Multi-platform studies of the MeyGen tidal energy site – using UAVs to measure animal distributions and hydrodynamic features

Benjamin Williamson[1,2], Shaun Fraser[3], Jason McIlvenny[1], Ana Couto[2], James Chapman[2], Helen Wade[4], Julien Martin[2], Jared Wilson[5], Tom Evans[5], David Hunter[2], Sarah Fenn[2], Ross Culloch[5], Adrian Tait[5], Marianna Chimienti[6], Ewan Edwards[5], Laura Williamson[2], Ian Davies[5], and Beth Scott[2]

[1] *Environmental Research Institute, University of the Highlands and Islands – benjamin.williamson@uhi.ac.uk*
[2] *School of Biological Sciences, University of Aberdeen*
[3] *NAFC Marine Centre, University of the Highlands and Islands*
[4] *Scottish Natural Heritage*
[5] *Marine Scotland Science*
[6] *Aarhus University*

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Top predators are known to forage in tidal stream sites [1]. High flow speeds, upwelling or shear may enhance prey availability and foraging efficiency [2]. We need to measure the distribution of animals to understand potential animal interactions with tidal stream energy developments.

Our studies have focused on the MeyGen tidal energy site in the Pentland Firth, UK. The FLOWBEC seabed platform [3] was deployed in 2015 to collect baseline measurements on hydrodynamics *(ADCP & ADV)*, prey and turbulence *(EK60)* [4], and predator-prey interactions *(multibeam sonar)*.

Temporal persistence of the FLOWBEC platform was complemented with spatial coverage from vessel surveys using *MRV Scotia* in 2016 as a baseline before turbines were installed, and in 2018 with turbines installed. Vessel surveys used a similar sensor package to FLOWBEC, to measure hydrodynamics and turbine wake effects *(ADCP)*, prey and turbulence *(EK60)*, and surface detections of animals *(observers and cameras)*.

In 2016 and 2018, we also demonstrated the use of Unmanned Aerial Vehicles *(UAVs)* for environmental monitoring of tidal energy sites. UAV imagery allows concurrent measurement of animal distributions and fine-scale hydrodynamic surface characteristics to investigate the behavioural associations between top-predator foraging and hydrodynamic features. UAVs also overcome the cost and therefore infrequency of vessel or aeroplane surveys which limit understanding of seasonal trends, and overcome the limitations of vantage point surveys which suffer from reduced detectability with increasing distance from the observer.

UAV flights ahead of the vessel ground-truthed UAV observations of animals against observers, and ground-truthed UAV hydrodynamic measurements against hydroacoustics from the vessel. Surveys were against the tide to avoid double-counting and validated to ensure no effect of the UAV on animal behaviour.

Ongoing work is developing algorithms for automated detection of animals and hydrodynamic features from UAV datasets. We will present a preliminary overview of the multi-platform datasets investigating changes arising since installation of the turbines, and proof of concept results from using UAVs to survey tidal stream energy sites.

Acknowledgements

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Understanding the effects of electromagnetic field (EMF) emissions from offshore windfarms on commercially important crustaceans

Kevin Scott[1,2], Petra Harsanyi[1], Alastair R. Lyndon[2]

[1] *St Abbs Marine Station, St Abbs,, Berwickshire, United Kingdom TD14 5PW - kevin.scott@marinestation.co.uk*
[2] *Heriot Watt University, Riccarton, Edinburgh, United Kingdom EH14 4AS*

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Preferred presentation medium (delete as appropriate): (i) oral or (ii) ~~e-poster format~~.

