**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.

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

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

U.S. 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 U.S. based work, along with international research efforts, to allow for meta-analyses of data from multiple research efforts.

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.

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.

Hastie, Gordon; Booth, Cormac; Maginnis,Andy and Gillespie, Doug

Sea Mammal Research Unit Ltd, University of St. Andrews New Technology Centre, North Haugh,

St. Andrews, Fife KY16 9SR, Scotland

**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.

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.

Copping, Andrea

Pacific Northwest National Laboratory, 1100 Dexter Ave N, Suite 400, Seattle WA 98109, USA

**Getting Devices in the Water - Understanding Environmental Effects of Marine Energy Development in the US**

The U.S. is deploying initial tidal and wave energy conversion devices, with leadership from the U.S. 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.

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* (e.g. 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 (e.g. 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 (e.g. 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.

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.

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.

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.

Woolf, David; Bowyer, Peter and Easton, Matthew

Environmental Research Institute, CfEE Building, UHI-NHC, Ormlie Road, Thurso KW14 7EE, Scotland

**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.

Fortune, Frank

Royal Haskoning UK, 10 Bernard Street, 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.

Fujii, Toyonobu

Oceanlab, University of Aberdeen, Main Street, Newburgh, Aberdeenshire AB41 6AA, Scotland

**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.

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.

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.

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.

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 10 m grid. This high spatial resolution allows the detail of resource quantification necessary to enable engineering decisions be made regarding the exploitation of tidal energy. Secondly, most assessments regarding tidal energy potential is based on total current vectors: in this research at 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 and compared. The paper concludes with main findings and recommendations.

**(WITHDRAWN)**

Hildenbrand, Kaety; Gladics, Amanda and Eder, Robert

OSU Lincoln County Extension, 29 SE 2nd Street, Newport OR 97365, USA

**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.

Benson,Thomas; Jones, Diane and Lepper, Paul

HR Wallingford Ltd, Howbery Park, Wallingford OX10 8BA, England

**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.

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, i.e. 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.

Langhamer, Olivia and Rosenqvist, Gunilla

Department of Biology, Norwegian University of Science and Technology, Høgskoleringen 5, N‐7491 Trondheim, Norway

**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.

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.

Marengo, iLaria

Biological and Environmental Sciences, School of Natural Sciences, University of Stirling, Stirling FK9 4LA, Scotland

**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 was 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.

McLay, Anne; Bruce, David; Watret, Robert; Barret, Elisa and Goldschmidt, Pippa

Marine Scotland Science, Marine Laboratory, 375 Victoria Road, Aberdeen AB11 9DB, Scotland

**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.

McNaughton, James; Afgan, Imran; Apsley, David; Stansby, Peter and Stallard, Tim

George Begg Building, The University of Manchester,Sackville Street, Manchester, England

M1 3BB

**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 turbulent flow is examined in the near-field wake as well as at the blades and tip vortices. The k-omega SST Reynolds Averaged Navier Stokes Model is used as well as demonstrating the gain in precision brought by Large Eddy Simulations using the Synthetic Eddy Method at the inflow boundary.

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 behavior, 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.

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.

Pollard, Edward and Littlewood, Mark

Marine Archaeology, Orkney Research Centre for Archaeology (ORCA), Orkney College UHI, Kirkwall, Orkney KW15 1LX, Scotland

**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.

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 causes 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.

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

Scottish Oceans Institute, SMRU Ltd, New Technology Centre, North Haugh, St Andrews, Fife KY16 9SR, Scotland

**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.

Zydlewski, Gayle; McCleave, Jim; Staines, Garrett; Viehman, Haley and Vieser, Jeff

University of Maine, School of Marine Sciences, 5741 Libby Hall, Orono ME 04469, USA

**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, U.S.A. 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.

**REVISED**

Stokes, C; Beaumont, E; Russell, P; Conley, D and Greaves, D

Buckland House, Drake Circus, Plymouth, Devon PL4 8AA, England

**Anticipated Coastal Impacts: What water users think of marine renewables and why**

This presentation explores the physical coastal impacts that are anticipated by the coastal water-user community in the lee of the Wave Hub facility (Cornwall, UK). In depth, semi-structured interviews were 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. The interviews focussed on anticipated impacts to inshore wave conditions, beach sedimentation, rip current formation and beach safety. A range of anticipated impact levels were observed and the results indicate that participants constructed their anticipations by weighing their perceptions of the technology against their perceptions of the coastal environment. A conceptual model is presented, which allows the level of anticipated coastal impact to be predicted, by categorising technologies and coastal environments in terms of their perceived properties. The model indicates that marine renewables deployments which are perceived to be large (small) scale, close to (far from) shore, wide (narrow), stationary (moving), or extracting high (low) percentages of wave energy are more likely to invoke anticipations of significant or severe (insignificant or no) coastal impacts. The implications for future marine renewables deployments are discussed.

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.

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.

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.

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.

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.

Wade, Helen; Masden, Elizabeth; Jackson, Angus; Furness,Robert and Bouten, Willem

Environmental Research Institute, University of the Highlands and Islands, 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.

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.

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.

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.

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 (40 m) 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.

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.