10.55 – 13.05 **Developing Ecological Methods**
Session Chair: **Dr Angus Jackson**

Keynote Speaker: **Dr Sarah Henkel**, Oregon State University

Poster elevator pitches

Helen Wade, Environmental Research Institute, UHI
Great skua Stercorarius skua foraging movements and potential effects of marine energy developments

Dr Steven Benjamins, Scottish Association for Marine Science
PODs adrift: A novel approach to monitoring cetaceans in tidal rapids

Nienke van Geel, Scottish Association for Marine Science
Potential to minimise impact of marine renewables construction on bottlenose dolphins by understanding their movement patterns

Prof Paul Thompson, University of Aberdeen
Methods for monitoring marine mammals at marine renewable energy developments

Dr Ben Wilson, Scottish Association for Marine Science
Are Scottish tidal-stream energy sites also porpoise hot-spots?

Dr Stuart Clough, APEM Ltd
Developing understanding of the offshore distribution of birds and marine mammals in the Pentland Firth and Orkney waters by use of advanced digital aerial surveys

PROGRAMME **Tuesday, 1 May 2012**

13.05 – 14.45 Lunch and Posters

14.45 – 15.55 **Marine Planning - managing sea space for renewable energy**
Session Chair: **Dr Ian Davies**

Keynote Speaker: **Prof Catherine Mitchell**, University of Exeter

Poster elevator pitches

Karen Alexander, Scottish Association for Marine Science
Attitudes of Scottish fishers' towards marine renewable energy

Dr Edward Pollard, Orkney Research Centre for Archaeology
Project Adair: Mapping marine heritage sites in Orkney and the Pentland Firth

15.55 – 16.15 Coffee

16.15 – 17.25 **Marine Planning - managing sea space for renewable energy (continued)**
Session Chair: **Dr Ian Davies**

Poster elevator pitches

Kaety Hildenbrand, Oregon State University
Collaborative Research as a method to engage existing ocean users in wave energy development in Oregon, USA

Dr Anne McLay, Marine Scotland Science
ScotMap: Mapping fishing activity in the Pentland Firth and Orkney waters

Dr Laura Watts, IT University of Copenhagen
The Orkney Electron: A socio-technical story of marine renewable energy

Christopher Stokes, University of Plymouth
Anticipated coastal impacts of the Wave Hub project

19.30 – 22.00 Conference Dinner - Harray Hall, Harray

PROGRAMME **Wednesday, 2 May 2012**

08.30 – 09.00 Invited Speaker **Prof Angus Jamieson UHI - High Accuracy Positioning**

09.00 – 10.40 **Classification of and impacts to benthic habitats**
Session Chair: **Dr Mark Shields**

Keynote Speaker: **Dr Dan Wilhelmsson**
Swedish Secretariat for Environmental Earth System Sciences (SSEESS)
Offshore renewable energy and the introduction of artificial habitats

Matthew Easton, Environmental Research Institute, UHI
The tides on the northwest European shelf, their environmental significance and implied limits to energy extraction

Lada Vybulkova, University of Glasgow
The impact of a tidal current turbine on the seabed

Astrid Harendza, Environmental Research Institute, UHI
Classification and temporal variability of habitats in extreme tidal flows

Dr Olivia Langhamer, Department of Biology, NTNU Trondheim
Population dynamics of the common shore crab (Carcinus maenas) in the Lillgrund offshore wind farm in southern Sweden

Poster elevator pitches

10.40 – 11.10 Coffee

11.10 – 12.50 **Ecology – Acoustics**
Session Chair: **Dr Ben Wilson**

Poster elevator pitches

Cormac Booth, Sea Mammal Research Unit, University of St Andrews
Long term remote monitoring of cetaceans using a solar powered autonomous detector

Hoyt Battey, US Department of Energy
National strategy for research and data aggregation to increase understanding of environmental effects of ocean renewable energy

Dr Andrew Gill, Cranfield University
Field scale experiments to assess the effects of offshore wind farms on marine organisms

Dr Diane Jones, HR Wallingford
Modelling underwater noise and marine species response

Dr Robert Batty, Scottish Association for Marine Science
The importance of marine mammal diving behaviour and depth distribution for estimating collision risk with tidal stream turbines

Daniel Wood, Centre for Environment, Fisheries and Aquaculture Science
The effects of pile-driving on the behaviour of cod and sole

PROGRAMME **Wednesday, 2 May 2012**

12.50 – 14.00 Lunch and Posters

14.00 – 15.15 **Marine Planning - managing sea space for renewable energy**
Session Chair: **Dr Sandy Kerr**

Dr Ian Davies, Marine Science Scotland
Spatial planning to support sustainable wave and tidal stream energy developments in Scotland

Dr Kate Johnson, Heriot-Watt University
Tensions in European Marine Policy - the Integrated Maritime Policy (IMP), Marine Strategic Framework Directive (MSFD) and Public Rights

Glen Wright, Australian National University
The regulation of marine renewable: An Australasian perspective on law and policy

Jiska De Groot, University of Plymouth
The impact of stakeholder engagement and regulatory frameworks on marine renewable energy deployment

Poster elevator pitches

15.15 – 15.40 Coffee

15.40 – 16.25 **Marine Planning - managing sea space for renewable energy (continued)**

Dr Anne Marie O'Hagan, University College Cork
Maritime spatial planning across Europe: how do marine renewables feature?

Dr iLaria Marengo, JNCC
GIS, Public participation and wave and tidal marine renewable energy in the context of the Shetland Islands

Frank Fortune, Royal Haskoning
Identification of cumulative impacts in the Pentland Firth, with a focus on wet renewables

16.25 – 17.55 **Ecological consequences for benthic assemblages**
Session Chair: **Dr Tom Wilding**

Dr Bob Rumes, Royal Belgian Institute of Natural Sciences
Offshore intertidal hard strata: A new habitat promoting non-indigenous species in the Southern North Sea

Dr Toyonobu Fujii, University of Aberdeen
Reef effect of offshore artificial structures on the distribution of gadoid fishes in the North Sea

Matthew Ashley, Plymouth Marine Laboratory
Effects of offshore windfarms on fish and epibenthos: Species specific effects and implications for designation of sites as no take marine protected areas

Raeanne Miller, Scottish Association for Marine Science
Shifting power: anticipating the benthic consequences of marine renewable energy development

Dr Tom Adams, Scottish Association for Marine Science
Population connectivity on complex coastlines and the impact of marine renewables

19.30 – 24.00 Ceilidh - Kirkwall Royal British Legion, Junction Road

PROGRAMME **Thursday, 3 May 2012**

08.30 – 10.00 **Marine Renewable Energy Resources (continued)**
Session Chair: **Dr David Woolf**

Keynote Speaker: **Dr John Huckerby**
Chairman of the Executive Committee of the International Energy Agency's OES
An International Vision for Ocean Energy

Dr Susana Baston, Heriot-Watt University
Modelling tidal flow in the Pentland Firth

Arne Vögler, Lews Castle College, UHI
Hebridean Wave-Power: Understanding the resource

Dr Andrew Dale, Scottish Association for Marine Science
The interaction between a tidal race and its low energy surroundings

Ben Timmermans, University of Southampton
Uncertainty in wave model prediction of WEC generated wave power

10.00 – 10.15 Coffee

10.15 – 12.00 **Introduction to WKWTETS**
Session Chair: **Dr Douglas Watson**
Henry Jeffrey, The Institute for Energy Systems
The European Energy Research Alliance (EERA)

Daniel Wood, Centre for Environment, Fisheries and Aquaculture Science
Designing turbines to comply with environmental legislation: De-risking the consenting process

Dr Mike Bell, International Centre for Island Technology
Background to WKWTETS and ICES SGWTE

Keynote Speaker: **Neil Kermode**, European Marine Energy Centre
The EMEC Story

Dr Graham Daborn, Acadia University, Nova Scotia
Tidal power from the Bay of Fundy, Canada: Environmental and socio-economic considerations

Discussion

Presentation of poster prize

PROGRAMME **Thursday, 3 May 2012**

13.00 – 14.00 Lunch and Posters

14.00 – 15.45 **WKWTETS**
Session Chair: **Mike Bell**

Keynote Speaker: **Dr Roland Cormier**
Ecosystem-based risk management

Dr Carol Sparling, Sea Mammal Research Unit, University of St Andrews
Monitoring marine mammals at the world's first operational scale tidal energy device

Andrew Want, ICIT, Heriot-Watt University
Monitoring Orkney's high-energy littoral environment: Photographic and image analysis methodologies for quantifying species and biotope coverage

Garrett Staines, University of Maine
Assessing effects of tidal hydrokinetic devices on fishes at deployment and ecosystem scales

Dr Beth Scott, University of Aberdeen
Seabirds and marine renewables: Are we asking the right questions?

Discussion

15.45 – 16.00 Coffee

16.00 – 17.45 **WKWTETS (continued)**

Sue Barr, OpenHydro
Short term temporal behavioural responses in Pollack, Pollachius pollachius to marine tidal turbine devices; a combined video and ADCP Doppler approach

Dr Jennifer Norris, EMEC
Environmental monitoring at EMEC

Andrea Copping, Pacific Northwest National Laboratory
Getting devices in the water - understanding environmental effects of marine energy development in the US

Davide Magagna, University of Plymouth
Gathering the perspectives and experience from test sites and device developers for environmental and socio economic impact assessment of wave energy

Discussion

Summarising Presentations: **Dr Gareth Davies**, Aquatera
James Mowat, MTDS Ltd
Priorities for research into marine energy – past, present and future - the importance of working together

17.45 Closing Comments by **Dr Mike Weston**

Oral Presentations

Abstracts for the oral papers to be presented to the conference, arranged alphabetically according to the name of the corresponding author (underlined).

Adams, Tom and Burrows, Mike
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Population connectivity on complex coastlines and the impact of marine renewables

The west coast of Scotland is a complex fjordic landscape that harbours great biodiversity. The dynamics of biological populations inhabiting this region can in part be explained by individual responses to local environmental conditions. However, it is also necessary to explicitly account for current patterns, as it is these that govern dispersal of larvae from existing adult populations to other areas of suitable habitat. Recent developments have made accurate hydrodynamic modelling of such complex coastal areas increasingly feasible. This is aiding our understanding of larval connectivity in these regions, and how different parts of the coastline may act as larval source or sink populations. I will discuss the potential impacts of offshore marine renewable energy devices, and the additional habitat that they provide, on such populations.

•

Alexander, Karen and Wilding,Thomas
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Attitudes of Scottish fishers' towards marine renewable energy

Increasing competition for the use of the marine space may lead to conflict as well as increased pressure upon existing users. In particular, the drive to develop the offshore renewable energy sector may have implications for fisheries in the form of restrictions upon access to areas fished and navigation, as well as ecological impacts upon fish populations. Historically a powerful lobby group, fishers' attitudes and behaviour has influenced the success of fishery management measures, compliance with regulations, and the success of Marine Protected Areas; suggesting they may also influence the success of offshore developments. The objectives of this study were to gather information on the attitudes of fishers' on the west coast of Scotland towards marine renewable energy development.

•

Ashley, Matthew; Mangi, Stephen; Rodwell, Lynda and Fletcher, Steve
PML, Prospect Place, The Hoe, Plymouth, Devon PL4 3DH, England

Effects of offshore windfarms on fish and epibenthos: Species specific effects and implications for designation of sites as no take marine protected areas

Offshore windfarm (OWF) development in European waters is progressing rapidly. This current marine renewable energy design of choice is due to cover many thousands of square kilometres of our seas. Knowledge of effects of developments on commercial fish species in shallow seas has not progressed at an even pace to understand the potential benefits and disadvantages to individual species. A systematic review of existing studies revealed benefits to commercial crustacean species, in particular crabs, however flatfish and elasmobranch species showed minimal effects or even decreases in abundance at renewable energy sites. To further investigate these trends underwater baited video surveys were conducted at the UK's oldest operational windfarm North Hoyle and results were spatially and temporally compared to existing environmental monitoring fish and epibenthos surveys. Preliminary results show overall species diversity remained similar inside and outside the OWF however, flatfish and elasmobranch species displayed significantly decreased abundance inside the array. This study highlights the requirement for longer term monitoring of OWF effects on commercial fish species and attention to potential causes for these changes in abundance to maximise potential conservation benefits from arrays operating as de-facto no take zones.

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Broadhurst, M and Barr, S
OpenHydro Group Limited, Muchgrange, Greenore, Co Louth, Ireland

Short term temporal behavioural responses in Pollack, Pollachius pollachius to marine tidal turbine devices; a combined video and ADCP Doppler approach

Combining biological and environmental survey techniques can further knowledge relating to species behavioural responses to marine energy technologies. Underwater video footage was integrated with ADCP doppler surveys to assess behavioural responses of Pollack, Pollachius pollachius to a deployed OpenHydro turbine at EMEC.
Surveys were conducted within 16 day trial periods during the summer months of 2009 and 2010 with fish abundance being compared to hour and day temporal scales and ADCP tidal velocity flow rates between years. Overall the study outlined a different approach to investigate behavioural responses with new anthropogenic activities

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Baston, Susana
ICIT, Institute of Petroleum Engineering (Heriot-Watt University), Stromness, Orkney KW16 3AW, Scotland

Modelling tidal flow in the Pentland Firth

Hydrodynamic numerical modelling is essential to assess the physical parameters on which tidal-stream resource estimation is based. The Pentland Firth has been chosen as one of the main tidal energy exploitation areas in the UK due to the kinetic energy of tidal races in this region. However, the fluid dynamics are very complex, not only because this channel connects the Atlantic Ocean with the North Sea but also because tidal propagation is influenced by topography. This is exemplified by eddies around tips of Swona and Stroma. In this paper the comparison of two advanced numerical models (SUNTANS vs Delft3D) will be addressed in order to identify the most suitable tool for modelling such complex environment.

•

Battey, Hoyt and Brown-Saracino, Jocelyn
US Department of Energy, 1000 Independence Ave, Room 5H-088, Washington DC 20585, USA

National strategy for research and data aggregation to increase understanding of environmental effects of ocean renewable energy

The United States Department of Energy is engaging in a suite of research projects aimed at strategically enhancing scientific

understanding of the potential environmental effects of ocean renewable energy technologies. Through a combination of laboratory-based, field, and modelling efforts, this research aims to help answer both site and species specific questions regarding environmental interactions with individual devices and investigate issues that may pertain to larger-scale deployments. The paper will briefly highlight a number of ongoing research projects, including measurements of the physiological impacts to fish species from exposure to acoustic noise from devices, modelling and analysis associated with energy extraction from marine systems, and development of new technologies to monitor for the presence of marine mammals and fish. The paper will feature detailed results from two DOE-supported research efforts: the Electric Power Research Institute's recently completed laboratory testing of three types of hydrokinetic turbines for potential blade strike and injury to three separate fish species; and DOE national lab testing on eleven species of marine organisms for potential effects of electromagnetic fields emitted from undersea cables. Finally, the Department seeks to aggregate information on the suite of US based work, along with international research efforts, to allow for meta-analyses of data from multiple research efforts.

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Batty, Robert; Benjamins, Steven and Wilson, Ben
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

The importance of marine mammal diving behaviour and depth distribution for estimating collision risk with tidal stream turbines

Collision risks between marine mammals and tidal stream turbines can be considered as a function of the probabilities of evasion (short range) and avoidance (long range) and encounter rate. Encounter rate depends on local animal abundance, behaviour as well as characteristics of the turbine and current. In order to reveal to which aspects of animal behaviour (depth distribution, swimming speed and orientation, etc) encounter rate is most sensitive, we refined an existing encounter rate model and developed a new model to predict the time allocation of depth distribution. Results indicate the importance of accurate depth distribution data to underpin risk assessment.

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Benjamins, Steven; Elliott, Jim and Wilson, Ben
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

PODs adrift: A novel approach to monitoring cetaceans in tidal rapids

Understanding usage of tidal rapids by marine mammals is necessary to advance marine renewable energy generation, but demanding environmental conditions often complicate detection equipment deployment and retrieval. In a novel approach, passive acoustic porpoise detectors (C-PODs) were repeatedly set adrift through a tidal rapid in Western Scotland (UK) during May 2010 and August 2011 to study harbour porpoises over a range of tidal conditions. C-PODs successfully recorded porpoises under a wide range of circumstances. Porpoise distribution proved similar to that found using more traditional survey methods. Drifting C-PODs thus provide new ways to study small cetaceans in these energetic environments.

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Hastie, Gordon; Booth, Cormac; Maginnis, Andy and Gillespie, Doug
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Long term remote monitoring of cetaceans using a solar powered autonomous detector

The use of autonomous passive acoustic devices is now well established as a method for long term cetacean monitoring. However, the duration of most deployments are restricted by battery life and, when monitoring at high frequencies, by data storage. SMRU Ltd present a system for long term monitoring of cetaceans using an autonomous solar powered system which provides multi-species detection in real time. Data volumes of detected calls were typically below 1MB per day and data is transmitted ashore in near real time using cell-/satellite phone networks. We present results of a deployment to date (approximately 11 months) off the east coast of Scotland in terms of numbers of dolphin and harbour porpoise detections, and discuss the potential and pitfalls associated with long term passive acoustic datasets.