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With the rapid increase in Offshore Renewable Energy Devices (OREDs) worldwide, there is a clear need for the implications to be properly assessed with regards to current ecological status and potential future consequences. Proposed sites and developments are based on current knowledge and assessments of the local environment, despite relatively little being known about the ecological effects of such developments on marine benthic organisms. Electromagnetic fields (EMF) originate from both anthropogenic (telecommunication cables, power cables, OREDs) and natural (Earth's natural geomagnetic field) sources. It has been shown that industry-standard AC (Alternating Current) sub-sea cables can be effectively insulated to prevent electric field (E-field) emissions but not magnetic field (B-field) emissions[1]. Several decapod crustaceans are known to be magneto sensitive, yet information available on the effects of electromagnetic fields emitted from OREDs is scarce[2]. The effects of simulated EMF, emitted from sub-sea power cables, on the commercially important brown crab (*Cancer pagurus*) were assessed. Stress related parameters were measured (L-Lactate, D-Glucose, Haemocyanin and respiration rate) along with behavioural and response parameters (antennular flicking, activity level, attraction/avoidance, shelter preference and time spent resting/roaming) during 24-hour periods. Exposure to EMF had no effect on Haemocyanin concentrations, respiration rate, activity level or antennular flicking rate. EMF exposure significantly disrupted haemolymph L-Lactate and D-Glucose natural circadian rhythms. Crabs showed a clear attraction to EMF exposed shelter (69%) compared to control shelter (9%) and significantly reduced their time spent roaming by 21%. Consequently, EMF emitted from Offshore Renewable Energy Devices (OREDs) will likely affect edible crabs both behaviourally and physiologically, suggesting that the impact of EMF on crustaceans must be considered when planning OREDs.

Follow on studies have recently been completed on the commercially and ecologically important species, European lobster (*Homarus gammarus*). Preliminary results show that similar impacts can be expected on the haemolymph circadian rhythm of both L-Lactate and D-Glucose, with a similar behavioural attraction a possibility. In addition to this study, the effects of EMF on egg development, hatching success rate, larval deformities and larval fitness of both *Cancer pagurus* and *Homarus gammarus* were conducted. Preliminary results suggest that EMF exposure results in an increase in larval deformities and a decrease in larval fitness. This suggests that exposure to EMF emissions during brooding could have negative impacts on future stocks.

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Area being submitted to: 1) General science session

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Using active-acoustic data in ecosystem model assessment

Roland Proud[1*], Martin J. Cox[2], Rudy Kloser[3], Nils Olav Handegard[4], & Andrew S. Brierley[1]

[1]*Pelagic Ecology Research Group, Scottish Oceans Institute, Gatty Marine Laboratory, University of St Andrews, UK,*
[2]*Australian Antarctic Division, Kingston, Tasmania, Australia,*
[3]*CSIRO Oceans and Atmosphere Flagship, GPO Box 1538, Hobart, TAS 7001, Australia,*
[4]*Institute of Marine Research, PO Box 1870, Nordnes, 5817 Bergen, Norway.*

Corresponding author email: rp43@st-andrews.ac.uk

Ecosystem models are important tools for open-ocean fisheries and conservation management and can provide predictions of future change under various fishing and climate-change scenarios, but accurate prediction requires realistic representation of biological processes. It is therefore important to carry out validation of ecosystem models to provide confidence in decision-making and planning, particularly as the majority of models do not quantify uncertainty in their predictions. The mesopelagic community (200 – 1000 m depth zone) is a poorly-known but important component of open-ocean ecosystems: it has been said to represent a 'dark hole' in understanding of ocean function (St. John et al. 2016). The mesopelagic community makes a major contribution to the biological carbon pump, for example, facilitating the transfer of carbon between the surface and the deep ocean, but the scale is hard to quantify since we do not even have an accurate estimate of mesopelagic biomass, let alone rate measurements (Proud et al. 2018a). Accurate simulation of the biological carbon pump in ecosystem models is required to improve future predictions of our climate. We can sample the mesopelagic community using echosounders, which produce soundwaves and record backscattering intensity from organisms in the water-column. Large volumes of archived echosounder observations are now available for download, providing near global coverage (Proud et al. 2017, Proud et al. 2018b). In this study, we develop an ecosystem model assessment and optimization framework, which links echosounder observations with ecosystem model predictions. We show how the mesopelagic component of ecosystem models can be assessed using echosounder observations by just considering model groups which contain the dominant mesopelagic scatterers (fish and siphonophores). We find that model validation using this framework is only viable when enough information regarding the scattering properties of the dominant model groups can be obtained from the model or from ancillary data (e.g. trawl samples). When echosounder observations are available across a range of frequencies, optimization of model parameters is also possible. The ecosystem model assessment and optimization framework developed in this study provides a first step towards improving the accuracy and reliability of ecosystem model predictions using echosounder observations.

