Moving forward with modelling deposition for aquaculture: integration of spatially variable currents

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Area being submitted to: (1) General science session

Presentation type: (ii) e-poster

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Abstract

Salmon aquaculture sites in Scotland are regulated on the basis of their influence on the seabed surrounding that site, both in terms of organic enrichment from waste feed and fish faeces, and in terms of the chemicals used to treat fish against parasitic sea lice. Farms exceeding agreed levels of enrichment (measured by faunal composition of the benthic environment) and chemical concentrations are liable to action by the regulator.

When new developments are proposed and agreed the modelling software DEPOMOD is used by site operators and the regulator (Scottish Environmental Protection Agency) in order to estimate the maximum biomass that can be contained at a particular proposed site. These predictions are made using information on the surrounding physical environment (bathymetry and coastline), and a current meter record collected by the site operator.

A principal limitation of this method has been the use of current data with no spatial component, which prevents the prediction of accurate spatial zones of influence for a particular farm site. The availability of high resolution spatial hydrodynamic models means that it is now possible to better represent the complex coastal environment in which farms are sited, and for a better understanding the environmental impact of sites to be gained. We present here the first results gained using this methodology, with application to specific sites on the west coast of Scotland.

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Effect of different wind forcing representations on hydrodynamic fields modelled by the Scottish Shelf Model

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Several studies investigating the effect of wind forcing on marine currents have previously been conducted. Wind stress is known to largely be the primary driving factor for circulation during the winter months and the main contributor to the upper layer circulation in an ocean (Siedler, Church, & Gould, 2001).

The Scottish Shelf Model (SSM) is a hydrodynamic model of Scottish shelf waters and is used for a wide range of scientific, industrial and societal applications. One of the most useful SSM outputs is a 1 year climatology (an "average" year) but the forcing of this climatology **smooths** out extreme events such as storms, which may potentially have a clear effect on modelled circulation. This current project aims to understand the sensitivity of the SSM to the preparation of wind forcing data for climatological runs.

Atmospheric data from the ECMWF ERA_Interim reanalysis was downloaded and treated in three ways: i) raw, 6-hourly forcing data; ii) climatological averaging based on just the year under consideration and iii) climatological averaging of the relevant months from 25 years of data, as currently used for the SSM climatological runs. The model was run for a period of two months with each version of the wind inputs, and the results compared in terms of differences in surface currents and in transport across a number of well-studied standard hydrographic transects. These included the JONSIS line in the North Sea, the Ellett line off the west coast and a transect line across the Fair Isle Gap. Each of these transects intersect important circulation features and have been under observation for extensive periods, so transport from the model runs can be compared with a long observational time series.

Specifically, the mean transport and time series of transport through each of the transect lines is to be explored and compared with the wind velocity at points across each transect. This allows for a comparison of the effect of raw and averaged wind forcing which gives opportunity for a better understanding of atmospheric forcing in the climatological runs.

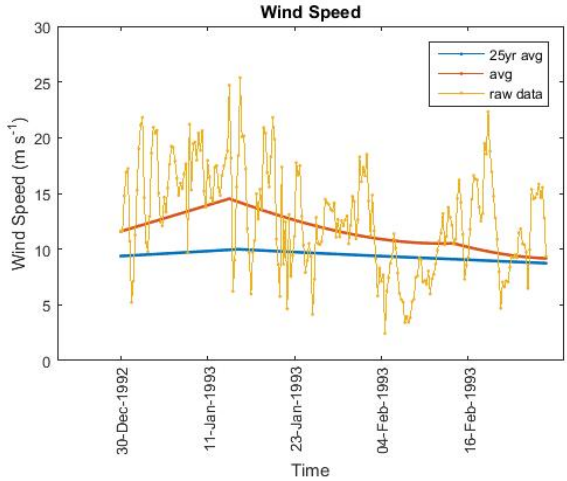

Figure 1: Graph demonstrating the difference between raw and averaged wind data

Acknowledgements

This work was conducted on an Equate Scotland placement at Marine Scotland Science. ECMWF are acknowledged for providing data and Michela De Dominicis(NOC, Liverpool) is to be thanked for her work on climatological atmospheric forcing.