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Clough, Stuart
APEM Ltd, Riverview, A17 Embankment Business Park, Heaton Mersey, Stockport SK4 3GN, England

Developing understanding of the offshore distribution of birds and marine mammals in the Pentland Firth and Orkney waters by use of advanced digital aerial surveys

APEM Ltd was contracted by The Crown Estate and Marine Scotland to investigate the utilisation of sea space by birds and marine mammals in the Pentland Firth and Orkney Waters area. This is one of the first studies of its kind for a large area of sea planned for multiple wave and tidal stream projects. APEM's approach was to use very high resolution aerial imagery to provide distribution and abundance data for seabirds and marine mammals. APEM employed a grid-based approach to data collection, spreading the survey effort evenly across the zone of interest. Surveys were conducted in each of 7 biologically relevant survey windows designed to encompass variability across non-breeding and breeding seasons for birds, broadly in line with those used by the DTI (2006) for its strategic offshore wind farm surveys. Results showed that fulmars are the dominant species with regional estimates (66,836; 28,003 – 120,200; CV = 0.05) peaking at a time when birds were expected to be returning to colonies in April/May 2011. At this time, very high concentrations were recorded close to Eday and Westray in to the North Sound, with birds recorded over open water in the northeast of the survey area. Lowest estimates of fulmars were made in August 2011 (9,997; 7,406 – 13,552; CV = 0.09), coinciding with post-breeding dispersal and increases in density in the North Sea. Auks were also relatively abundant with peak abundance recorded in the vicinity of coastal areas in July 2011 (41,902; 23,775 – 63,575; CV = 0.06) reflecting the extensive breeding colonies in the area. Most auks identified were guillemots or razorbills, with puffins and black guillemots also identified in summer surveys. A range of other seabirds and wildfowl were also recorded in the study area. The highest abundance of phocids and cetaceans were recorded in the Pentland Firth. Digital aerial techniques have been proven to be well suited to covering large survey areas in a relatively short space of time, and make good use of short weather windows in challenging environments such as the Pentland Firth area.

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Copping, Andrea
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Getting devices in the water - Understanding environmental effects of marine energy development in the US

The US is deploying initial tidal and wave energy conversion devices, with leadership from the US Department of Energy. The permitting (consenting) process is complex, led by numerous agencies, and requires a very high level of understanding of potential environmental effects. Pacific Northwest National Laboratory, in partnership with other national laboratories, university partners and the industry, pursues research that addresses permitting needs and fills gaps in understanding effects. Results of studies will be presented on effects of electromagnetic fields, acoustics, direct interactions with marine animals, and risk assessment processes. A knowledge management system that organizes and presents effects will be demonstrated.

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Daborn, Graham and Redden, Anna
Acadia Centre for Estuarine Research, Acadia University, Nova Scotia, Canada

Tidal power from the Bay of Fundy, Canada: Environmental and socio-economic considerations

Over the last 100 hundred years, the potential of the tidal movements in the Bay of Fundy (Nova Scotia, Canada) for electricity production has been assessed more than a dozen times. These schemes have included both potential energy (eg barrage-based) approaches and kinetic energy (TISEC) devices, and generated extensive research into the Bay of Fundy ecosystem. Studies have assessed the implications of both turbines and barrages on fish, mammals and birds, on hydrodynamics (eg current flows, mixing parameters, tidal range, phase etc), sediment dynamics, groundwater movements and primary and secondary production processes. Because impedance of flow associated with tidal barrages has the potential for effects over great distances, and because the annual migrations of numerous species of fish, birds and mammals link the Bay to North, Central and South America and both the North and South Atlantic, the scope of environmental studies has been geographically wide. A 20MW tidal generating station established at Annapolis Royal in 1985, has served as a platform for research into near-field environmental effects, particularly the direct effects of turbine passage on fish and mammals, and the local effects on groundwater, sediments and biota. In 2008, Nova Scotia began to explore the potential of commercial-scale TISEC devices in the Bay of Fundy. A Strategic Environmental Assessment involved extensive community input, and recommended a phased approach that would examine the potential and implications of both large scale arrays and small scale local installations. A major testing facility in Minas Passage is being developed as the Fundy Ocean Research Centre for Energy (FORCE), with four cabled berths. Tests of smaller scale devices are being conducted in other high flow passages. FORCE has recruited an independent advisory group (EMAC) of scientists from academia, government, and local resource users, to advise on design of the monitoring programme and interpretation of results. In addition, an independent group of natural and social scientists formed the Fundy Energy Research Network (FERN), which is hosted by Acadia University. Research initiatives include: hydrodynamic and sediment modeling; monitoring movements of fish and marine mammals; implications for shoreline erosion, ice formation and mobilisation, and submerged debris; effects on benthos and plankton; primary and secondary production; and on socio-economic implications (eg fisheries displacement, community development, supply chain implications, etc). This presentation will review both the scope of the monitoring and assessment programme, and the challenges presented – especially the technical challenges of monitoring in high flow environments.

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Dale, Andrew; Jackson, Keith; Benjamins, Steven and Bell, Christopher
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

The interaction between a tidal race and its low energy surroundings

The Gulf of Corryvreckan, between Jura and Scarba, supports a powerful tidal race and provides a case study of the physical and ecological interaction between a race and its low-energy surroundings. Field observations and model studies reveal this to be a highly non-linear system in which asymmetry drives a pump-like exchange through the Gulf. A turbulent, eddying plume develops to the west but not to the east. We describe this asymmetry, its variation with tidal strength, and its ecological implications as a baseline for understanding the potential consequences of removing energy from such a system.

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Davies, Ian; Watret, Robert and Gubbins, Matt
Marine Science Scotland, Marine Laboratory, 375 Victoria Road, Aberdeen AB11 9DB, Scotland

Spatial planning to support sustainable wave and tidal stream energy developments in Scotland

Scottish Government targets for renewable energy developments are ambitious. The creation of new marine industries requires a structured approach that links marine spatial planning with Strategic Environmental Assessment and Sustainability Appraisal. Marine Scotland Science has worked with The Crown Estate spatial decision support tool MaRS to plan for wave, tidal and wind power in Scottish waters. This multi-factorial spatial modelling system has been used to visualise and balance the relative opportunities and constraints on development arising from a wide range of environmental, industrial and socio-economic factors. Areas of search for development sites have been identified, explored through Regional Locational Guidance and adopted in development plans.

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de Groot, Jiska
School of Geography, Earth and Environmental Sciences, 8 Kirkby Place, University of Plymouth, Devon PL4 8AA, England

The impact of stakeholder engagement and regulatory frameworks on marine renewable energy deployment

Marine Renewable Energy (MRE) is set to play a major part in the delivery of the UK's targets for renewable energy to 2020 and beyond. Securing the future of MRE deployment will, however, require appropriate regulatory frameworks across a range of issues and gives a direct imperative for strong engagement with stakeholders to mitigate problems experienced for on-shore technologies. This paper explores the practical implications of stakeholder engagement in the deployment of MRE in the UK and presents a critical review of existing and planned regulatory frameworks related to stakeholder engagement on MRE deployment.

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Woolf, David; Bowyer, Peter and Easton, Matthew
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The tides on the northwest European shelf, their environmental significance and implied limits to energy extraction

Approximately 250 gigawatts of tidal power crosses into the northwestern European shelf seas and is dissipated in the shelf seas and coastal waters. Several gigawatts are dissipated in each of a few regions of exceptional currents, including the Pentland Firth in northern Scotland. An engineer or entrepreneur may regard this natural dissipation of energy as wasteful, but sustainable management of the tidal energy resource requires us to consider the environmental function of the tides. Tides control the physical environment of the shelf seas, particularly of coastal regions of high tidal currents or range. Among other functions, the tides are critical in determining stratification, mixing and fronts; transport and dispersion of organisms and sediment; and the extent of the inter-tidal zone. The consequences of modifying these functions through energy extraction can only be predicted accurately through detailed shelf sea modelling.

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Fortune, Frank
Royal Haskoning UK, 10 Bernard St, Leith, Edinburgh EH6 6PP, Scotland

Identification of cumulative impacts in the Pentland Firth, with a focus on wet renewables

Royal Haskoning has developed guidance on potential cumulative impacts for wave and tidal project developers in the Pentland Firth, on behalf of The Crown Estate. The study is one of a series of Enabling Actions projects commissioned by The Crown Estate, aimed at accelerating and de-risking project development. Based on consultation with industry, developers and wider user groups, guidance was produced which reviews technologies with potential for deployment, considers environmental (including human, biological and physical) receptors, and advises as to the focus of further joint studies. At the end of the process a series of areas for further assessment were identified, including: ornithology, including consideration of both distribution and behavioural data collection as well as connectivity between designated sites; shipping and navigation including consideration of navigational risk as a result of staged development of the zone and potential 'knock on' displacement effects on other users, such as commercial fisheries; marine mammals, with the use of the data collected by TCE as an enabling action and including consideration of distribution and behavioural data; and commercial fisheries, collecting and presenting data on distribution and activity of activity, linked closely to shipping and navigation studies.

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Fujii, Toyonobu
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Reef effect of offshore artificial structures on the distribution of gadoid fishes in the North Sea

During a 25-year period, the physical presence of offshore oil/gas platforms is one of the most important parameters consistently explaining variation in the distribution of gadoid fishes across the North Sea. A possible mechanism for the phenomena is a reef effect which attracts large number of fish around the network of such structures and thereby alters the spatial patterning of relative abundance in the rest of the open seafloor. The results have profound implications for sustainable resource and fishery management particularly in view of the emergent pressure to develop and use marine space for the installation of offshore renewable energy facilities.

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Bowyer, Peter; Marchi, Giacomo and McIlvenny, Jason
Centre for Energy and the Environment, Environmental Research Institute, North Highland College, University of the Highlands and Islands, Ormlie Road, Thurso, Caithness KW14 7EE, Scotland

Tide gauge data for the testing of tide and surge models in the Pentland Firth

The Crown Estate's concession for energy production development in the Pentland Firth and Orkney Waters area has led to a growing interest for a focused site characterisation. The objective of assessing both resources and risks of the local tidal streams can be reached through the use of numerical models. The reliability of any model used to replicate the local hydrodynamic regime needs to be proved through validation. With this purpose we used local field data, including data from a weather station and two tide gauges, expressly mounted at the extremities of the Pentland Firth, to perform hindcasts on hydrodynamic models of the area.

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Gill, Andrew; Mueller-Blenkle, Christina; McGregor, Peter; Andersson, Mathias; Metcalfe, Julian; Bendall, Victoria; Sigray, Peter; Wood, Daniel; Wearmouth, Victoria and Thomsen, Frank
Cranfield University, Natural Resources Department, Cranfield MK43 0AL, England

Field scale experiments to assess the effects of offshore wind farms on marine organisms

To obtain ecologically relevant results at a scale appropriate for OWFs, we have taken the experimental approach, incorporating a treatment and control, into the coastal environment using large underwater netted structures (mesocosms). To date, our studies have used the mesocosms to increase understanding of two relatively unknown effectors on fish: underwater pile-driving sounds (during construction) and Electromagnetic Fields (EMF), associated with the production of the electricity by OWFs (during operation). The approach presented here clearly demonstrates that specific effects of OWFs on fish (and potentially other marine organisms) can be determined at a scale that is ecologically relevant. Furthermore, it provides an important step in assessing what effectors need to be considered in terms of their possible impacts, thereby moving the research agenda forward whilst also meeting the needs of the stakeholders involved with OWF.

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Harendza, Astrid; Jackson, Angus; Shields, Mark; Le Bas, Tim and Blondel, Philippe
University of the Highlands & Islands, Environmental Research Institute, Thurso KW14 7EE, Scotland

Classification and temporal variability of habitats in extreme tidal flows

Ecological and physical baseline data of highly energetic marine environments are urgently needed to improve our understanding of possible ecological impacts due to the installation of marine renewable energy devices. Sidescan sonar data from the Inner Sound of Stroma, a subchannel of the Pentland Firth with a designated tidal energy development of 400 MW, are presented.

Multiple surveys, using vessel-mounted Starfish CHIRP sonar, were done over two years. Post-processing of raw acoustic data was undertaken using PRISM. Acoustic textures were computed in TexAn and seabed features classified accordingly. This allowed investigation of changes in habitats through time.

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Hartnett, Michael; Nash, Stephen; O'Brien, Noreen and Olbert, Agnieszka
National University of Ireland, Galway, Ireland

Quantification of tidal power in a highly dynamic estuary

The Shannon River and its estuary is one of the largest systems in the British Isles. The tidal range at the mouth of the estuary is over 5m during normal spring tides, inducing currents up to 2.5m/s in water depths of 35m. The estuary has been rightly identified as a potential location for tidal energy extraction; however, little detailed analysis has been carried out to determine accurate potential.
This research consists of two components: Firstly, a hydrodynamic model is developed at a horizontal resolution of 500m; a newly developed nested modelling procedure (developed by the authors) is then applied to resolve the areas of interest on a 10m grid. This high spatial resolution allows the detail of resource quantification necessary to enable engineering decisions to be made regarding the exploitation of tidal energy. Secondly, most assessments regarding tidal energy potential is based on total current vectors: in this research both the coarse and high resolutions 'fields' of tidal ellipses are constructed and plotted. Since tidal turbines cannot rotate into the tidal stream as vectors are orientated during different stages of the tide, the full vector over predicts tidal energy potential. From these tidal ellipses a more accurate assessment of tidal resource is made. Results from the models are presented, resource potential is calculated using complete vectors and tidal ellipses are compared. The paper concludes with main findings and recommendations.

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Hildenbrand, Kaety; Gladics, Amanda and Eder, Robert
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Collaborative research as a method to engage existing ocean users in wave energy development in Oregon, USA

Conflict between existing ocean users and marine renewable energy projects can often occur. Existing user concerns are often fragmented into conversations specifically around the potential conflict and not integrated into other aspects of the project. Meanwhile, potential marine renewable energy projects require baseline studies that can often be expensive, time intensive and difficult to obtain. This presentation outlines a project completed in Oregon which used commercial fishermen as research collaborators to obtain data needed for wave energy baseline studies on Dungeness crabs. The project both obtained the needed data, but also acted as an engagement tool to commercial fishermen.

•

Johnson, Kate
International Centre for Island Technology, Heriot-Watt University, Old Academy, Stromness, Orkney KW16 3AW, Scotland

Tensions in European marine policy - the Integrated Maritime Policy (IMP), Marine Strategic Framework Directive (MSFD) and Public Rights

The ambitions to use marine space and the emergent regimes for Marine Spatial Planning reveal tensions in Europe between the economic policy expressed by DG MARE, environmental law hosted by DG ENV and ancient rights. This paper examines the gaps between the three pillars supporting activities and conservation in European seas and the prospects for a Marine Spatial Planning (MSP) Directive. Examples are drawn from marine renewable developments in Scotland and the anticipated remedies (or lack of them) to conflicts at key points of interaction.

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Benson, Thomas; Jones, Diane and Lepper, Paul
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Modelling underwater noise and marine species response

Anthropogenic underwater noise is an area of increasing interest and some concern as increased human activity related to marine energy projects move into new areas of the global marine ecosystem; with special emphasis on marine mammals. HR Wallingford and Loughborough University have developed a numerical predictive modelling tool which combines hydrodynamic, bathymetric and acoustic information to produce a map of the potential sound propagation from a source point. A newly developed individual based ecological model is then used to predict the response of local marine life to the modelled noise field using known behavioural and acoustical response patterns for the target organism. The model can be run for a variety of scenarios and can aid in the planning and consenting process for offshore activities.

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Kawase, Mitsuhiro and Gedney, Marisa
School of Oceanography / Northwest National Marine Renewable Energy Center, University of Washington, Seattle WA 98195, USA

Effects of localised energy extraction in an idealized, energetically complete numerical model of an ocean-estuary tidal system

Numerical modeling is expected to play a crucial role in the assessment of resource size and environmental impact of tidal energy development. Tide is a global phenomenon, forced by astronomical processes at the largest spatial scale; however, most regional models of marine hydrodynamics have tides imposed as boundary conditions instead. Whether or not these models represent the energetics of the tide accurately for tidal energy applications is a matter needing verification. In order to address this issue, we have constructed a highly idealized model of the ocean-estuary system, in which tides are forced astronomically and thus the system is energetically complete, ie the integrated energy balance has no exchange with the "outside" ocean. We perform benchmark energy extraction experiments to establish the scaling between additional energy dissipation in the estuary, representing a tidal array, and changes in the tidal parameters within the estuary and the surrounding ocean. We then repeat the experiments with a series of subdomain models, for which tides sampled from the complete model are used as boundary conditions. We assess the consequences of limited domain representation on the scaling and resource characterization; we will consider both normal and near-resonant estuaries. Our goal is to help establish a best practice guideline for implementation and verification of a regional numerical model for tidal energy applications.