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Mapping and modelling widespread underwater noise pollution from acoustic deterrent devices

Findlay, C.R.[1], Ripple, H.D.[1,4], Coomber, F.[2], Froud, K.[2,3], Harries, O.[2], van Geel, N.C.F.[1,2], Calderan, S.V. [1,2], Benjamins, S.[1], Merchant, N.D.[5], Risch, D.[1], Wilson, B.[1]

[1]*Scottish Association for Marine Science (SAMS), University of the Highlands and Islands, Oban, Argyll, Scotland, PA37 1QA, UK (Corresponding Author: charlotte.findlay@sams.ac.uk)*

[2] *Hebridean Whale and Dolphin Trust, 28 Main Street, Tobermory, Isle of Mull, Scotland, PA75 6NU, UK*

[3] *Glengorm Wildlife Project, Glengorm Estate, Tobermory, Isle of Mull, Scotland, PA75 6QE, UK*

[4] *2543 Pine Street, Boulder CO 80302, USA*

[5]*Centre for Environment, Fisheries and Aquaculture Science (Cefas), Pakefield Road, Lowestoft, NR33 0HT, UK*

Area being submitted to: (1) General science session
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Acoustic deterrent devices (ADDs) are used in attempts to mitigate seal depredation on finfish aquaculture sites through the emission of loud and pervasive underwater noise (Coram et al., 2014; Götz and Janik, 2013; Jacobs and Terhune, 2002; Quick et al., 2004). This study quantified spatio-temporal changes in ADD noise detections on the west coast of Scotland over 11 years. Acoustic point data ('listening events') collected during cetacean (whales, dolphins, and porpoises) line-transect surveys by the Hebridean Whale and Dolphin Trust were used to map ADD presence between 2006 and 2016. A total of 19,601 listening events occurred during this period, with ADD presence recorded during 1,371 listening events. Results indicated an increase in ADD detections from 2006 (0.05%) to 2016 (6.8%), with the highest proportion of detections in 2013 (12.6%), as well as a substantial geographic expansion (Findlay et al., *in press*). This study demonstrates that ADDs are a significant and chronic source of underwater noise on the west coast of Scotland with potential adverse impacts on target (seals) and non-target (e.g. cetaceans) species.

Future work will model in greater detail the spatial footprint of underwater noise from ADDs on the Scottish west coast using shallow water sound propagation models (Porter and Liu, 1994; Weston, 1971) for known ADD locations, and assess the risks for marine mammal populations. Specifically, the risks for injury (hearing damage) and habitat displacement for harbour porpoise (*Phocoena phocoena*) and harbour seals (*Phoca vitulina*) will be examined. Results from this work will be used to consider management options for this stressor in Scotland and better inform legislation addressing underwater noise and species protection.

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Deep Scattering Layers, the feeding ground of Antarctic deep-diving predators

Camille Le Guen[1], Roland Proud[1], Matteo Bernasconi[2], Lars Boehme[1], Inigo Everson[3], Paul Fernandes[4], Christophe Guinet[5], Robert Harcourt[6], Akiko Kato[5], Joshua Lawrence[4], Norman Ratcliffe[7], Yan Ropert-Coudert[5], Richard Sherley[8], Andrew Brierley[1]

[1] *Pelagic Ecology Research Group, University of St-Andrews, UK – cmmalg@st-andrews.ac.uk*
[2] *Institute of Marine Research, Bergen, Norway*
[3] *University of East Anglia, Norwich, UK*
[4] *University of Aberdeen, Aberdeen, UK*
[5] *Centre d'Etudes Biologiques de Chize, Villiers-en-bois, France*
[6] *Department of Biological Sciences, Macquarie University, Australia*
[7] *British Antarctic Survey, Cambridge, UK*
[8] *University of Exeter, Exeter, UK*