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Flood protection services of tidal marsh ecosystems: current and historical wave attenuation at Sturgeon Bank in British Columbia, Canada

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Area being submitted to: 4) Increasing resilience to natural hazards

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Coastal communities are facing an increasing risk of flooding from storm surge and future sea level rise due to climate change. Many communities are looking towards infrastructure like dikes and seawalls for increased coastal protection; however, coastal ecosystems may also be an important protective feature of some coastlines. Tidal marsh ecosystems, comprised of both estuarine and marine systems, are important ecosystems for flood protection. Coastal vegetation in these areas can act as a potential buffer for flooding by reducing wave height and dissipating wave energy across a foreshore tidal marsh, thus reducing the potential wave run-up on dikes and other coastal structures. In the Fraser River delta British Columbia, Canada, research is documenting how tidal marsh ecosystems are receding which may suggest that the degree of wave attenuation from these ecosystems may also be decreasing.

A case study is being conducted in the Sturgeon Bank Wildlife Management Area located adjacent to the City of Richmond in British Columbia. This study will examine how vegetation in a tidal foreshore marsh can act as potential flood protection for a coastal community, and how historical wave attenuation has changed since 1975. This research will assess the potential changes in flood protection to a coastal community from tidal marsh ecosystems.

A vegetation survey is being undertaken at the Sturgeon Bank foreshore marsh to measure the current state (stem height, stem density, and stem diameter) of dominant plant species within the brackish marsh, while historical vegetation surveys and air photos will be used to map the tidal marsh in 1975. A second vegetation survey will be completed in January 2019 to measure the changes in vegetation between growing season and non-growing season.

Data from these vegetation surveys will be used to model the dissipation in wave energy from storm surge across the foreshore system, from the marsh leading edge to the protective dikes. Using the SWAN wave model, coupled with the *SalishSeaCast* and *WaveWatch* III hydrodynamic models, the wave attenuation profile across Sturgeon Bank will be shown by mapping changes in wave height and wave energy dissipation.

This research will provide a baseline for wave attenuation in the tidal foreshore marshes of Sturgeon Bank and will measure the potential change in wave attenuation since 1975 for the coastal community of Richmond, British Columbia. This will also add support to the stewardship of these tidal marshes in the future by quantifying the protective services offered by the vegetation. As there remains a focus on coastal hazard resilience, documenting changes in wave attenuation may also add another method of valuation to the existing ecosystem services.

Acknowledgements

I would like to acknowledge the guidance of my supervisor, Stephanie Chang, committee member, Susan Allen, and Eric Balke from the British Columbia Ministry of Forests, Lands, Natural Resource Operations & Rural Development. Additionally, many thanks to Janelle Bode, my fieldwork partner with whom I spent many days in the foreshore marshes of the Fraser delta.

NERC Changing Arctic Ocean: Implications for marine biology and biogeochemistry

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Area being submitted to (delete as appropriate): 5) The changing Arctic Ocean: identifying and quantifying the Arctic response to climate change;

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The Arctic is responding in unknown ways to profound changes in the physical environment as well as to multiple natural and anthropogenic events that place stress on Arctic ecosystems. The scale of the challenges facing the Arctic is immense and is further compounded by the rapid rate of change.

To address the uncertainties generated by climate change in the Arctic Ocean, NERC has invested £16 million in a research programme called ***"Changing Arctic Ocean: Implications for marine biology and biogeochemistry."*** This flagship research programme runs over a 5 year period, from 2017 to 2022. The over-arching goal is to understand how change in the physical environment (ice and ocean) affect the large-scale ecosystem structure and biogeochemical functioning of the Arctic Ocean. The science outputs will address the potential major impacts and provide projections of change for future ecosystem services.

At the core of the programme are four large projects (Arctic PRIZE, ARISE, ChAOS, DIAPOD) that started in February 2017. A further 12 projects joined the programme in July 2018, co-funded for the first time by NERC and the German Federal Ministry of Education and Research. This co-funding of research projects by the UK and Germany represents a first and brings with it benefits for the programme's international collaboration, greater access to large-scale research infrastructure, and the advantages of shared scientific expertise.

The strength of its international collaboration is an important aspect of the programme, reflected by the links established with scientists in 15 other countries. Ultimately, the aspiration of the CAO programme is to forge lasting engagement with the international Arctic community beyond the funded lifetime of the programme.

With an extensive array of different approaches employed to monitor change in the Arctic, substantial datasets are being generated that cover physical, chemical and biological parameters of change in the Arctic Ocean. In this contribution, I summarise these as well as outlining the scope of the programme and the focus of the projects.