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Langhamer, Olivia and Rosenqvist, Gunilla
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Population dynamics of the common shore crab (Carcinus maenas) in the Lillgrund offshore wind farm in southern Sweden

Worldwide growth of offshore renewable energy production will provide marine organisms with new hard substrate for colonization in terms of artificial reefs. The artificial reef effect is important when planning offshore installations since it can create habitat enhancement. Wind power is the most advanced technology within offshore renewable energy sources and there is an urgent need to study its impacts on the marine environment. We conducted a short-term study to estimate the density of the common shore crab (Carcinus maenas) in the Lillgrund offshore wind farm at the Swedish south coast and in two close-by control areas. About 3000 crabs were marked and released; the mark-recapture model was applied to estimate probabilities of recapture and the size of the local populations. From the differences in recapture rates, behavioural patterns and population dynamics are assessed and will give implications for whether beneficial effects of the wind farm can be expected for the common shore crab.

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Magagna, Davide; Greaves, Deborah; Conley, David; O'Hagan, Anne Marie; Holmes, Brian; Witt, Matthew; Simas, Teresa; Huertas Olivares, Cristina; Chambel Leitão, Jose; Mouslim, Hakim; Torre-Enciso, Yago; Sundberg, Jan and Rosseau, Nathalie
University of Plymouth, School of Marine Science and Engineering, Drake Circus, Plymouth PL4 8AA, England

Gathering the perspectives and experience from test sites and device developers for environmental and socio economic impact assessment of wave energy

The SOWFIA (Streamlining of Ocean Wave Farms Impact Assessment) project aims to make recommendations to streamline impact assessment and to develop coordinated tools that will contribute to advancing the wave energy sector across Europe. This paper examines the types of, and methods used in, environmental scoping studies whilst investigating the applicable consenting process in six test sites in different jurisdictions. The experiences of site and device developers in relation to consenting and financing of scoping studies were gathered in order to understand the non-technological barriers that the wave energy industry faces. The capturing of such experience highlights the urgent need to adopt a common approach to Impact Assessment and thereby facilitate development of the sector.

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Marengo, iLaria
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GIS, Public participation and wave and tidal marine renewable energy in the context of the Shetland Islands

Between the North Atlantic Ocean on the West and the North Sea on the East, the Shetland Islands have an advantageous location which provides them with some of the best marine resources in the world, particularly in wave energy. This project is aimed at the identification of potential resource areas for the development of wave and tidal marine renewable energy, potential sites for cable landing and of potential constraints due to environmental and socio-economic factors characterising the marine and coastal ecosystem of the Shetland Islands. The investigation was carried out through the development of a GIS-based methodology which was built in the framework of a public participation process. Representatives of the marine renewable industry and local stakeholders were consulted and provided information on the technical, environmental and socio-economic factors which can influence, positively or negatively, the identification of resource areas for marine renewable devices. The outcomes from the consultation process were imported in GIS and transformed in data layers. In order to consider the level of uncertainty expressed during the assessment of the factors and to add correctly data layers measured in different units, the approach adopted by the GIS-based analysis was to standardise the data and apply fuzzy logic techniques. The analysis gained strength from the incorporation and support of experts' knowledge. Nevertheless it showed limitations due to the lack of critical and fundamental data on some economic and recreational activities and environmental variables. Hence the resulting maps of potential resource areas and potential constraints should be considered initial informative tools and not definitive planning tools in favour or against the development of marine renewable devices. As being part of an applied research project, the overall GIS-based analysis can be refined to meet more specific requirements of the marine renewable industry and can be tailored to become applicable to other sectors.

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McLay, Anne; Bruce, David; Watret, Robert; Barret, Elisa and Goldschmidt, Pippa
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ScotMap: mapping fishing activity in the Pentland Firth and Orkney waters

We report on the methodological development and findings of a pilot study aimed at mapping small vessel (<15 m) fishing activity in the Pentland Firth and Orkney waters. Data were collected during face-to-face interviews with over 180 fishermen, recorded via a graphical user interface and assembled in a geodatabase. Participants identified over 490 'fishing polygons', representing the areas in which they fish, and provided associated information on gear, target species, seasonal usage and value. A range of data analysis and mapping techniques are applied to the dataset to evaluate and depict marine usage by fishing at the métier and community level.

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McNaughton, James; Apsley, David; Afgan, Imran and Stansby, Peter
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CFD study on the influence of the turbulent environment on tidal turbines

Detailed 3D modelling of tidal turbines is performed using a new sliding-mesh method implemented in EDF's open-source Computational Fluid Dynamics solver, Code_Saturne. Validation is provided for laboratory scale experiments through a comparison of power and thrust measurements for varying tip-speed-ratios. The method is then used to study the effects of turbulence and waves on a full scale 1MW tidal turbine at EMEC in the Orkney Islands. The k-epsilon and k-omega SST Reynolds Averaged Navier Stokes Models are used as well as considering the gain in precision brought by Large Eddy Simulations using the Synthetic Eddy Method at the inflow boundary.

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Miller, Raeanne; Hutchison, Zoë; Macleod, Adrian; Burrows, Michael; Cook, Elizabeth; Last, Kim and Wilson, Ben
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Shifting power: anticipating the benthic consequences of marine renewable energy development

As marine renewable energy technologies rapidly develop in many parts of the world, the size of planned installations grows. Impact assessments provide some insight into the environmental and ecological consequences of individual developments, but the cumulative effects of installing multiple arrays along coastlines are poorly understood. Though robust benthic studies on marine renewable energy deployments are few, we discuss the ecological consequences for benthic flora, fauna, and habitats through the life-cycle of renewable energy deployments from device to array scale. Lessons will be drawn from the larger body of research on the benthic ecology of man-made coastal infrastructure.

•

Norris, Jennifer
EMEC, Old Academy, Back Road, Stromness, Orkney KW16 3AW, Scotland

Environmental monitoring at EMEC

EMEC undertakes baseline monitoring of the receiving environment at all its four test sites. Data collected is driven by regulatory need (typically expressed as conditions on developers' licences to deploy their marine energy devices). Monitoring includes wildlife presence and behaviour, and acoustic characterization of the sites. There are some data collection recommendations for which there are as yet no 'best practice' methodologies, and for which therefore such methodologies need to be developed and tested. The paper will describe EMEC's involvement in a range of environmental and other research projects, which include wildlife distribution, acoustic characterization of the deployment sites, and a ground-breaking fisheries project that works collaboratively with local fishers and looks at the distribution of lobster around the EMEC wave site.

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O'Hagan, Anne Marie
Hydraulics and Maritime Research Centre (HMRC), University College Cork, Pouladuff Road, Togher, Cork, Co Cork, Ireland

Maritime spatial planning across Europe: how do marine renewables feature?

Marine renewable energy developments are growing across Europe. The European Union has advocated the use of Maritime Spatial Planning (MSP) as an appropriate tool to deliver rational use of the sea by providing a stable and transparent planning system for maritime activities. Progress on this across Member States is varied. Well-established activities seem to be included with less consideration given to developing industries, such as ocean energy. This paper examines MSP in the EU and how ocean energy is reflected, if at all. It reviews relevant MSP research initiatives and explores future policies likely to influence planning of marine renewable energy developments.

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Pollard, Edward and Littlewood, Mark
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Project Adair: Mapping marine heritage sites in Orkney and the Pentland Firth

ORCA in collaboration with Historic Scotland and Royal Commission on the Ancient and Historical Monuments of Scotland has collated marine data sets for interrogation to enhance and amend the existing historic environment records of Orkney and the Pentland Firth. This project will ensure that the information is made widely available to support new marine legislation in Scotland to establish a marine planning system and create a network of Marine Protected Areas. The study will improve our knowledge about the survival and character of seabed archaeology and test the value of interrogating existing marine data for heritage. These waters have been prioritised due to archaeological potential and where marine renewable developments will be progressed.

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Kerckhof, Francis; Degraer, Steven; Norro, Alain and Rumes, Bob
Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine Ecosystem Management Section, Gulledelle 100, B-1200 Brussels, Belgium

Offshore intertidal hard strata: A new habitat promoting non-indigenous species in the Southern North Sea

Expansion of non-indigenous species alters local biodiversity and can cause competition with native species, some of which are of commercial interest. This is especially the case in shallow coastal waters, subject to a multitude of human activities, including the increasing construction of artificial hard substrata. We took the opportunity of the construction of two wind farms off the Belgian coast to study the colonisation of non-indigenous species on these new artificial structures. We monitored the fouling communities of the wind farms on a regular basis from the beginning of their installation. We demonstrated that the new artificial hard substrata of the wind mills offer new opportunities for non-indigenous species (introduced and southern North-east Atlantic range-expanding species) to enter the Southern North Sea. Or, if already present, to expand their population size and hence strengthen their strategic position in the Southern North Sea. This is particularly important for the obligate intertidal hard substrata species, for which other offshore habitat is rare to non-existing.

•

Scott, Beth; Philpott, Evelyn; Langton, Rebecca and Waggitt, James
University of Aberdeen, School of Biological Sciences, Aberdeen, Scotland

Seabirds and marine renewables: Are we asking the right questions?

The research on potential environmental interactions between marine renewables and marine animals needs a much clearer ecological focus which incorporates hypothesis testing rather than the production of distributional abundance maps. We suggest the rapid way forward towards this approach can be found via a fundamental focus and understanding of seabird foraging. The research presented will cover the 4 main issues influencing seabird foraging which are: 1) identifying locations of (and the mechanisms producing) foraging areas, 2) foraging energy expenditure, 3) underwater foraging behaviour and 4) the cumulative effects that influence prey abundance, quality and availability. The presentation will cover how surveys and monitoring for renewable developments can incorporate these ecology based hypothesis testing approaches. Recommendations and examples from current research projects, including the new

upward facing acoustic instrument (EK60 + Multi-beam) for exploring seabird and fish underwater interactions at the EMEC tidal and UK WaveHub sites will be covered.

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Sparling, C; Hastie, G; Duck, C; McConnell, B; Lonergan, M; Mackay, A; Booth, C; Northridge, S; Savidge, G; Birkett, D; McKenzie, M; Donovan, C; Ainsworth, D and Boyd, I
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Monitoring marine mammals at the world's first operational scale tidal energy device

MCT's SeaGen turbine has been operational in Strangford Lough since July 2008. Strangford Lough is an environmentally sensitive area and has several conservation designations. One of the qualifying features is a breeding population of harbour seals. Grey seals and harbour porpoise are also frequently seen there. A monitoring programme has been in place since 2006, examining the effects of the turbine across different spatial and temporal scales. Three years post-installation, we've detected no significant effects of the turbine, although some local displacement of porpoises and seals may have occurred. The challenge is to use these results to scale up from single devices to arrays and to develop cost-effective monitoring methodologies at future developments.

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Zydlewski, Gayle; McCleave, Jim; Staines, Garrett; Viehman, Haley and Vieser, Jeff
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Assessing effects of tidal hydrokinetic devices on fishes at deployment and ecosystem scales

Fish are a key part of the Cobscook Bay ecosystem likely to be affected by marine hydrokinetic devices in Eastport, Maine, USA Our research on these effects consists of three approaches: 1) Active acoustics documenting vertical fish distribution at proposed deployment and control locations through tidal, diel, and seasonal cycles. 2) DIDSON acoustic imaging fore and aft of a device to document behavioural responses through complete diel and tidal cycles. 3) Seine, fyke, and trawl sampling to document fish community structure. The strength of our approach is pre- and post-deployment data and both experimental and control sites for quantitative comparison.

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Stokes, C; Beaumont, E; Russell, P; Conley, D and Greaves, D
Buckland House, Drake Circus, Plymouth, Devon PL4 8AA, England

Anticipated coastal impacts of the Wave Hub project

We explore the physical coastal impacts that are anticipated by the coastal water user community, as the deployment and activation of devices at the Wave Hub facility (Cornwall, UK) becomes increasingly likely. In depth, semi-structured interviews are analysed using a grounded theory approach in order to explore contemporary anticipations as well as the process of opinion formation that has occurred for participants and the coastal user community as a whole. The interviews focussed on anticipated impacts to inshore wave conditions, beach sedimentation, rip current formation and beach safety as well as the level of consultation that has occurred with the coastal water user community. The results indicate that while there was a concern initially with regards to wave height reduction and knock-on impacts to the surf industry/surf tourism, this concern has waned and participants are either unconcerned about coastal impacts, predicting insignificant changes, or are concerned more by potential risks from equipment breaking free, the project being poorly executed, or socio-economic benefits not being felt by the host communities.

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Thompson, Paul; Brookes, Kate and Graham, Isla
University of Aberdeen, Institute of Biological & Environmental Sciences, Lighthouse Field Station, Cromarty IV11 8YJ, Scotland

Methods for monitoring marine mammals at marine renewable energy developments

Several different survey methods have been proposed to characterise marine mammal communities at potential development sites and/or monitor changes in abundance or distribution during and following construction. Whilst there have been reviews of the theoretical advantages and disadvantages of these different approaches, direct comparison of their performance is lacking. In 2010 we carried out parallel studies at two 25 x 25km offshore survey blocks in the Moray Firth using three key methods: 1) visual line-transect surveys using aircraft 2) static passive acoustic monitoring 3) Hi-def video aerial surveys. Additional data from boat-based line-transect surveys were also available from one of these survey blocks. This paper compares the performance of these different methods in terms of 1) quality and transparency of data 2) performance under different weather regimes 3) costs and 4) capacity of the supply chain to provide comparable survey data across multiple sites and years.

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Timmermans, Ben; Challenor, Peter and Gommenginger, Christine
University of Southampton, School of Ocean and Earth Science, National Oceanography Centre Waterfront Campus, European Way, Southampton SO14 3ZH, England

Uncertainty in wave model prediction of WEC generated wave power

Our ability to forecast wave power from a WEC is dependent upon our ability to forecast the power in the incoming waves. This is usually done via a wave model. For complex and high dimension models, such as those used to predict waves, the effect of uncertainty about model input is not always well understood and cannot easily be analysed. In this work, statistical techniques based upon Gaussian process emulators are used to perform uncertainty analysis on the operational wave model Wavewatch III. For simple models, uncertainty in model response, in terms of wave power, is explored with respect to uncertainty in various input parameters, including variable grid resolution. The implications for the forecasting of wave power are discussed.

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van Geel, Nienke; Hastie, Gordon and Wilson, Ben
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Potential to minimise impact of marine renewables construction on bottlenose dolphins by understanding their movement patterns

Scotland is rapidly becoming the focus for marine renewable developments. Progression of these industries will require considerable construction activities with the potential to pose

risks to nearby cetaceans. Globally, bottlenose dolphins show considerable variation in their degree of mobility; some communities may be resident while others appear nomadic. This study investigates patterns of mobility and detection methods of the resident bottlenose dolphin population on the west coast of Scotland. Understanding how and when dolphins use areas targeted for development has the potential to provide an effective means of mitigation by timing activities to when dolphins are unlikely to be in the vicinity or are known to be elsewhere.

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Vögler, Arne
University of the Highlands and Islands, Lews Castle College, Stornoway, Isle of Lewis HS2 0XR, Scotland

Hebridean Wave-Power: Understanding the resource

This talk presents wave data for autumn and winter 2011 obtained from a wave buoy and ADCP sensor network currently deployed to the north-west of the Isle of Lewis. A full understanding of the wave resource is important for developers and investors alike to predict energy yield and to inform the site selection and array layout design process. The data will be beneficial to validate model outputs of numerical resource assessments and will be made available to wave energy developers to support their interests in the area. The general wave climate over the investigative period will be described, together with an overview of some particular events of interest.

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Vybulkova, Lada; Brown, Richard; Karunarathna, Harshinie and Vezza, Marco
University of Glasgow School of Engineering, Glasgow G12 8QQ, Scotland

The impact of a tidal current turbine on the seabed

One of the most important aspects of the environmental impact of tidal current turbines (TCTs) is their effect on the dynamics of the suspended sediment load. High resolution computational simulations of the hydro-dynamics of a TCT have been conducted using the Vorticity Transport Model together with several different erosion models. The resultant extra sediment erosion rate is expressed as a function of tidal current velocity. The present study shows that studies claiming that changes in bed level are minimally affected by the presence of TCTs can be misleading since the high vortex-induced velocities in the wake of the turbine can cause elevated local rates of erosion.

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Wade, Helen; Masden, Elizabeth; Jackson, Angus; Furness, Robert and Bouten, Willem
Environmental Research Institute, North Highland College UHI, Ormlie Road Thurso, Caithness KW14 7EE, Scotland

Great skua Stercorarius skua foraging movements and potential effects of marine energy developments

The Pentland Firth and Orkney waters are the focus for significant deployments of marine renewable energy devices (MREDs). These waters are also of national and international importance to breeding seabirds but the effects of MREDs on seabirds are largely unknown. To accurately predict potential effects of MREDs on seabirds, greater knowledge of their foraging distributions and behaviour are required. Using GPS telemetry, we have begun to investigate foraging movements of great skuas (Stercorarius skua), breeding on Hoy, Orkney. Data provide information of foraging locations, which could inform developers and regulators about potential interactions between great skuas and MREDs in this area.