During the day, myctophids (lanternfish), krill, squid and jellyfish form layer-like aggregations in the mesopelagic zone (200-1000m deep) to reduce exposure to visual predators. These layers can be detected by echosounders and are known as deep scattering layers (DSLs). Myctophids are very abundant in DSLs and offer great potential as a protein source for human consumption but play a key trophic role as food for predators. In the framework of the Commission for the Conservation of Antarctic Marine Living Resources, pressing management issues arise because myctophids make up to 90% of the diet of deep-diving air-breathing predators such as King Penguins (*Aptenodytes patagonicus*, dive depth >350m) and Southern Elephant Seals (*Mirounga leonina*, dive depth >1500m). More data on DSLs are needed to develop a biogeographic zonation and understand likely future responses to climate change before any large-scale exploitation begins. A unique data set of DSL geographic variability in depth and echo-intensity (proxy for biomass) throughout the Southern Ocean was collected during the Antarctic Circumnavigation Expedition (ACE), along with CTD data and satellite remote sensing. We also collected position, depth and accelerometry data from predators off the coasts of South Georgia and Kerguelen as the ACE vessel approached each island. The tracking data are co-located with the DSL landscape to better understand predator-prey interactions and inform fisheries and conservation management.

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Individual foraging niches of black guillemots in relation to tidal stream turbines

Daniel Johnston[1], Robert W. Furness[2], Alexandra Robbins[3] , Glen Tyler[3], Mark Taggart[1], Elizabeth Masden[1],

1. Environmental Research Institute, North Highland College, University of the Highlands and Islands, Thurso, KW14 7EE – Daniel.Johnston@uhi.ac.uk
2. MacArthur Green Ltd, 93 South Woodside Road, Glasgow, G20 6NT
3. Scottish Natural Heritage, Great Glen House, Leachkin Road, Inverness IV3 8NW

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ABSTRACT:

Tidal streams are an important foraging habitat for several species of marine top predator. This foraging habitat is potentially vulnerable to alteration from the construction of tidal stream turbines such as those currently being installed within the Pentland Firth's Inner Sound. Tidal turbines may affect inshore habitat or prey distribution by shifting tidal flow patterns, altering benthic composition and forming reefs. However, different species will be affected to varying extents based upon their foraging niche. A variety of foraging niches may exist within a species' population leading to the extent of impacts varying between individuals. The inshore diving black guillemot *Cepphus grylle* has been identified as one such species vulnerable to tidal turbines. This study investigates individual foraging niches of chick-rearing black guillemots, and how these relate to diet, nest success, and vulnerability to tidal turbines. This was achieved by using GPS tracking technology, and monitoring breeding success and chick diet (using camera traps and visual observations).

Thirty-five breeding adult black guillemots were GPS tracked during the 2016 and 2017 summer breeding seasons on the Scottish islands of Stroma and North Ronaldsay. Both islands are associated with tidal streams, and Stroma is in close proximity to ongoing turbine installations within the Inner Sound. The tracks revealed individual specific foraging locations, with individuals foraging exclusively within or out with tidal streams, rarely both. Using predictive biotope data and tidal models, this study identified the partitioning of habitats between individuals. These included both high tidal energy/deep water/kelp associated habitats and shallow water/low energy/sandy/muddy habitats. Diet monitoring established links between prey collected for chicks and their likely habitat of origin. Further nest monitoring and chick weighing provided a measurement of breeding success related to prey type and potentially the habitat of origin. The knowledge of individualistic foraging behaviour of black guillemots will allow for the population and individual level impacts of environmental alteration by tidal turbines to be assessed and potentially quantified.

Acknowledgements

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Broad-Scale Acoustic Monitoring For Cetaceans And Underwater Noise In Relation To Offshore Wind Farm Construction In Scotland

Ross Culloch* (1), Kate Brookes (1), Finlay Bennet (1) Ewan Edwards (1), Nathan Merchant (2) and Ian Davies (1)

*(1) Marine Scotland Science, Scottish Government, Marine Laboratory, 375 Victoria Road, Aberdeen, UK, AB11 9DB (2) CEFAS, Pakefield Road, Lowestoft, Suffolk, UK, NR33 0HT; *Ross.Culloch@gov.scot*

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Are you a student? (Delete as appropriate): No.