First insights on temporal changes of the benthic ecosystem in the Pechora Sea (SE Barents Sea, Russian Arctic)

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Pechora Sea in the south-east basin of the Barents Sea has a unique ecosystem that is currently challenged both by changing climate conditions in the Arctic (most important factors being global warming, ocean acidification and sea ice loss) and by growing pressure from human activities including offshore oil production, fishery and shipping. Prirazlomnaya oil platform in the Pechora Sea operated by Gazprom Neft Shelf is the only offshore stationary platform in the Russian Arctic with the ongoing oil extraction.

Although Barents Sea is considered the most studied sea in the Russian Arctic, there is a lack of integrated research focused on ecosystem dynamics for the Pechora Sea. Understanding how benthic ecosystem responds to the changing environment can advance modelling of the future reaction to the further changes and developing Marine Spatial Planning for the area. The first benthic habitat mapping for the Pechora Sea was published in 1927 (*Zenkevich, 1927*) and remained key reference on the benthic assemblages of the Pechora Sea until the late 1990-s. Later major benthic survey was conducted in the Pechora Sea in 1991-1195 and led to several publications (*Dahle et al., 1998; Denisenko et al., 2003*). Recently Denisenko published review of the long-term changes in the benthic ecosystem of the Barents Sea (*Denisenko, 2013*) based on the same data. However, it was not specifically for the Pechora Sea, also no data collected after 1995 were used for analysis, therefore modern state of benthic fauna in the Pechora Sea needs revealing.

According to Denisenko (2*013*), the Pechora Sea has a total of 712 described taxa with >500 identified to species level, which represent approximately 35% of the benthic biodiversity of the Barents Sea. Macrobenthic fauna of the Pechora Sea is mainly comprised of Boreal-Arctic species with a significant limnetic contribution from the Pechora river estuary. It is characterised by a relatively high faunal diversity and an extremely high variability in the spatial distribution presumably caused by changing environmental conditions, that includes: water depth, bottom landscape topography and sediment type (*Dahle et al., 1998; Denisenko et al., 2003*).

Thirteen types of macrobenthic assemblages were identified in the latest survey (*Denisenko, 2013*). Noticeably, over ¾ of the total area corresponded to communities (1) with the dominants *Spiochaetopterus typicus – Astarte borealis* or (2) *Serripes groenlandicus*.

We intend to analyse benthic grab samples (bottom grabs *Ocean-0.25* and *Ocean-0.1*) along with *Sigsbee* trawl samples and ROV *Super GNOM Plus* video recordings collected during RV Kartesh cruises to the Pechora Sea in 2015-2018 to contribute to more recent and detailed understanding of the state of benthic ecosystem in the Pechora Sea as well as to assess changes in benthic communities by comparing with literature data from 1990-s.

Preliminary analysis of samples collected in 2016 (a total of 67 grab samples and 16 ROV recordings) showed that the study area between Vaigach, Matveev and Dolgiy islands described by Denisenko as *S. typicus – A. borealis* or *S. groenlandicus* in fact had more diverse structure of benthic assemblages, four types of communities were identified: (1) *Astarte borealis*; (2) *Nicania montagui - Macoma calcarea*; (3) *Ciliatocardium ciliatum*; (4) remaining stations were poor in biomass, barren and each having different dominant species including *Hamingia arctica, Thyonidium commune, Nephthys ciliate* and others. Noticeable, Polychaete species *S. typicus,* which was described by Denisenko as one of the dominants for most of the Pechora Sea was not anymore dominant for any of the stations, reason for that is a question for further research.

Additionally, presence of snow crab *Chionoecetes opilio* was shown on video recordings. Snow crab was recorded in the Barents region for the first time in 1996, its population is currently growing, and species can potentially over compete native benthic predators in the area. Climate change is suggested as one of the potential drivers for snow crab migration from the Bering Sea and expansion to the Pechora Sea.

Acknowledgements

Authors are kindly grateful to LMSU MRC and RV Kartesh team for providing with the opportunity to conduct field work and assess samples.