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Want, Andrew; Side, Jon and Bell, Michael
International Centre for Island Technology, Heriot-Watt University, Stromness, Orkney KW16 3AW, Scotland

Monitoring Orkney's high-energy littoral environment: Photographic and image analysis methodologies for quantifying species and biotope coverage

The West Mainland shoreline of Orkney is characterised by dramatic sandstone cliffs, complex geomorphologic features including sea stacks and caves, and a few embayments. With a westerly fetch of over 3000 km, wave energy plays a dominant role in both shaping this landscape and determining the ecological community. Access to this considerable wave energy resource has been one of the factors in the recent decision to deploy energy extraction devices off this coastline. We have begun a long-term monitoring programme to assess the consequences of altering wave energy exposure on these rocky shores alongside responses to other systemic forcing agents such as climate change. Within this programme are several photographic surveys including quadrat and fixed view point techniques used to study individual species and biotopes. In addition, we have developed software for economically analysing these images and producing quantitative baseline data on species and biotope coverage.

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Watts, Laura
IT University of Copenhagen, Rued Langgaards Vej 7, Copenhagen DK-2300, Denmark

The Orkney Electron: a socio-technical story of marine renewable energy

Electricity may be ethereal, of the ether, but it has social, political, environmental, economic, as well as electrical power. Following approaches in social studies of science and technology, this paper will draw together results of an ethnography of how the future of marine renewable energy continues to be imagined and made in Orkney. In particular, it will explore the diverse socio-technical and environmental stories associated with the making of the elusive but potent particle that is the 'Orkney electron'; a conceptual object that can help explore issues of community ownership and participation in marine renewable energy.

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Wilson, Ben; Benjamins, Steven; Gordon, Jonathan; Calderan, Susannah; van Geel Nienke and Elliott, Jim
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Are Scottish tidal-stream energy sites also porpoise hot-spots?

Habour porpoises are the UK's most common cetacean and the literature is split on whether tidal-energy sites are hot - or cold-spots for them. We investigated porpoise density in two Scottish tidal narrows. We used standard boat surveys but redesigned them because the water itself was moving close to vessel speed. Porpoises were detected 126 times visually and 504 acoustically during summer surveys (2009/10, 1310km). Porpoises were at low densities in areas of high flow in contrast to neighbouring habitats. These findings are discussed in relation to energy developments and the suitability of existing techniques for marine mammal surveys in flowing water.

Wood, Daniel; Birchenough, Silvana; Bremner, Julie; Ellis, Jim; Rees, Jon; Mueller-Blenkle, Christina and Thomsen, Frank
Cefas, Pakefield Road, Lowestoft NR33 0HT, England

Designing turbines to comply with environmental legislation: De-risking the consenting process

Environmental impacts and legislation tend only to be considered during the EIA process. By this point, many millions have already been spent on R&D. Environmental scientists at Cefas worked with two teams of engineers, NOVA and DIWET5 from early in the design process. The NOVA turbine is a vertical access turbine while the DIWET5 project focused on a floating platform design. The aim was to design out environmental impacts of two new wind turbines, at the desk-based stage. In both projects the design team gained valuable information on the environmental impacts of their turbines. Areas of potential higher than desirable impacts were identified, allowing the engineers to mitigate them.

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Mueller-Blenkle, Christina; McGregor, Peter; Gill, Andrew; Andersson, Mathias; Metcalfe, Julian; Bendall, Victoria; Sigray, Peter; Wood, Daniel and Thomsen, Frank
Cefas, Lowestoft, Suffolk NR33 0HT, England

The effects of pile-driving on the behaviour of cod and sole

Behavioural reactions of marine fish to pile-driving sound playback were investigated in two large (40m) net pens located in a quiet bay. Fish movements were analysed using a novel acoustic tracking system. Received sound pressure level and particle motion were monitored during the experiments. The results show a significant movement response to the pile driving stimulus in cod and sole at relatively low received sound pressure levels. This might indicate a rather large area of avoidance during real pile driving operations. The results of the study have important implications on regulatory advice and the implementation of mitigation measures in the construction of offshore wind farms.

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Wright, Glen
Australian National University, 91 Darcey Road, Castle Hill, NSW 2154, Australia

The regulation of marine renewable: an Australasian perspective on law and policy

Australia and New Zealand both host fledgling industries seeking to develop and deploy marine renewables, but projects face barriers to deployment as a result of an underdeveloped regulatory framework. In particular, the regulatory frameworks are yet to reflect the nuanced nature and diversity of marine renewable technologies, or the fact that most projects currently proposed are small-scale prototype projects. The first part of this paper will assess the projects and Environmental Impact Assessment regime in Australia and how it applies to marine renewables. The second part of the paper will discuss the regime in New Zealand. The focus here will be on the recently approved Crest Energy Kaipara Harbour tidal power project, New Zealand's first large-scale marine energy project. The project was given approval to proceed after five years of proceedings in the Environment Court, primarily due to community concerns and uncertainty regarding environmental impacts.

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Poster Presentations

Abstracts for the posters accepted for the conference, arranged alphabetically according to the name of the corresponding author (underlined).

Alexander, Karen; Heymans, Sheila and Wilding, Thomas
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Modelling the opportunities of marine renewable energy: potential mitigation?

Marine renewable energy devices and associated infrastructure will be placed on the seabed, affecting benthic infauna and epifauna (important food sources for many commercial species). It is likely that exclusion zones will be created around offshore renewable energy installations, turning the areas into no-take zones, or creating areas which are closed to certain gear types. These effects may offer opportunities for the fishing industry and mitigate any negative impacts. Using the ecosystem model Ecopath with Ecospace, this study tested spatial scenarios on the artificial reef effect and the exclusion zone effect upon both the fishing industry, and the ecosystem upon which this industry relies.

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Bald, Juan; del Campo, Andrea; Franco, Javier; Galparsoro, Ibon; González, Manuel; Hernández, Carlos; Liria, Pedro; Menchaca, Iratxe; Muxika, Iñigo; Solaun, Oihana and Uriarte, Ainhize
AZTI-Tecnalia/Marine Research Division, Herrera kaia portualdea z/g, 20110 Pasaia (Gipuzkoa), Spain

The Biskay Marine Energy Platform (bimep), environmental impacts and monitoring plan

On 1 June 2009, the General Council on Environmental Quality Assessment of the Ministry of Rural, Marine and Natural Environment of the Spanish Government, in the light of the Environmental Impact Assessment (EIS) of the bimep project undertaken by AZTI-Tecnalia, decided not to submit the project to the whole Environmental Impact Assessment (EIA) process. In any case, the Environmental Impact Statement (EISt) of the Ministry, taking into account the great uncertainties about some predicted environmental impacts, underlined the need to implement the proposed Environmental Monitoring Program (EMP) of the EIS. Consequently, on 29 August 2011, the Basque Entity of Energy (developer of the bimep project) entrusted to AZTI-Tecnalia the development of the pre-operational phase of the EMP. This work presents the methodology and first results of this pre-operational phase on some environmental factors such as, icthiofauna, benthic communities, marine acoustics, mammals, and hydrodynamics.

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Side, Jonathan and Beharie, Robert
International Centre for Island Technology (ICIT), Heriot-Watt University, Stromness, Orkney KW16 3AW, Scotland

Disturbance to the marine environment by underwater sound sources in developing marine renewable energy

The Marine Strategy Framework Directive identifies underwater noise as a descriptor of good environmental status; yet marine energy developments have only recently considered the sources of underwater noise arising from many current installation methodologies. A review of underwater noise sources related to device installations and studies conducted to date are presented

together with other sources of anthropogenic noise in the marine environment. Models used for transmission loss and present thresholds applied to the disturbance of marine mammals are examined, highlighting those of most concern with suggested methods of mitigation.

•

Beharie, Robert and Side, Jonathan
International Centre for Island Technology (ICIT), Heriot-Watt University, Stromness, Orkney KW16 3AW, Scotland

New wave action measurement of the energetic intertidal zone to enable long-term environmental monitoring and predictions of ecological impact due to wave energy convertor arrays

The ecological impact to shoreline species and habitats by the reduction of wave energy in total and seasonal amplitudes due to future wave energy converter (WEC) arrays is not well understood. Current ecological classification systems have no quantitative values in energy levels associated with individual shoreline biological assemblages, mainly by the historical difficulty of using equipment in this harsh environment. A new device and methodology has been developed to provide a reliable long-term measurement of wave action adjacent to WEC developments, enabling predictions of possible impacts to vulnerable species. Results presented highlight seasonal difference in biotopes currently classed as equivalent.

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Bell, Michael; Rouse, Sally; Porter, Joanne; Baston, Susana and Side, Jonathan
International Centre for Island Technology (ICIT), Heriot-Watt University, Stromness, Orkney KW16 3AW, Scotland

Hydrodynamic energy and the distribution of marine organisms: sensitivity to change

Water movements define some of the most important factors determining the functioning of marine ecosystems and the distribution of marine organisms. Hydrodynamic energy is a property of moving water, from which it follows that the extraction of energy for power generation inevitably involves changes in water movements. The potential ecological consequences will depend on the nature, spatial scales and levels of these changes. We use survey data on the incidence of marine organisms to determine the extent to which hydrodynamic energy can be identified as an ecological factor, and consider how sensitive distributions are likely to be to near- and far-field hydrodynamic changes resulting from wave and tidal energy extraction.

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Broudic, Mérin; Cheong, Sei-Him; Willis, Miles; Croft, Nick and Masters, Ian
Low Carbon Research Institute (LCRI Marine), School of Engineering, Swansea University, Singleton Park, Swansea SA2 8PP, Wales

The impact of sediment motion on underwater ambient noise in Ramsey Sound

In May 2011, LCRI Marine led a research Program in Ramsey Sound named the Celtic Odyssey. These underwater recordings carried out during the Neap and Spring shows that sediment transportation and notably shellfish noise have a strong impact on the underwater ambient noise in Ramsey Sound. This physical and particular noise has shown to be strongly dependent on time and location. This sound also occurs at a specific frequency band: 8 kHz to above 22 kHz. The results show that sediment movement influences background noise in Ramsey Sound during high and low water and can reach up to 126 dB re 1mParms/Hz at the 22 kHz 1/3rd Octave band.

•

Carter, Caroline; Wilson, Ben and Burrows, Mike
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Underwater acoustic interactions between emerging tidal-energy technologies and marine mammals

Marine mammals have excellent underwater sensory perception and agility; their primary sense is considered to be hearing. However, existing collision parallels have highlighted that they are not always able to avoid hazards. Very little is known about the underwater acoustic environment in tidal-stream areas, how these devices may acoustically modify the area, or whether the devices will be audible in time for collision avoidance. Our underwater mapping work suggests considerable heterogeneity in underwater ambient noise and that the noise levels are linked to tidal flow and bathymetry. Measured broadband levels range between 81-128 dB re 1µPa. These results will help inform the debate regarding the perceived collision risk to marine mammals.

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Christie, David
Hebridean Marine Energy Future, Lews Castle College, Stornoway HS2 0XY, Scotland

Marine renewable arrays and the wave climate

As the deployment of large scale arrays of marine energy devices in Scottish waters approaches, agencies, developers and stakeholders have expressed a requirement for further research on their effects on the wave climate. Cumulative scattering, absorption and radiation can alter the wave spectrum in and around a development, affecting the available wave resource and local geomorphology. However, array effects are yet to be fully incorporated into current wave modelling software, and the various ad hoc numerical treatments used are yet to be systematically compared with observation, theory, or even each other. We consider the most promising analytical approaches to the problem, and compare the results with those obtained from the numerical codes.

•

Cooper, Bill and Moore; Michelle
ABP Marine Environmental Research, Waterside House, Town Quay, Southampton SO14 2AQ, England

An improved resolution hydrodynamic model of the Pentland Firth and Orkney waters area

ABPmer was commissioned by The Crown Estate to create a new hydrodynamic model of the Pentland Firth and Orkney waters strategic area, at higher resolution and with greater spatial coverage than previous models. This was to inform a review of the area by The Crown Estate, which, given the existing commercial-scale projects and some interest in further schemes, was assessing two key factors: 1) Best use of energy resources, given potential for additional commercial-scale projects in future; and 2) Potential risks to existing projects posed by additional development in the near-term, with respect to resource use and other cumulative impacts. The hydrodynamic model provided an enhanced characterisation of the resources in order to inform this assessment. The model was based on the DHI Mike 21

software, and ABPmer's work covered gathering source model inputs, calibration with observed data sets and creating technical modelling setup files. It also considered representation of wave and tidal stream farms within the model domain.

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Dufaur, Juvenal
Environmental Research Institute, North Highland College UHI, Ormlie Road Thurso, Caithness KW14 7EE, Scotland

The tidal races in the Pentland Firth as an obstacle to the tidal stream energy development The Stroma Skerries: could the interactions between vortices explain the formation of kolk-boils?

The so-called Stroma Skerries is a tidal race occurring in the Inner Sound, the channel between Stroma and the mainland of Scotland. This race has various features: strong currents, a big shear layer, vortices and kolk-boils. These kolk-boils are observable over the majority of the sea surface in the Inner Sound. The kolk-boil phenomena occur in rivers and tidal flows and are due to the interaction of flow with the seabed, in specific flow and roughness conditions. They consist of a "slow" up-welling, a "quadrant 2 event", moving from the seabed all the way up to the surface, preceded and followed by inrushes of "fast" down-wellings "quadrant 4 events". They are often called horse-shoe vortices because of their shape and appearance at the surface of the water. [1]

[1] J. Best, 2005, The fluid dynamics of river dunes: A review and some future research direction, Journal of Geophysical Research, Vol 110, 1-20

•

Easton, Matthew, Woolf, David and Goddijn-Murphy, Lonneke
Environmental Research Institute, North Highland College UHI, Ormlie Road Thurso, Caithness KW14 7EE, Scotland

Using acoustic underway surveys for the spatial calibration of a 2-dimensional hydrodynamic model

High-resolution hydrodynamic models are now being used to assist in the planning and decision-making of tidal-stream energy projects. There exists the potential for significant detrimental, long-term economic and environmental impacts if the resource is not fully appraised prior to development: this includes a priori assumptions on the spatial structure of the flow. Models require selection of input parameters that are not completely known and which can only be measured, at best, in a subset of the model domain. Consequently, models are calibrated and/or validated with respect to measured data at few, often sparsely distributed, locations.
Acoustic underway surveys are frequently used to determine the spatial pattern of tides in oceanic and coastal waters. Here, we use underway data in an effort to improve the spatial representation of tidal currents by a 2-dimensional hydrodynamic model.

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Elliott, Jim; Benjamins, Steven; Carter, Caroline and Wilson, Ben
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

A review of methods for studying marine mammals in tidal stream sites

Few inshore environments present greater difficulties for the study of marine mammal distribution, abundance and habitat use than tidal streams due to the large and variable forces associated with the rapid flow of water. These areas are, however, of increasing interest for tidal energy development, and much more detailed information is required on how marine mammals make use of them. Over the years, a range of different survey and monitoring methods have been developed that could potentially be applied in these environments; each with its own benefits and drawbacks. This presentation's aim is to illustrate a review for their applicability in studying marine mammal distribution, abundance and habitat use in tidal streams, with particular focus on Scotland. It will include examples of specific developments used by the authors in five locations at tidal speeds greater than 4m/s acquiring over 500 hours of operational data.

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Garbe, Jennifer; Beevers, Lindsay and Matthews, Peter
School of the Built Environment, Heriot-Watt University, Edinburgh EH14 4AS, Scotland

Environmental conflicts with offshore renewable energy

Scottish Government plans to achieve 50% of electricity from renewable energy by 2020 have caused controversy surrounding both environmental and land use/marine spatial planning conflicts it may cause. Using Orkney as a case study, a series of interviews were carried out with relevant stakeholders to determine the perceived environmental conflicts this ambitious increase in offshore development will have. The 'Deploy and Monitor' approach is a main catalyst for incorrect perception of environmental issues relating to marine renewables. Following from this, ways toward reducing the conflicts identified are suggested, the main focus being on longer term, more localised management and planning practices.

•

Gay, Marybeth; Perotto-Baldivieso, Humberto and Gill, Andrew
Department of Environmental Science & Technology, Building 56b, Cranfield University, Bedfordshire MK43 0AL, England

Spatial analysis of fish distribution in relation to MRED cable networks

With the extensive deployment (existing and planned) of marine renewable energy electrical cable networks, and evidence of responses by electromagnetic-sensitive species to their emissions (EMF), it is important to understand the likelihood of species encountering cables and EMFs at the appropriate scale. We are using spatial analysis techniques to assess data on the current distribution of EM-sensitive taxa (primarily benthic elasmobranchs) in relation to benthic habitat type, the location of subsea cables and predicted EMF emissions in English waters. The approach used is generic enough to provide a basis on which to analyse spatial distribution of organisms in relation to environmental changes.