Marine construction projects, such as offshore wind farms and port developments often use techniques that produce significant levels of noise underwater, which could have effects on marine wildlife. Marine Scotland is the government body responsible for regulating these activities in Scottish waters and for ensuring that wildlife populations are protected in line with legislation.

Large scale offshore wind farm construction started off the Scottish east coast in 2017, using piled foundations. To monitor for potential broad scale changes in distribution of protected cetacean species during construction activities, Marine Scotland deployed an array of 30 click detectors and 10 broadband acoustic recorders across the Scottish east coast each summer since 2013. Here we present baseline distributions for dolphins and harbour porpoises, along with ambient noise levels recorded concurrently.

Dolphin detections across the monitored area are highly variable, with some locations that are clearly favoured. Harbour porpoise are ubiquitous and in more than 60% of locations are detected on 100% of monitored days. This is likely to mean that there is more power to detect changes in porpoise distribution in relation to offshore wind farm pile driving than for dolphins.

BioFREE: an international study of biofouling impacts on the marine renewable energy industry

Andrew Want[1], Joanne S Porter[1]

1 *International Centre for Island Technology,School of Life and Earth Sciences, Heriot-Watt University Orkney Campus, Old Academy, Back Road, Stromness, KW16 3AW, Orkney, Scotland, UK* a.want@hw.ac.uk, j.s.porter@hw.ac.uk

Understanding the Influence of Man-made structures in the Ecosystem - progressing the science

Preferred presentation medium: oral

Are you a student? No

The success of the marine renewable energy (MRE) industry is dependent upon maximising energy capture and minimising down-time. Device performance is negatively impacted by the growth of fouling organisms, leading to reduced efficiency and reliability; anti-fouling strategies are costly and time consuming. Biofouling also reduces accuracy of data buoys and sensors used to assess the hydrodynamic resource and device performance. While biofouling has been a recognised problem for centuries, deployment of MRE devices creates several unique issues: devices utilise moving parts unique to MRE technologies; materials are used in novel ways that have not been trialled before in marine environments; and, deployments are taking place in habitats where structures have not been previously installed and studied (e.g. in very strong tidal flow areas). Additional concerns exist over the role that MRE infrastructure may play as 'stepping-stones' promoting the spread of non-native and invasive species. A paucity of published studies exists concerning biofouling in this sector. With a general trend towards stricter environmental controls, it is essential that the MRE industry demonstrate commitments that minimise disturbance and promote positive impacts. Given small margins for MRE, there are potentially substantive benefits from tackling biofouling in terms of increased investor confidence.

The BioFREE project (a collaboration between Heriot-Watt University and the European Marine Energy Centre (EMEC) in the UK) is addressing these issues by detailed characterisation of the biofouling communities from multiple habitats used by the MRE sector, and monitoring benthic impacts following deployment and decommissioning. BioFREE is developing a workable Standard Monitoring System designed to facilitate data collection using practical and effective methods. Frames are populated with settlement panels, data loggers, and components comprised of materials of greatest concern to MRE developers. Components of this system can be treated with anti-fouling coatings. Frames are being deployed in a variety of habitats at several additional test centres and research institutes including Japan, Chile, France, and the USA; organisms are recorded quarterly to identify the major foulants, determine the rate of settlement and growth, and study successional changes. These studies indicate strong species-specific seasonal settlement patterns. Fouling communities varied between deployment habitats depending on factors such as hydrodynamic conditions, water depth, and substrate type.

These findings will allow recommendations for test centres and developers to minimise the impacts of fouling, chiefly through selective scheduling of deployments and maintenance, in different habitats, to times when the settlement of fouling organisms will be minimal or their removal will be least costly. In addition, BioFREE has created training materials to help inform the MRE industry of ways to better capture biofouling information when conducting operations at sea. Practical suggestions are informed by recent maintenance and decommissioning operations conducted on MRE infrastructure. These studies have identified structural areas and materials of particular concern from the impacts of biofouling. The lead role of EMEC, as a representative of MRE developers in the sector, is allowing promotion of project outputs within the industry and between test centres. These findings are being disseminated through conference presentations, technical reports, scientific publications, public engagement, and webinars planned for the near future.

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