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Using Acoustic Backscatter to Improve Spatial Analysis and Quantification of Scotland's Sedimentary Carbon Resources: A Case-Study of Loch Creran, Argyll

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The marine sedimentary environment is a long-term repository of sinking particulate matter, effectively burying carbon (C). In addition to marine-sourced C, coastal environments, including estuaries, wetlands, fjords and the continental shelf, receive large inputs of C from the terrestrial environment via surface run-off and riverine discharge. Fjords are natural sinks of terrestrial C due to their proximity to land and geomorphology, trapping settling sediments in over-deepened glacial basins before currents can transport them to the neighbouring shelf. We will use Loch Creran as a case-study to improve our spatial understanding of where C is stored in the surficial sediments. A current detailed sedimentary C-stock estimate showed that Loch Creran stores 4.8±0.7 Mt C, from combined marine and terrestrial sources (Smeaton *et al.*, 2017). However, a recently completed multi-beam bathymetric (including backscatter) survey of Loch Creran suggests that the surficial sedimentary store is heterogeneous, implying a highly variable depositional environment and therefore C storage potential. Acoustic backscatter data can be used for seabed sediment mapping, while sediment type can influence the preservation of organic carbon. Using a new integrated approach, we attempt to combine acoustic backscatter, photographic and ground-truthing data to improve spatial mapping and quantify the variability of C storage in Loch Creran's sedimentary store. Over the next 50 years, the significance and value of sedimentary marine C as an important component of Scotland's natural capital is likely to be realised in terms of new management strategies for its protection and, potentially, in helping to meet Scotland's climate change mitigation targets.

Acknowledgements

All the co-authors are kindly thanked for their valuable input into and support of this project. Additionally, thanks go to Dr. Urska Demsar for her support.

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Blue carbon of shellfish beds – understanding the vaults of biogenic reefs

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Shellfish beds provide ecosystem services, from habitat provision for benthic organisms and facilitating bentho-pelagic coupling to commercially important extractive resources. However, shellfish beds are also some of the most threatened marine habitats, historically having been targeted by fisheries, subject to disease spread and at risk from changing marine environments and marine development. The Blue Carbon in the NE Atlantic MPA network is poorly known[1] but shellfish beds within them have the potential to be substantial carbon stores[1,2,3,4] on a par with mangroves, seagrasses and saltmarshes [4,5]. The present study aims to quantify the role of a number of native shellfish species in the marine carbon cycle; European flat oysters (*Ostrea edulis*), horse mussels (*Modiolus modiolus*) and blue mussels (*Mytilus edulis*). *O. edulis*, is the focus of emerging restoration projects throughout Europe, therefore quantifying the potential carbon processing services which restored reefs can provide is important grounds to inform such work. Seasonal depositional rates of native shellfish will be studied under realistic environmental settings of flow rate and seston availability, using facilities at the St Abbs Marine Station. This study will also be replicated in-situ at a potential restoration site in the Dornoch Firth. Further experiments are planned to quantify carbon stored in both blue mussel and horse mussel beds and to investigate carbon budgeting of native shellfish, assessing carbon input and output and quantifying carbon flux.

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Stable Isotope ($\delta^{15}N$ and $\delta^{13}C$) analyses of tooth collagen as a methodology for determining trophic level in Harp seals.

Mettam, C[1]., Smout, S[1]., and ARISE team members and collaborators

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High-resolution stable isotope analyses of tooth collagen and trophic level in Harp seals.

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The trophic level of pinnipeds can reflect the quality and availability of food related to ecosystem perturbations in high-latitude marine settings, with studies of nitrogen ($\delta^{15}N$) isotopes from seal protein suggesting that over time some species have adapted foraging strategies and are increasingly relying upon resources from lower trophic levels. Unlike other proteins, tooth collagen is stable once formed, and thus potentially provides a through-ontogeny isotopic archive, with fine-scale sampling constrained by the presence of growth annuli. Newsome et al. (2010) argue that the $\delta^{15}N$ of proteins in animal tissues is higher during periods of nutritional stress, and lower during optimal feeding. Further, Bowen et al. (1983) identify opaque sub-annual structures in Harp seal teeth that they attribute to periods of low food intake e.g. during lactation when mothers attend pups and during moulting. We therefore investigate whether we see higher $\delta^{15}N$ in collagen from these opaque bands to test whether this is consistent with low food intake.

Newsome et al. (2010) Using stable isotope biogeochemistry to study marine mammal ecology. Mar. Mam. Sci. 26, 509-572
Bowen et al. (1983) Validation of age estimates in Harp seals. Can. J. Fish. Aquat. Sci. 40, 1430 -1441

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References

Authors (Year). Title. Journal title, number (issue) and page numbers.

Scotland's blue carbon: the contribution from seaweed detritus

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Preferred presentation medium : (ii) e-poster

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Kelp and seaweed constitute a significant proportion of coastal biomass and as photosynthetic organisms, macroalgae accumulate carbon in their thallus in the form of sugars, lipids and proteins (Kelly and Scheibling, 2012). Significant biomass of kelp is removed from its holdfast regularly and becomes detrital. The fate of this detrital biomass, and significance to sediment carbon stores is as yet, little studied (Krause-jensen and Duarte, 2016).