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Goddijn-Murphy, Lonneke; Woolf, David and Easton, Matthew
Environmental Research Institute, North Highland College UHI, Ormlie Road Thurso, Caithness KW14 7EE, Scotland

Combining ADCP survey data and low resolution model data for tidal site selection

In support of tidal energy developments in the UK, current profiles were measured in the Inner Sound of the Pentland Firth, Scotland, using a vessel mounted Acoustic Doppler Current Profiler (ADCP). We performed numerous four to six hour surveys to identify promising sites. The tidal changes were rapid, and because underway measurements take time, the apparent

spatial patterns were affected by temporal variation. We describe a method that estimated and corrected this temporal distortion using a hydrodynamic model. A revised model prediction could be calculated from a combination of ADCP and model data.

•

Gormley, Kate; Porter, Joanne; Hull, Angela; Sanderson, Bill and Bell, Mike
School of the Built Environment, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS, Scotland

Mapping marine shellfish resources: knowledge of their ecosystem to underpin the Marine Planning process

It has been acknowledged that there is a lack of research regarding the interactions of shellfish and fish with other important maritime industries, eg renewable energy; despite an understanding of all ecosystems and their functioning being necessary to the implementation of Marine Spatial Planning and a requirement to achieve Good Environmental Status (GES) under the MSFD. This research project aims to contribute to this understanding of the ecosystem; and to ultimately aid the understanding of how dedicated marine renewable energy zones, for example, may influence species distribution. This knowledge will be gained through examination of current shellfish species distribution (in progress); investigation of how important communities of shellfish (Modiolus modiolus) are genetically linked (in progress); how these communities may be influenced by changing climate conditions (future work); and how species distribution modelling can be used to underpin the marine planning system (in progress).

•

Greenwood, Charles
HebMarine Project, Lews Castle College, UHI, Stornoway, Isle of Lewis HS2 0XR, Scotland

A preliminary study on the potential impacts of large scale wave energy converter arrays on wave climates

Future developments off the West coast of Lewis will deploy larger scale wave energy converter (WEC) arrays. Developers and stakeholders are calling for research into the impacts of devices and arrays on the surrounding wave climate. A review of previous literature is applied to assess modelling techniques used when calculating wave energy coefficients and the cumulative array effects of scattering for the proposed development sites. This study uses a simple model, validated with buoy data, to quantify the alteration in the wave climate, compared to baseline values, following the arrays' installation.

•

Guerin, Andrew and Masden, Elizabeth
Environmental Research Institute, North Highland College UHI, Ormlie Road Thurso, Caithness KW14 7EE, Scotland

Marine renewable energy devices and fish aggregation: beneficial habitats or ecological traps?

Fish have a tendency to aggregate around structures in the marine environment, such as oil rigs and offshore wind farms. Such structures may therefore act as refugia from commercial fishing. Wave and tidal energy devices may also aggregate fish, meaning that marine energy farms could act as de facto protected areas. However, there may be negative impacts on fish populations if this aggregation leads to increased mortality, either as a result of device interactions ie collision or entrapment, or increased predation. Here we discuss whether marine renewable energy developments have the potential to act as ecological traps for fish.

•

Guerin, Andrew; Bowyer, Peter and Jackson, Angus
Environmental Research Institute, North Highland College UHI, Ormlie Road, Thurso, Caithness KW14 7EE, Scotland

Marine renewables in the North of Scotland: using hydrodynamic models to explore risks to migratory fish

It is increasingly recognised that marine renewables may impact migratory fish, such as Atlantic salmon (Salmo salar), during their migrations through Scottish coastal waters. To understand this risk, it is not only necessary to evaluate the interactions between fish and devices, but also to determine the probability of fish passing through areas for development. We have focussed on the latter, concentrating on the specific case of migratory fish passing through the Pentland Firth and Orkney waters. We use a hydrodynamic model to estimate the likelihood of passively drifting objects entering areas of risk and explore factors affecting this likelihood.

•

Hastie, Gordon; Sparling, C and Murray, A
SMRU Ltd, New Technology Centre, North Haugh, University of St Andrews, St Andrews, Fife KY16 9SR, Scotland

Sonar as a tool to monitor interactions between marine mammals and tidal turbines; pitfalls and possibilities

Advances in tidal energy have led to concerns about potential impacts on marine mammals. To assess interactions, active sonar is being considered as a means of tracking animals. However, there is the potential that sonar acoustic signals could cause behavioural changes or communication disruption. Results showed that although marine mammals could be detected in tidal environments, acoustic signals could cause overt reactions depending on the sonar used. We discuss that while sonar can be used effectively to track marine mammals, such deployments should be carried out with caution, as sonar can influence behaviour with potential ecological consequences.

•

Hutchison, Zoë; Last, Kim; Hendrick, Vicki; Beveridge, Christine; Wilson, Ben; Burrows, Michael; Jackson, Angus and Davies, Andrew
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Responses of benthic species to burial and suspended sediments as a result of renewable energy developments

Disturbance to the seabed will occur from installation of marine renewable energy devices and associated infrastructure. Extraction of energy will change hydrodynamics, which may also alter movement and dynamics of sediments, but information is limited. We present behavioural responses and levels of mortality observed in some commercially important and biogenic reef building benthic organisms whilst under increased levels of suspended and deposited sediments. Laboratory experiments were conducted in specialist mesocosms and near/farfield sediment simulations were based on field data from the marine aggregates industry. Responses were species-specific and differed to those predicted based on literature alone. This emphasised the need for and value of an experimental approach.

•

McGovern, Dave; Ilic, Suzana; McClelland, Stuart; Folkard, Andrew and Murphy, Brendan
Lancaster Environment Centre, Lancaster University, Farrer Avenue, Lancaster LA1 4YQ, England

Can collars on offshore supporting structures reduce the effect of offshore wind turbines on the sea bed?

Deployment of offshore wind farms is progressing rapidly around the world and in particular around the UK coastal waters. Their deployment and operation has an effect on the environment. The alteration of flow in the presence of the mounting structures results in changes in the sedimentary processes and sea bed changes, all of which can have effect on the benthic habitat. We will present results from an extensive series of laboratory tests that were conducted to examine the detailed tidal flow and turbulence structures and evolution of scour around a monopile. Also we examined the effectiveness of modified piles in reducing the near bed turbulence and resulting scour. This study has informed a complementary numerical model of the scour processes around the pile.

•

Irvine, Ryan and Maher, Micky
Gardline Environmental Ltd, Endeavour House, Admiralty Road, Great Yarmouth NR30 3NG, England

Review of boat-based seabird survey methodologies in the UK

There have been attempts to standardise methodologies for boat-based seabird surveys for offshore renewables industry in the past by Camphuysen et al (2004) and Maclean et al (2009), however there are still several methodologies currently in use in the UK and European waters. This paper aims to compare and evaluate the methodologies used, breaking these down into their component parts and discussing the best protocol for future surveys with an emphasis on data collection suitable for Cumulative Impact Assessments.

•

Jackson, Angus
Environmental Research Institute, North Highland College UHI, Ormlie Road Thurso, Caithness KW14 7EE, Scotland

Scour around moorings for offshore wave devices

Scour is the change in shape of the seabed through time caused by the presence of an object. Moorings for offshore wave devices are likely to be of considerable size. They are likely to be used at locations where water movements near the seabed caused by large waves, can move grains of sediment. We will sample sediment grain-sizes and rates of water flow to help predict expected scour. Scour pits will then be measured using vessel-mounted side-scan sonar and video footage from a remotely operated vehicle. If possible, development of scour will be related to wave climate and stage of the tidal cycle.

•

Jackson, Angus and MacLeod, Adrian
Environmental Research Institute, North Highland College UHI, Ormlie Road Thurso, Caithness KW14 7EE, Scotland

Growth of biofilms and potential implications of developments in marine renewable energy

The mechanisms, magnitudes and extents of ecological impacts from extraction of marine renewable energy are not yet known with any certainty. Most attention has been on species living on the seabed, in the water column or the air. Less attention has been paid to intertidal species. Photosynthetic biofilms are key components of intertidal systems and are likely to be influenced by rates of water flow. Using a combination of field studies with colour-infrared cameras and laboratory experiments with flumes, we demonstrate how amounts of biofilm respond to differences in water flow and make some general predictions about how biofilms may change as the industry develops.

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Jeffcoate, Penelope; Stansby, Peter and Apsley, David
University of Manchester, Pariser Building, Sackville St, Manchester, England

Near-field flow downstream of a barrage: experimental, 2-D and 3-D modelling of turbines

A key problem perceived to arise from tidal barrages is the detrimental environmental impact; however, near-field, 3-D modelling has not been conducted, so accurate flow effects are largely unknown. Flume experiments, with three-component velocity measurements, and 2-D and 3-D CFD modelling were conducted to assess the velocity profiles, surface fluctuations and bed shear stresses downstream of a barrage. An experimental seven-duct barrage with both no turbine representation and turbines with stators was assessed; the turbine and resulting swirl velocity in the CFD modelling were represented by an in-channel blockage and body force respectively. The effectiveness of computational modelling for predicting flow effects of barrages was determined, including the location at which each method of modelling is most appropriate. The predicted changes to the flow velocity and the sediment transport caused by the barrage could, therefore, lead to better predictions of environmental effects.

•

Keir, Alison
Archaeology Department, Orkney College, University of the Highlands and Islands, Kirkwall, Orkney, KW15 1LX Scotland

Coastal change and heritage in Northern Scotland

Coastal change creates a series of challenges for the management of archaeological heritage. The development of industries such as those connected with renewable energy poses an additional threat to archaeological sites and landscapes. This project will research the various values which are placed on the archaeological heritage; and the potential of seamlessly utilising the land-based, coastal and marine heritage resource for the benefit of community, education and tourism. A research aim is to provide information, methods and strategies relating to the coastal historic environment that will be of value to planners and developers in connection with renewable energy and other coastal developments.

•

Kershaw, Peter; Brazinskaite, Raminta; Busch, Malte; Cooper, Philip; Jackson, Emma; Jessop, Mark; Judd, Adrian; Kannen, Andreas; Kenny, Andrew; Le Quesne, Will and Paltriguera Lucille
Cefas, Pakefield Road, Lowestoft NR33 0HT, England

Assessing the social-ecological effects of large-scale offshore windfarm development – challenges and potential solutions

We describe the preliminary findings of an investigation into the possible changes to ecosystem services and benefits as a result of large-scale offshore windfarm development in the southern

North Sea, covering ecological, social and economic impacts. A key underlying question is to what extent such large-scale activity will affect the achievement of Good Environmental Status (under the Marine Strategy Framework Directive) for a range of GES descriptors (eg noise, seafloor integrity and biodiversity). This forms part of the European-funded Knowseas programme (Knowledge-based sustainable management of Europe's seas, www.knowseas.com).

•

Langton, Rebecca; Davies, Ian and Scott, Beth
Institute of Biological and Environmental Sciences, Zoology Building, University of Aberdeen, Tillydrone Avenue, Aberdeen AB24 2TZ, Scotland

Predicting the impacts of marine renewables on seabird populations

There is potential for marine renewable developments to affect individual seabirds through collisions or modifications of habitat, prey distribution and bird behaviour. Any such changes would alter the energetic balances of adult birds and their chicks. An individual based model simulating the behaviour and energetics of family units of seabirds predicts the direction and magnitude of impacts, on adult survival and fledging mass, of different scenarios of renewable deployment and bird responses. The model will be spatially explicit and consider the affect proposed development sites in Scotland could have on the populations of seabirds nesting in the region.

•

Lawrence, John
European Marine Energy Centre (EMEC) Ltd, Old Academy, Back Road, Stromness, Orkney KW16 3AW, Scotland

Numerical modelling at EMEC's wave and tidal test sites

EMEC has commissioned wave and tidal numerical models of Pentland Firth and Orkney waters to inform decision making at EMEC's wave and tidal test sites. The model uses the "MIKE by DHI" technology, implemented on a flexible mesh. This allows good resolution of local complex flows while not overloading available computer resources. Results from the wave model operating in a forecasting mode will be presented, with applications for device installation and operation. Results from tidal resource extraction studies at local sites will be presented. Results from a 10 year wave and tidal hindcast run will be presented, describing relevant hydrodynamic data at the EMEC test sites.

•

Lacey, Claire; Gillespie, Doug and Quick, Nicola
SMRU Ltd, New Technology Centre, North Haugh, St Andrews, Fife, Scotland

Introducing PAMLA: Using novel passive acoustic techniques to study fine scale behaviour of odontocetes relative to marine structures

This study describes the use of a novel technique to investigate porpoise movements, relative to a bridge, in order to assess the potential for barrier effects. This novel application of existing techniques is designed to investigate fine scale movement patterns of individual animals.
A four element hydrophone array was used to calculate sequential bearings to odontocete clicks thus assess fine-scale behaviour. This novel methodological approach was found to work successfully and with further studies could make an invaluable addition to the suite of monitoring and mitigation techniques which are currently available for assessing potential effects of static marine developments.

•

Lees, Kirsty; Grecian, James; Masden, Elizabeth and Jackson, Angus
Environmental Research Institute, North Highland College UHI, Ormlie Road Thurso, Caithness KW14 7EE, Scotland

The impact of wave energy devices on the distributions of seabirds

The UK has great potential for generation of electricity from wave power, with northern Scotland having a particularly large wave resource. The UK also supports internationally important populations of seabirds, but how these will respond to this emerging industry is unclear. Here, we investigate the potential for interactions between wave energy devices and seabirds. By combining several years of observational data on seabird distributions with information on the marine environment and the location of devices, we explore the potential consequences of this type of development for seabirds. Our results will provide better understanding of how seabirds use the marine environment and will be of direct value to the marine energy industry.

•

Lyndon, Alastair
Centre for Marine Biodiversity & Biotechnology, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS, Scotland

Potential positive impacts of marine renewables: fisheries and aquaculture

Environmental impact assessments for marine renewable energy structures have generally concentrated on potential negative effects, for instance in relation to birds. This paper addresses the possibility that such structures might have positive impacts in relation to fisheries ("artificial reef" and "protected area" effects) and aquaculture (enhanced potential for "offshoring" of intensive marine farming). Parallels are drawn with existing offshore structures in an effort to estimate present beneficial effects, and the extent to which these might be maintained or augmented by sympathetic placement of new structures. It is suggested that collateral benefits of marine renewable deployments should be factored into EIAs.

•

Macleod, Adrian; Cook, Elizabeth; Stanley, Michele and Day, John
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Colonisation of offshore marine renewable energy structures: The effects of deployment time, tidal flow and geographical region

The large scale addition of artificial substrate associated with the marine renewable energy industry has the potential to change the recipient habitats greatly. However, little is known about how high flow environments, suitable for many types of energy generation, shape the typical fouling communities resident on devices. A network of 43 navigation buoys throughout Scotland was used to study epibenthic communities typical of artificial substrate in tidal and wave areas proposed for marine energy generation. These communities were found to be complex across a wide range of hydrodynamic conditions. Geographical region, rather than tidal flow or submersion time explained most of the variation in community composition.

Macleod, Adrian; Cook Elizabeth; Stanley, Michele and Day, John
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Life in the renewables fast lane: Do artificial hard substrate communities facilitate the propagation of non-native species in high energy environments?

Marine renewable energy structures may facilitate the spread of non-native species. From a network on marine navigation aids, two common fouling species of amphipod were identified - the native amphipod, Jassa marmorata, and the non-native amphipod, Caprella mutica. A purpose built biological flume was used to study the behaviours of these species with respect to elevated flow rates typical of the environment experienced by marine renewable energy devices. Behavioural responses for J. marmorata, were less sensitive to elevated flow. A number of control and mix species treatments at different flow rates found displacement in the mixed species treatments were not significantly different to control treatments. Work is ongoing to investigate how ambient flow rates, habitat complexity, and species interactions influence non-native species introductions.

•

Masden, Elizabeth; Reeve, Richard; Desholm, Mark; Fox, Anthony; Furness, Robert and Haydon, Daniel
Boyd Orr Centre for Population and Ecosystem Health, Institute of Biodiversity, Animal Health and Comparative Medicine, College of Medical, Veterinary and Life Sciences, University of Glasgow, Glasgow G12 8QQ, Scotland

Assessing the impact of marine wind farms on birds through movement modelling

Advances in technology and engineering, along with EU energy targets, have stimulated rapid growth of the wind power sector. Wind farms contribute to carbon emission reductions but there is a need to ensure that these structures do not adversely impact the populations that interact with them, particularly birds. We developed movement models based on observed avoidance responses of common eider Somateria mollissima to wind farms to predict, and identify potential measures to reduce impacts. Using flight trajectory data collected post-construction of a Danish offshore wind farm, we demonstrate how such models can contribute to the spatial planning of wind farms.

•

McIlvenny, Jason; Woolf, David; Elver-Evans, Joanna; McClatchey, John and Gleizon, Philippe
Environmental Research Institute, North Highland College UHI, Ormlie Road Thurso, Caithness KW14 7EE, Scotland

Wind and wave climatology of the North Atlantic, North Sea and Scottish waters: a review of historical data

An understanding of the availability and reliability of wind and waves as a renewable energy resource requires good data. All offshore activity is sensitive to storm events. Long data series are important to the calculation of robust climatological statistics and an understanding of decadal variability requires data series spanning several decades. New initiatives to measure waves at important development sites need to be complemented by studies of historical sources that provide a long-term perspective. Diverse sources of data are available for the world's oceans. Some shipboard observations date back centuries, but the quantity and quality of available data improved dramatically through the latter half of the twentieth century; firstly through the establishment of a weather ship network - strongest in the North Atlantic – and a strengthening Voluntary Observing Ship (VOS) network. The weather ship network declined from the 1970s but other data sources emerged including satellite data sets, wave buoys, coastal radar and diverse measurements associated with the North Sea oil and gas industry. Numerical weather prediction outputs and wave model outputs are also underpinned by the observational networks. Generally, data is adequate to describe broadly wind and wave statistics offshore of Scotland over the last several decades, but insufficient near shore, for example at most potential tidal or wave energy sites.

•

Miller, Raeanne; Burrows, Michael; Fox, Clive and Inall, Mark
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Population connectivity of offshore renewable energy structures: does larval vertical positioning hold the key?

The deployment of marine renewable energy infrastructure in a range of oceanographic environments creates a diversity of hard habitat types in areas previously devoid of vertical relief. Many organisms colonising these structures possess a pelagic larval stage connecting coastal and renewable energy structure populations. Vertical positioning of these larvae in coastal flow fields may influence transport, dispersal, and connectivity. Using laboratory and field-based observations to parameterise a biophysical model, we explore the influence of vertical positioning on the dispersal of acorn barnacles along the Scottish west coast. Understanding the dispersal processes of fouling species such as barnacles may be important when assessing potential connectivity and biogeographic impacts of expanding renewable energy infrastructure, with further application to the spread of invasive species and the development of marine protected areas.

•

Morrison, James and Greenwood, Charles
HebMarine Project, Lews Castle College UHI, Stornoway, Isle of Lewis HS2 0XR, Scotland

Tools for interpreting and disseminating wave data

As wave energy developers are planning large scale installations off the west coast of the Isle of Lewis, the Hebmarine project deployed three Datawell wave buoys to aid the assessment of local wave resources. This paper reviews the open source software code that we developed, its features, processes and limitations in enabling the dissemination and interpretation of wave buoy data in a real-time automated process. The software developed will be released under an open license to benefit the wave energy community and to aid the development of a free common platform for disseminating and interpreting wave data.

•

Nicholls-Lee, Rachel and Starzmann, R
Fluid Structure Interactions Research Group, Faculty of Engineering and the Environment, University of Southampton, Southampton, SO17 1BJ, England

Adaptive composite blades for noise reduction of wave and tidal energy converters

The acoustic signature of a marine energy converter is a product of the combination of the different sources of noise within each device. In underwater devices the main cause is cavitation, whilst for above ocean devices it is the high operational speed of air-based equipment. Noise can travel long distances underwater, having implications for the navigation and communication methods of certain animals. This paper demonstrates the

reduction of cavitation, hence noise levels, in free stream tidal turbines through application of passively adaptive, composite blades. It is considered that such blades may also be suited to certain above ocean wave energy devices. A further benefit is the increased annual energy capture achievable.

•

O'Brien, Joanne; Berrow, S and Beck, S
Marine Biodiversity Research Group, Galway-Mayo Institute of Technology, Dublin Road, Galway, Ireland.

Using static acoustic monitoring to model cetacean occurrence at fine spatial and temporal scales at a wave energy test site

Sustainable Energy Ireland is developing a full scale, grid-connected, wave-energy test site off Co Mayo, Ireland. As part of the Environmental Impact Assessment of the Atlantic Marine Energy Test Site, the Irish Whale and Dolphin Group have been monitoring cetaceans acoustically using C-PODs. Static Acoustic Monitoring can provide robust datasets for exploring fine-scale occurrence at a site, especially at exposed sites where visual surveys are constrained. We modelled this acoustic dataset to determine how many sites should be monitored, and for what period monitoring should be carried out in order to detect changes once the test site is operational.

•

Oehninger-Storvoll, Karen-Christine; Langhamer, Olivia; Dahlgren, Thomas G and Rosenqvist, Gunilla
Department of Biology, Norwegian University of Science and Technology, Høgskoleringen 5,
N-7491 Trondheim, Norway

Stress influence of offshore wind farms on the reproduction of the viviparous eelpout (Zoarces viviparus)

Disagreements around offshore wind farms considering the stress it may cause on both species and ecosystem made this a hot topic in need of more research. There are concerns about the potential impacts on biodiversity, like habitat loss, killing of sea birds, noise disturbance and increased risk for settling of invasive species. Here we investigate offshore wind farm impact on reproduction in fish. We use pregnant eelpout (Zoarces viviparus) as model species and we compare fish fecundity in a wind park with a control area. Future offshore energy projects can gain from these results since they will give important input to environmental impact assessments and monitoring.

•

Orr, Kyla; Heymans J, and Wilding T
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Predicting the ecosystem effects of harvesting beach-cast seaweed for biofuel: A field-based approach combined with food-web modelling

Global declines in fossil fuels, together with climate change and energy security issues have led to an urgent need to find viable biofuel alternatives to petroleum products. Several sources of seaweed have been proposed as biofuel feedstocks on the West Coast of Scotland. One such major feedstock is beach-cast kelp. Before this seaweed can be removed for biofuel it is necessary to understand its ecological role and predict the impacts of removal. This study combines field-based studies with ecological food-web modeling, using software Ecopath with Ecosim, to predict the ecosystem effects of removing seaweed for biofuel. Results from the field studies indicate that use of beach-cast seaweed for biofuel would be detrimental to the functioning of beach ecosystems.

•

Philpott, Evelyn and Scott, Beth
Zoology, School of Biological Sciences, University of Aberdeen, Tillydrone Ave, Aberdeen AB24 2TZ, Scotland

Interactions between seabirds and oceanographic variables off the Isle of May to inform the potential deployment of a tidal energy device

This project examines the relationship between small scale oceanographic variables and seabird distribution and at sea behaviour in a tidal stream area. This will lead to quantitative definitions of seabird foraging habitat which will allow the predictions of the environmental effects of tidal turbines. Land based seabird surveys were undertaken in the breeding season alongside biophysical data collection. Results indicate seasonal variation in usage between species and low proportions of foraging. Ongoing analysis is targeting the finer temporal scales to test if species use different physical aspects of the daily tidal cycle for foraging. An approach to predicting probability of collision risk has also been developed.

•

Rouse, Sally; Porter, J and Wilding T
Scottish Association for Marine Science, Scottish Marine Institute, Oban PA37 1QA, Scotland

Understanding benthic productivity on artificial structures: maximising the benefits of marine renewable energy devices

Marine renewable energy devices (MRED) constitute artificial reefs and have the capacity to host biological assemblages that deliver ecological services. Understanding the performance of artificial reefs, in terms of productivity, has been identified as one of the pressing research needs in relation to the ecological impacts of offshore renewables. Cuttings of the bioindicator bryozoan Flustra foliacea will be collected and redeployed to the Loch Linnhe Reef, a 6200 tonne multi-modular, purpose-built underwater experimental matrix located off the west coast of Scotland. Variations in the growth of these colonies will be linked to variations in the food supply, as a function of flow interactions and sedimentation on, or within, a single reef unit (eg height on the reef), and between different reef units. Understanding the processes that govern the productivity associated with artificial structures will enable us to both predict the ecological consequences of deploying MRED and inform us how to modify proposed, or existing structures, in order to maximise their benefit to coastal ecosystems. Such an approach will mitigate against the potential loss of access (eg to fishermen) that may occur around offshore renewable devices.

•

Sankaran-Iyer, Abhinaya; Wallace, A; Harrison, G and Couch S
Institute for Energy Systems, School of Engineering, University of Edinburgh, King's Buildings, Mayfield Road, Edinburgh EH9 3JL, Scotland

Scenarios for evaluating tidal current energy potential in the UK

Tidal current energy can provide a predictable and periodic power output that can make a significant contribution in meeting the UK government's renewable energy targets. However, unlike the mechanical availability of the conventional generation,

tidal current energy is dependant on the resource availability and therefore presents a variable output. This paper presents different scenarios that can be developed for tidal current energy in the UK waters. The scenario incorporates constraints specific to first generation tidal technology considered for deployment over the next decade. Time-series data is used for sites identified as high energy and economical to assess the overall spatial and temporal variability of the resource. Temporal variability of the different sites are investigated to better understand tidal phasing of the majority of sites in the UK.

•

Sharman, Paul
ORCA and ORCA Marine, Orkney Research Centre for Archaeology, Orkney College UHI, Kirkwall, Orkney KW15 1LX, Scotland

Marine renewable energy technologies and the [marine] historic environment

The development and deployment of marine renewable technologies has driven rapid changes to national legislation and policy concerning their interaction with and impact on the historic environment. These changes often lag behind the rapidly evolving industry. There are both problems and opportunities presented by regulations and statutory requirements to assess the impact of developments on the historic environment at sea as well as on land. The investigation of heritage, archaeological and cultural considerations is presented, as experienced by a commercial heritage consultancy working with developers in the marine renewables sector in the north of Scotland.

•

Weber Smit, Anke; Carlström, J; Piwowarczyk, J; Holen, S N; Rabaut, M; Stelzenmüller, V; Vega Fernández, T; Wijkmark, N and Backer, H
Norwegian Institute for Water Research (NIVA), Havnegata 9, Pirsenteret, 7462 Trondheim, Norway

Evaluating the Baltic Sea action plan with the help of a newly developed assessment tool (mesma): experiences and lessons learned

This paper provides the first results from the pilot application of a new generic and flexible methodological framework tool (MESMA FW) for monitoring and evaluation of spatially managed marine areas. The MESMA FW addresses the demand for a practical tool for integrating monitoring, evaluation and implementation of Spatially Managed Areas (SMA) in coastal and offshore waters. It has integrated the lessons learned from existing frameworks (Integrated Environmental Assessment and Marine Spatial Planning) and aims to provide guidance for assessing and achieving good environmental status in line with the EU Marine Strategy Framework Directive (MSFD). This paper shows how the MESMA FW has been applied on the international and cross-sectoral Baltic Sea Management Plan.

•

Weber Smit, Anke and Willis, Kathy
Norwegian Institute for Water Research (NIVA), Havnegata 9, Pirsenteret, 7462 Trondheim, Norway

Ecosystem recovery: how long does it take?

A key question for any habitat manager dealing with a degraded landscape is how quickly it will recover. A recent metadata study looking at rates of recovery in over 240 long-term ecological datasets spanning the past 150 years concluded that 30% of the studies showed full recovery. The recovery time depends strongly on ecosystem type and can take over 100 years, if it occurs at all. We argue that in terms of planning, information on recovered versus non-recovered ecosystems is in many ways more insightful than the actual number of recovered ecosystems. Knowledge on why specific types of ecosystems are likely or unlikely to recover from a specific disturbance provides essential information for current and future environmental perturbation management.

•

Wilson, Siân
Black & Veatch, Grosvenor House, 69 London Road, Redhill, Surrey RH1 6EA, England

ETI Tidal Resource Modelling Project

This project will model the UK's tidal energy resources to help improve understanding of the possible interactions between the various tidal energy extraction systems expected to be deployed between now and 2050.
It will develop models of the whole UK Continental Shelf that will be used to investigate how energy extraction at one site may affect the energy available elsewhere. A wide range of possible future tidal current and tidal range sites, with differing technology possibilities, will be represented in the models.

The project will identify how the interactions between different sites around the UK combine to form overall flow effects, and what constraints these interactions will place on the design, development and location of future systems.

At the end of the project the models will be made available to the wider marine industry to help inform future plans and strategies through a service provided by HR Wallingford.

•

General Information - Conference

EIMR Conference Office
The area opposite the café - The Noust - will be used as a 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
The name badge issued to delegates on registration serves as an admission pass to all sessions and social events. Delegates are asked to ensure they wear their lanyards at all times.

Breakfast Vouchers at the Pickaquoy Centre Café
In order to estimate our catering needs, delegates have been asked to pre-book vouchers for continental breakfasts – (there is no charge for this). The café will open at 8am and there may be a limited number available from the conference office.

Business Centre
Photocopying and faxing can be done at the Pickaquoy Centre reception.

Car Parking
Delegates can use the free car park at the Pickaquoy Centre or follow signs to Orkney Rugby Club on Muddisdale Road which is two minutes walk away.

Cloakroom Facilities
There are no secure cloakroom facilities at the Pickaquoy Centre. Please ensure you keep any valuable belongings with you. Toilet facilities are located on the ground and first floors.

Conference Secretariat
Agenda Events: Jim Brown: 07974 804037; Iona MacDonald: 07515 145350; Ruth Whitfield: 07510 319803

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All best endeavours will be made to present the programme as printed. However, EIMR and its partners reserve the right to alter or cancel without prior notice, any arrangements, timetables plans or other times relating directly or indirectly to the conference for any cause beyond its reasonable control. EIMR and its partners are not liable for any such loss or inconvenience caused as a result of such cancellation. Delegates are advised to take out their own travel insurance and to extend their policy to cover personal possessions as the conference does not cover individuals against cancellation of bookings or theft or damage to belongings. Transport run by third parties may be subject to cancellation.

Dress Code
The dress code during the conference sessions is casual and comfortable. For the conference dinner at Harray Hall on Tuesday evening it is casual but smart, while the ceilidh on Wednesday is informal.

Internet Services
Wireless broadband is available at the Pickaquoy Centre; the strongest signal is around the café area. It is also available in most hotels, Kirkwall Library, 44 Junction Road; Buster Diner, Mounthoolie Place and Support Training, 2 West Tankerness Lane opposite the Job Centre on Junction Road.

Lost Property
Enquiries regarding items lost or found can be made at the reception desk on the ground floor of the Pickaquoy Centre. 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 Pickaquoy Centre.

Medical Information
There are dedicated first aid trained staff within the Pickaquoy Centre 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: 51 Albert St., Kirkwall 01856 872097
Sutherlands Pharmacy: 43 Victoria St., Kirkwall 01856 873240

Mobile Phones
Please switch off mobile phones when delegates are in session.

Posters
The Poster Exhibition will be held in the Grainayre Room. Detailed instructions have been sent to each author, but they should be assembled between 08.00-08.30 and dismantled at the end of each day. EIMR and its partners cannot be responsible for posters that are not removed on time.

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General Information - Scotland

Electricity
The voltage in the UK is 220-240V.

Scottish Bank Notes
Scottish banks issue their own bank notes for all denominations which differ from English notes, but they are of the same value and generally accepted elsewhere in the UK. English 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.

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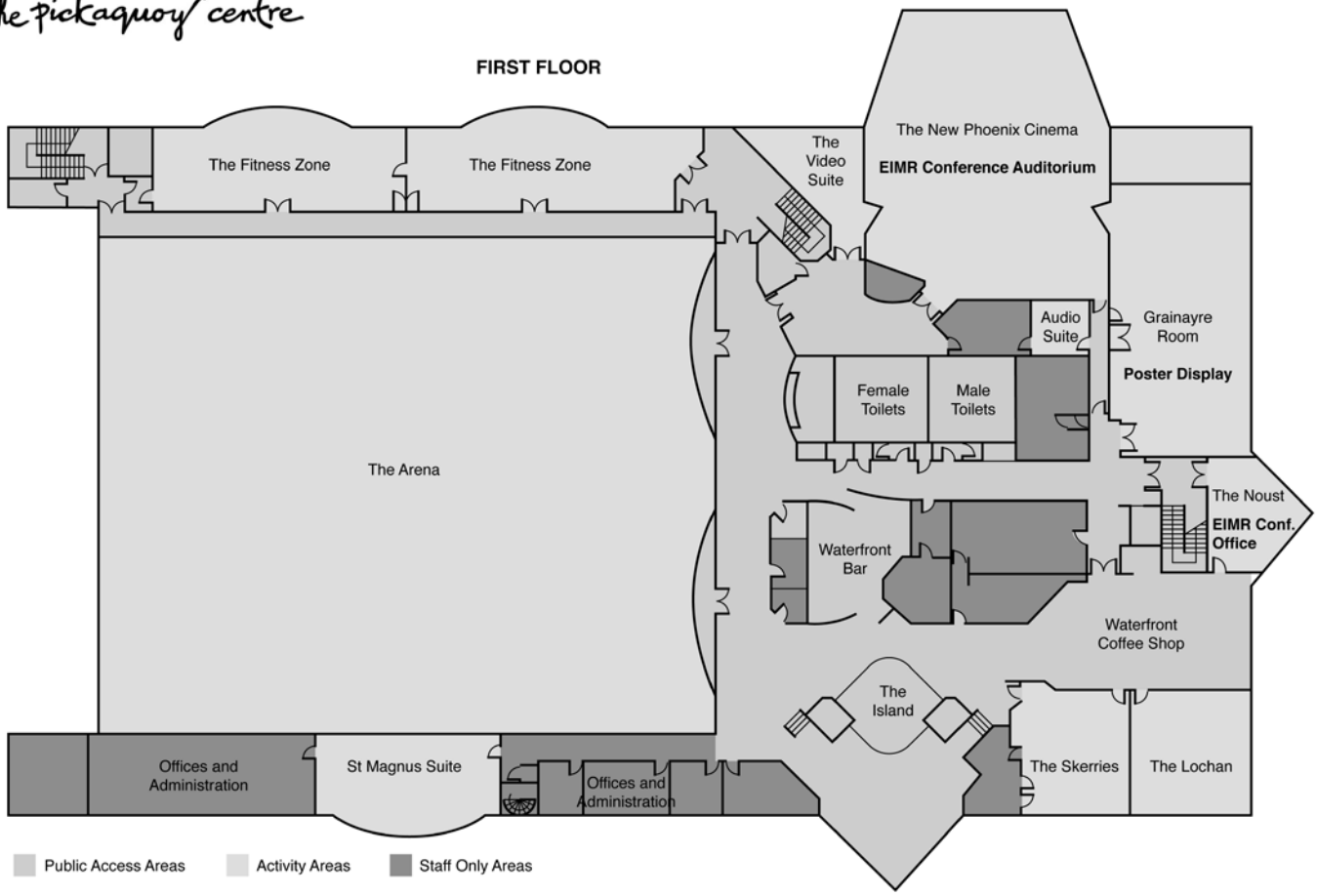

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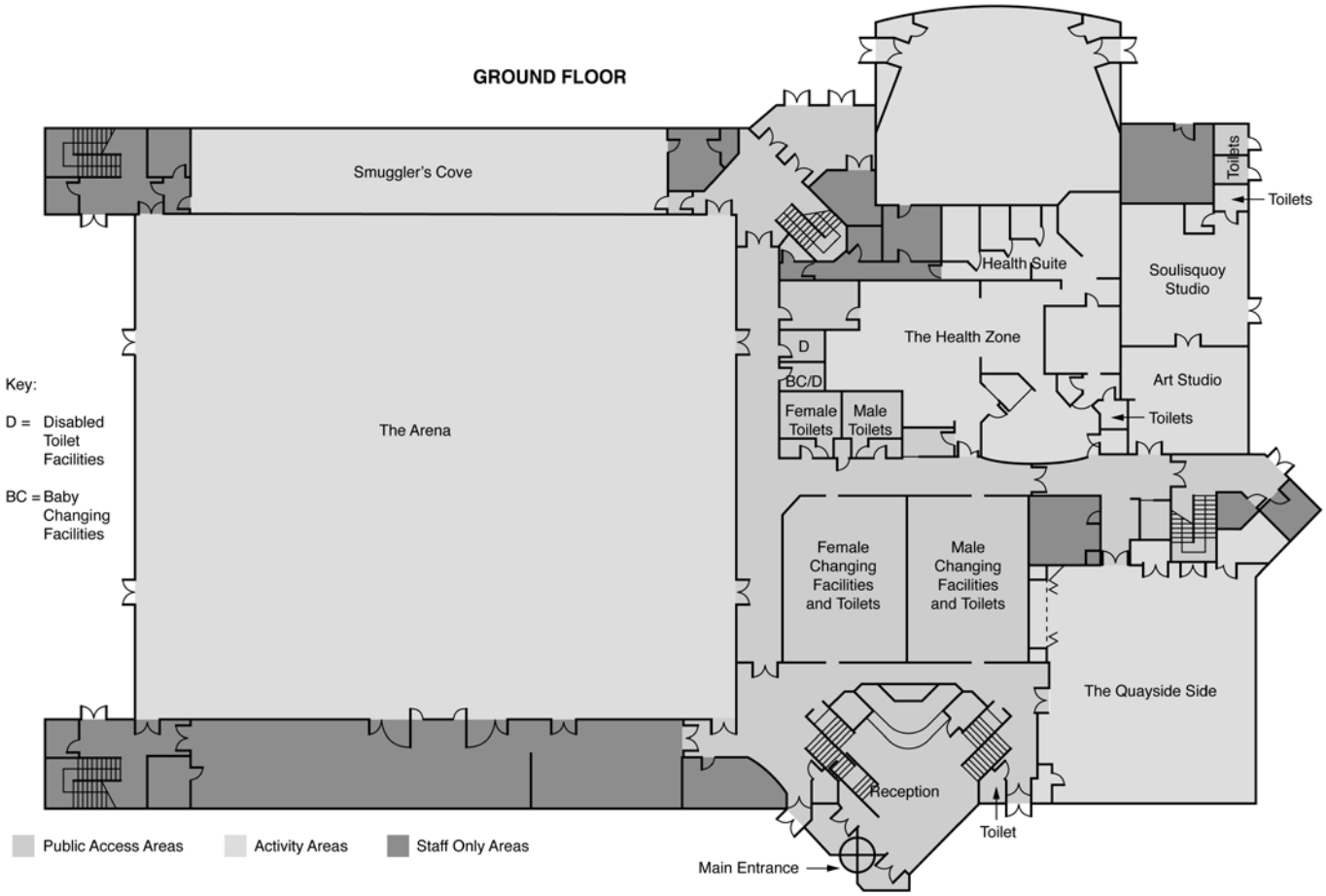

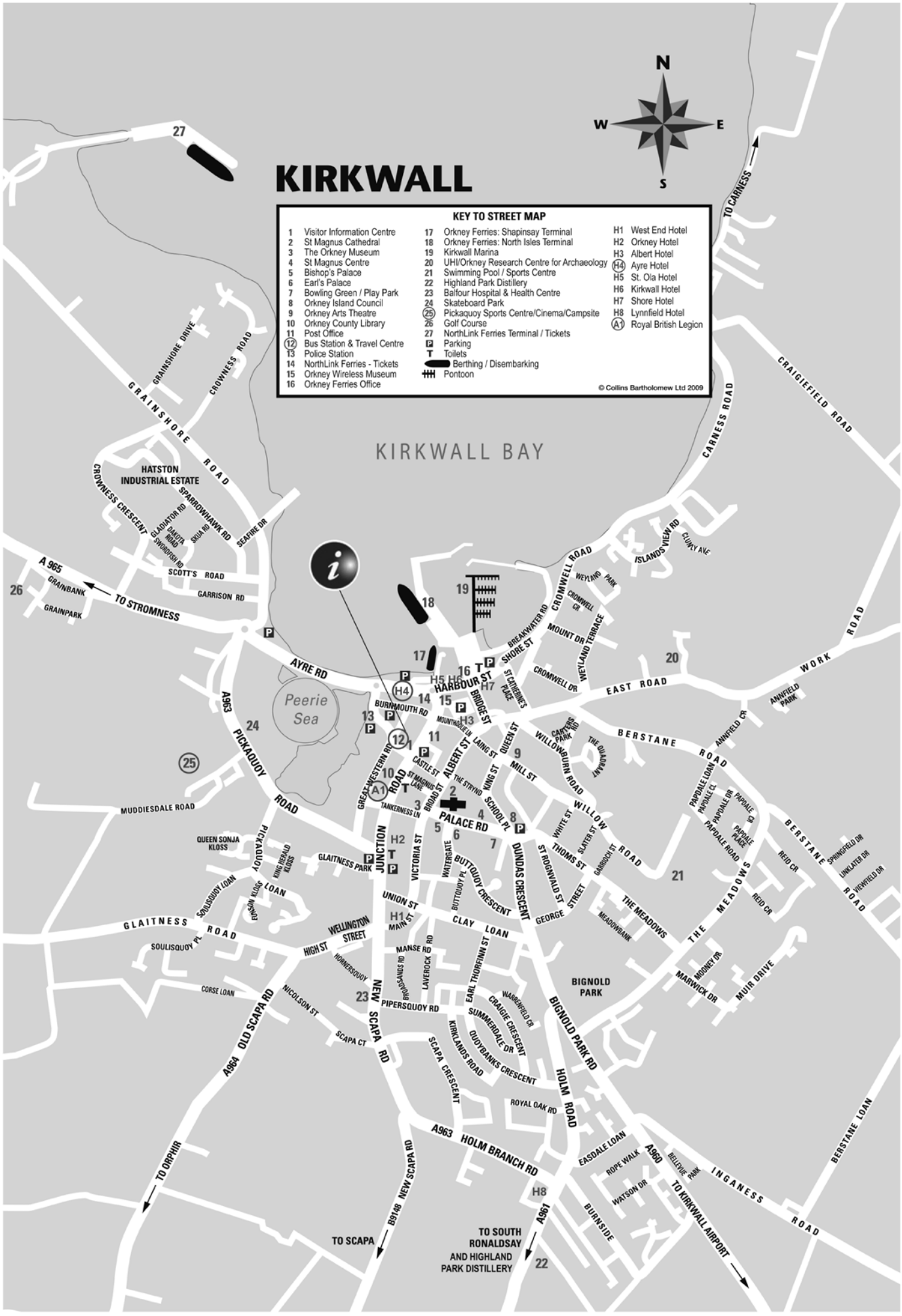

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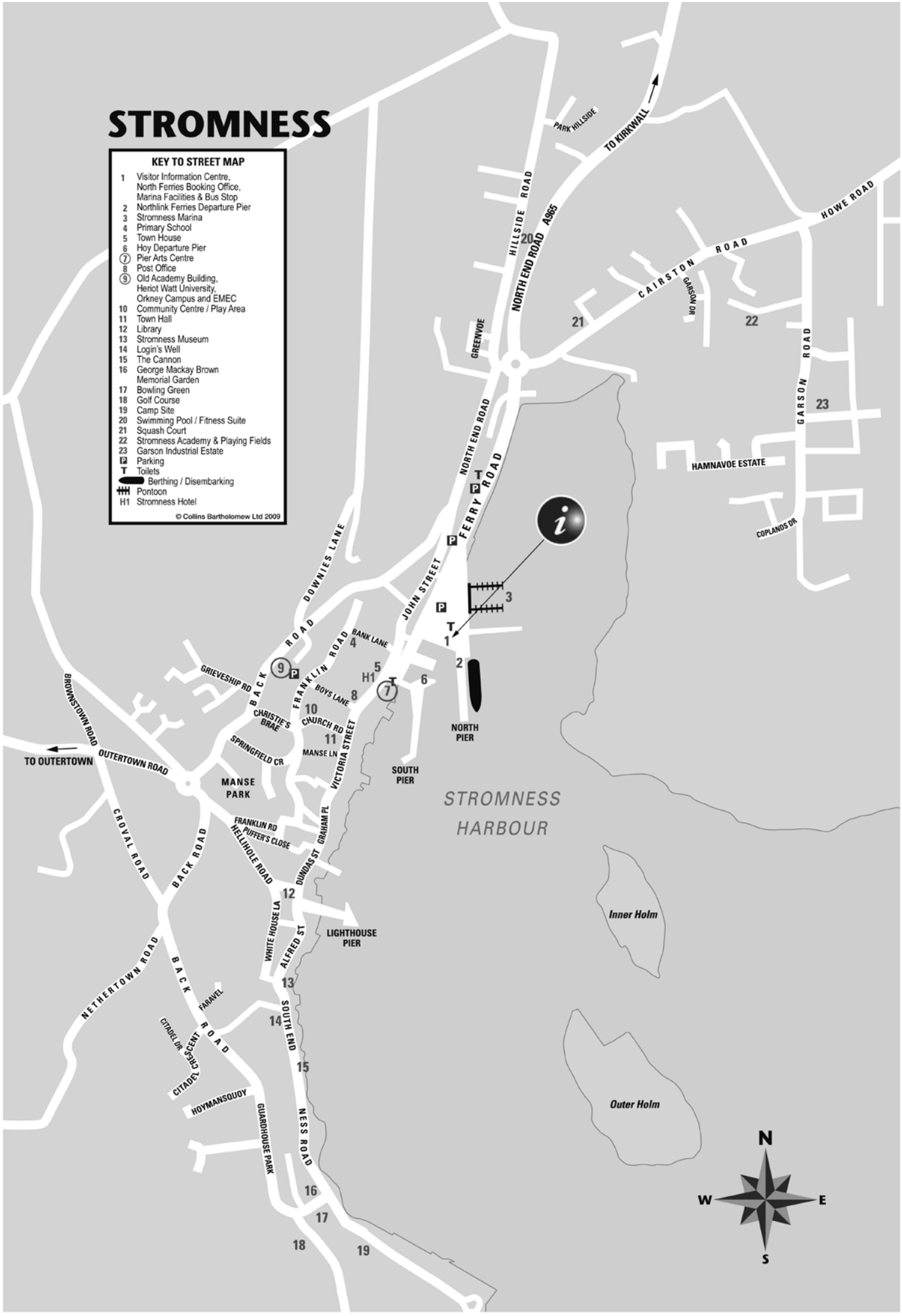

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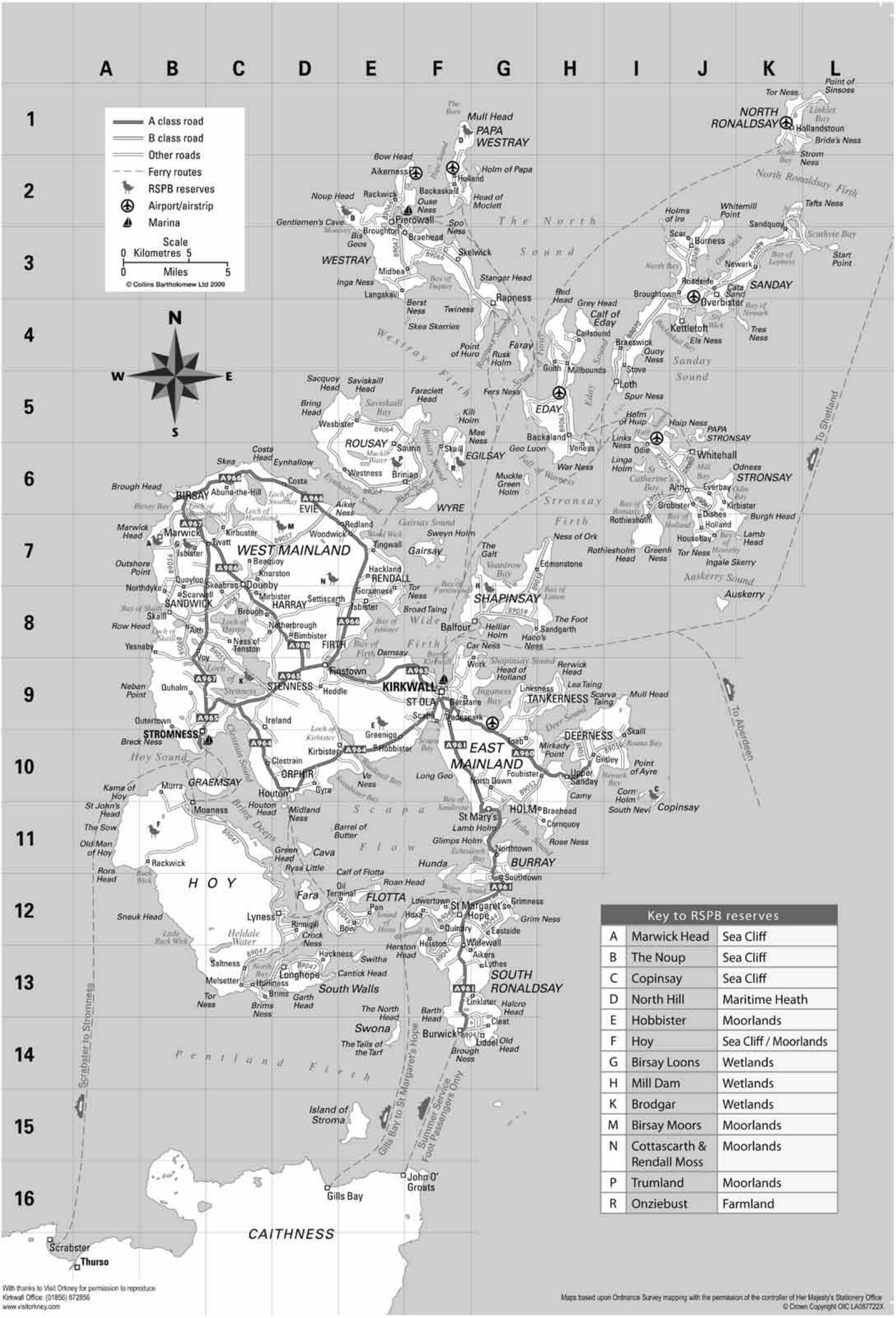

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D	North Hill	Maritime Heath
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F	Hoy	Sea Cliff / Moorlands
G	Birsay Loons	Wetlands
H	Mill Dam	Wetlands
K	Brodgar	Wetlands
M	Birsay Moors	Moorlands
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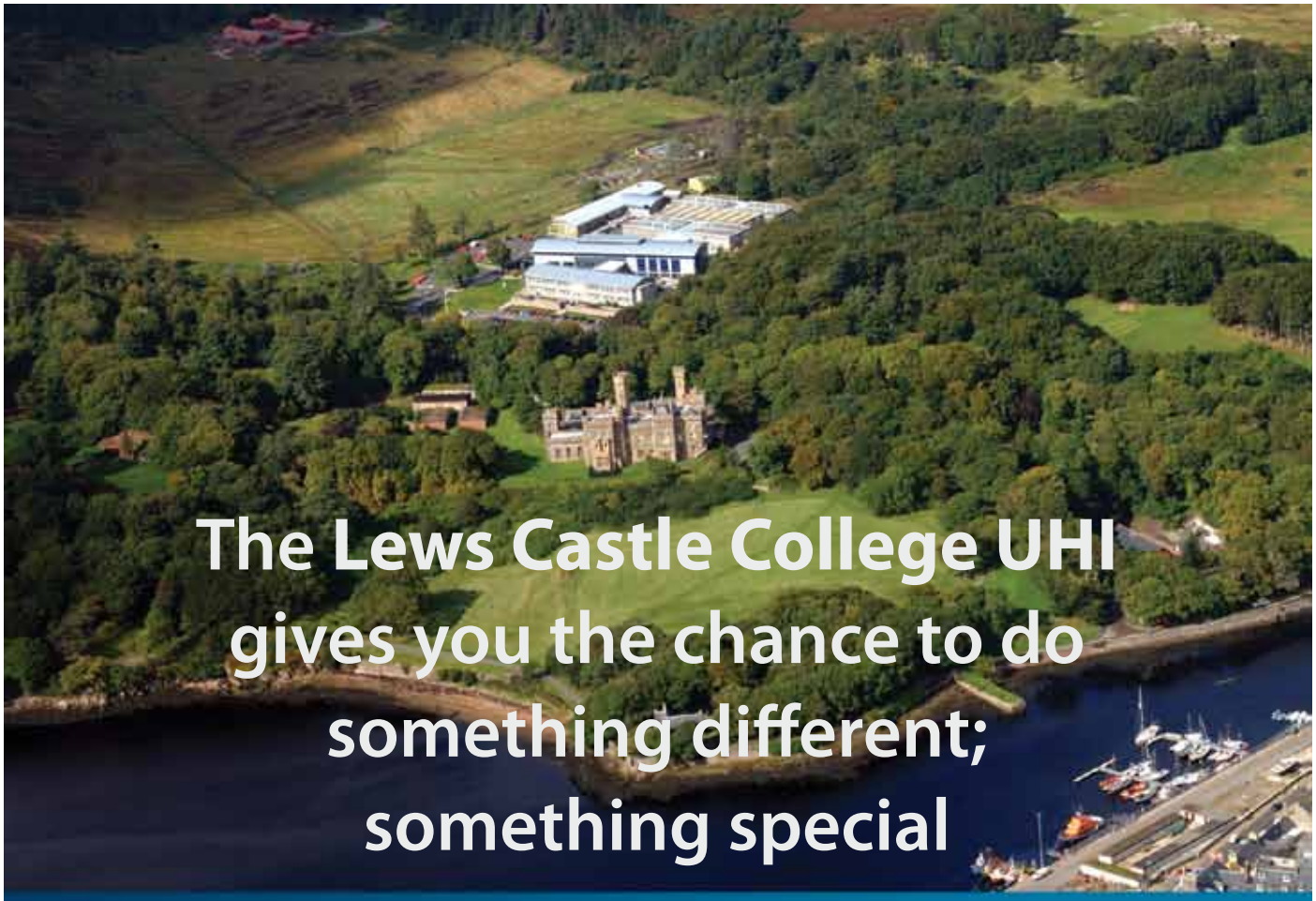

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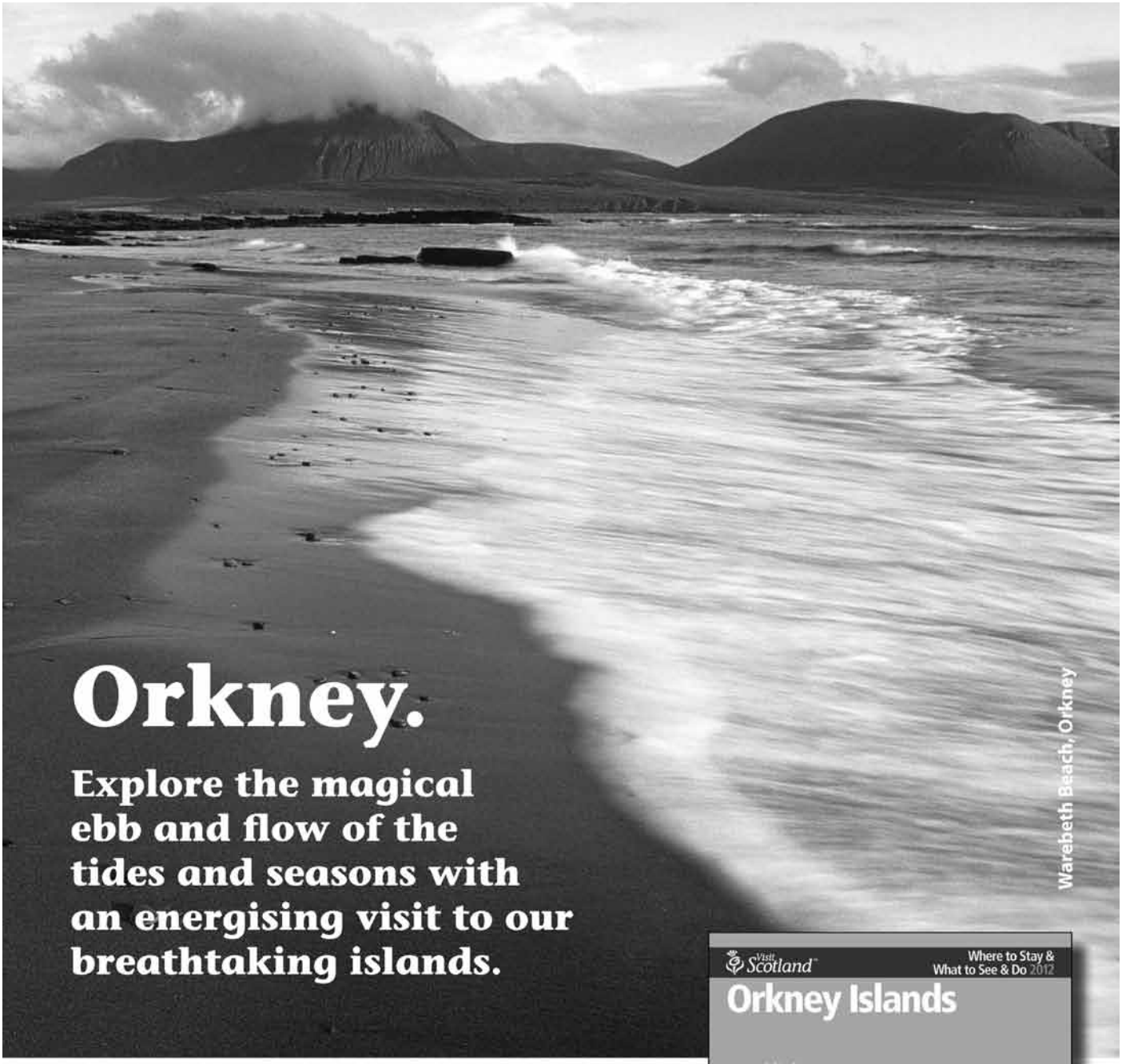

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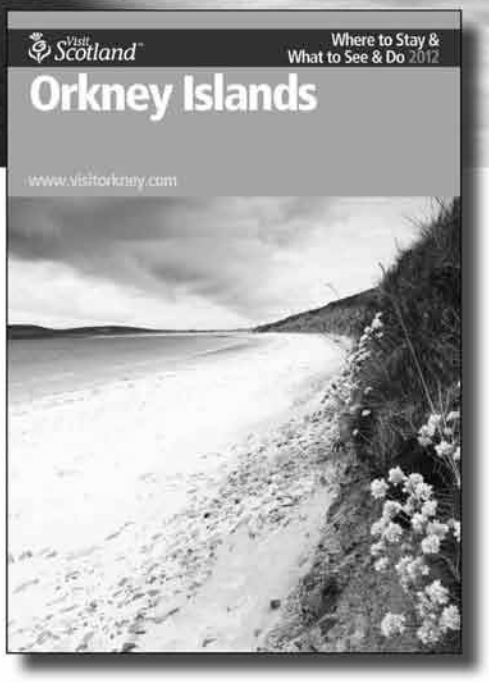

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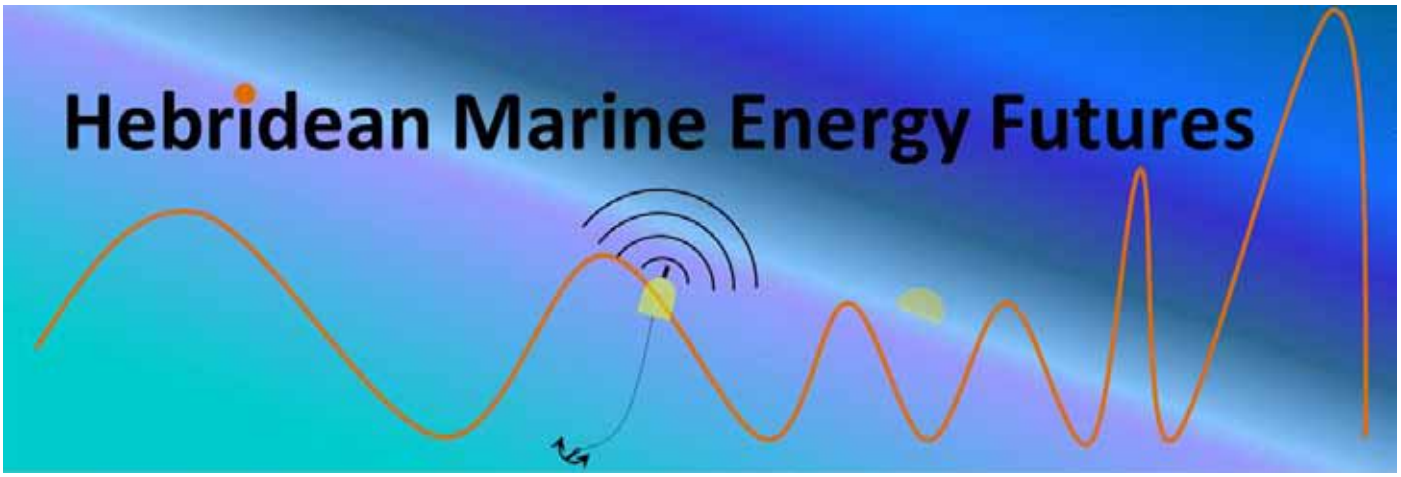
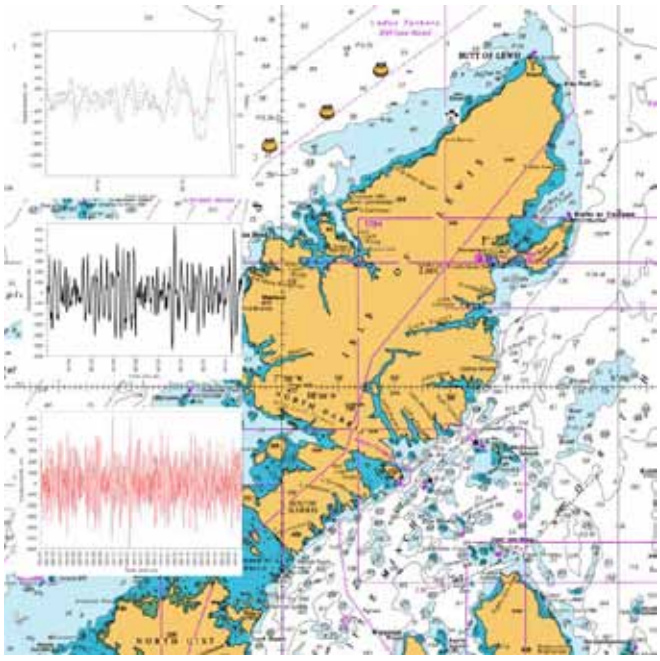


Wave Power Resource Assessments, Data Acquisition, Electrical Grid Integration of Marine Renewables, Environmental Interaction of Wave Energy Converters

The Hebridean Marine Energy Futures project is a knowledge exchange activity driven by industry demands with the aim to accelerate the development of wave energy conversion sites in the Outer Hebrides and North of Scotland.

Led by Lews Castle College of the University of the Highlands and Islands (UHI) and primarily based in Stornoway, the project is supported by key wave energy developers such as Aquamarine Power as lead partner, Voith Hydro Wavegen, and Pelamis Wave Power, all of which are presently developing sites to the west of the Isle of Lewis (40MW, 30MW and 10MW respectively). Additional support is provided by utility companies E.ON and Scottish Power Renewables whose key interest is currently in the development of sites in Pentland Firth and Orkney Waters.



With academic support from the universities of Edinburgh, Strathclyde and Heriot Watt and UHI partners SAMS and ERI the project is well equipped to undertake activities and deliver results as are required by the burgeoning wave power sector. The project has received financial support from the Scottish Funding Council, Highlands and Islands Enterprise and industry and is scheduled to run for three years from 2011 – 2014.

Activities are focussed on four technical packages with one additional knowledge exchange and management work stream.

Scottish Funding Council
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Workstream1: Numerical Wave Resource Modelling

A high resolution GIS wave power resource map for the north-west of the Isle of Lewis is developed during the first stage of this work stream. Led by University of Edinburgh and the resource modelling team of Aquamarine Power, researchers from Lews Castle College evaluate the wave resource for the Outer Hebrides and the north of Scotland by using commercial hydrodynamical modelling software (DHI Mike21). Open source software will be used at a later stage of this activity and outputs will be compared against each other – and against the directional wave data which is currently gathered in the second work stream.

WS2: Data Acquisition and Site Surveying

Three directional wave buoys were deployed in autumn 2011 by Lews Castle College at the locations shown in the map. The buoys, one supplied to the project by Voith Hydro Wavegen, are fitted out with a radio link so live data can be received by the shore station. Early 2012 the buoys were supplemented by an ADCP mounted to the seabed in a bespoke modular frame. Data is retrieved at quarterly intervals and is used to calibrate the numerical model outputs from stream 1. The combined readings of the sensor network will also give valuable information on the wave shoaling processes in the area. Buoy data is available at: http://www.hebmarine.com/wave/combinedResults.html

WS3: Electrical Grid Integration of Marine Renewables

Led by University of Strathclyde the correlation of wave power and onshore wind energy is investigated in this work package. Wind and wave data is fed into a Hebridean grid model and various power flow scenarios are assessed based on demand curves under different supply arrangements. Results of this study will enable utilities and renewable energy developers to make informed decisions on the constraints and modernisation requirements of the existing grid infrastructure.

WS4: Environmental Interaction of Wave Energy Converters

Access to two Pelamis P2 devices currently deployed at the EMEC test site west of Orkney has been made available by E.ON and Scottish Power Renewables. Investigations on the impact of wave energy devices on Birds and Benthos are carried out by the ERI. New sensor deployment methodologies and technology is used by SAMS to assess the interaction between multiple P2 devices and marine mammals. A team from the Orcadian ICIT campus of the Heriot Watt University is carrying out an assessment of noise propagation and anticipated consequences originating from the deployment of arrays of wave energy converters.

WS5: Knowledge Exchange and Project Management

Co-ordinated by Lews Castle College the findings of the project will be adequately disseminated through this work stream.

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Contact: HebMarine, UHI-Lews Castle College, Stornoway, Isle of Lewis, Scotland, GB-HS2 0XR, Tel. 0044 (0) 1851 770 325, e-mail: arne.vogler@lews.uhi.ac.uk

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Knowledge Exchange

In order to increase the impact of science on society, the economy and the environment, the research councils' first introduced the concept of 'knowledge exchange' around 5 years ago – yet, some scientists are still uncertain what the term really means! In fact for many, developing an 'impact plan' is an inconvenient appendage to research proposals causing them a last minute headache before a deadline! Of course KE can be interpreted literally – as 'exchange-of-knowledge' – but of what and by whom and why? As our team are now discovering, this innocuous little term seriously understates its own real aspirations!

Marine Renewable Energy KE programme

When the Natural Environment Research Council (NERC) decided to support a knowledge exchange programme for Marine Renewable Energy it effectively issued a challenge to potential end users of NERC science – 'if you see value in our science - then come and get it; here is a mechanism for you to exploit it'. Consequently our programme has resources to facilitate the direct application and adaptation of NERC science – whether research products or services, knowledge or scientific expertise for the whole range of potential end users. We can also help to facilitate the development of novel technology and tools to support the sector by providing inputs to new funding calls, building new partnerships for collaborative R&D and using these to respond to new market opportunities.

In order to make sure that we prioritise KE activity appropriately in the Marine Renewable Energy programme we have consulted with a wide range of end users and developed a summary of 'knowledge needs and issues'– this will appear on our portal and be regularly updated, so that it is easy to see how understanding from different end user perspectives of the interaction between the environment and technology deployment is progressing.

Find out more:

- Visit the portal - **https://nerc.ac.uk/keservices/marine**
- Contact the team - **mrekep@nerc.ac.uk**

Marine Renewable Energy
Knowledge Exchange Programme

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