To better understand the contribution of Scottish intertidal seaweed species to long term 'blue carbon' stores this study will use a combination of traditional beach surveying techniques, SCUBA surveys and 3D photogrammetry as well as chemical analysis of seaweeds and sediments. A survey cruise of northern Scottish lochs in summer 2018 will examine the distribution and biomass of seaweed detritus on the seabed and collect sediment inside sea lochs and on the open coast. The analysis of this sediment will be combined with chemical analysis of incubated decomposing seaweed species with a particular focus on lipid profiles that indicate a contribution from seaweed, and polysaccharides, such as fucoidans, that are unique to the class Phaeophyceae (brown algae). SCUBA surveys in areas adjacent to kelp beds will measure detrital biomass at key stages in the year, and 3D photogrammetry will look at beach-cast detritus movement and biomass loss.

Atmospheric carbon dioxide (CO_2) has risen from 278 to 400 parts per million (ppm) since the beginning of the industrial revolution and is expected to continue to rise (Bala, 2013). The detrimental impacts of increased gaseous CO_2 include ocean acidification (Doney et al., 2009), climate change (Hansen et al., 2008) and the alteration of many ecosystem processes (Norby and Luo, 2004). The direct effects of increased CO_2 may benefit photosynthetic macroalgae by increasing available carbon for sequestration, but the indirect ecosystem effects remain unclear (Porzio et al., 2011). The global carbon budget circulates around large biological carbon stores in both terrestrial and aquatic ecosystems. Carbon stored in marine systems has been termed 'blue carbon' and until recently, research has focused on mangrove, salt marsh and seagrass systems given their capacity to form soils via roots (Nellemann and Corcoran, 2009). My study aims to expand this view of blue-carbon producing organisms to include the extensive coastal macroalgae of temperate coasts.

Acknowledgements

This work is funded by Marine Scotland, Scottish Natural Heritage and the University of the Highlands and Islands.

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THREE DIMENSIONAL TURBULENCE CHARACTERISTICS NEAR THE MARINE STRUCTURE LIKE PIER

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Area being submitted to: General science session

Preferred presentation medium: e-poster format.

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Abstract

There are several difficulties in the field of flow modelling around marine infrastructure, ranging from monopiles to other support structures for wind tidal and wave turbines, which need a thorough understanding of the near bed surface turbulent and time-averaged flow characteristics. Likewise, benthic habitat about marine infrastructure and operations, is very sensitive to the process or scouring and deposition of sediment, which may disrupt its normal ecological function. Recent research by the authors has demonstrated that the criteria linked to the mean flow field around such infrastructure are only phenomenologically linked to scouring and that characteristics of the individual turbulent flow structures (vortices), such as lengthscale (size) and energy, are important in obtaining a better understanding of the physical mechanisms of the scour processes.

The goal of the present study is to undertake a detailed experimental campaign, to assess infrastructure scour in marine environments, under the presence of strong currents, and measure the flow characteristics that cause it. The experiments, conducted at the research flumes of the University of Glasgow's Water Engineering lab, are specifically designed to obtain detailed spatio-temporal measurements of the flow field about a physical model of the infrastructure, with a range of flow diagnostics techniques, such as acoustic Doppler velocimetry. This will be done for a series of experiments leading to a range of steady state (equilibrium) scour, representative of the scour about infrastructure in marine environments. The novelty of this research lays in the analysis of the obtained hydrodynamic data, enabling the development of predictive equations for marine infrastructure scour (depth and width), using a probabilistic description of the turbulent flow field energy and associated criteria.

This research, has many implications for marine energy stakeholders, marine engineers and marine bio-geomorphologists alike, as it offers new methods that can be used for the prediction and modeling of scour about marine infrastructure, affecting from the safety of the infrastructure and risk to energy production, to the benthic and marine habitat development.

Acknowledgments

The authors would like to thank MASTS Annual Science Meeting, for the inviting this research.

New hydrodynamic models of the Clyde Sea and Shetland waters

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Area being submitted to (delete as appropriate): 1) General science session;

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

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The Scottish Shelf Model is a suite of FVCOM numerical hydrodynamic models commissioned, developed and/or managed by Marine Scotland Science, and available to other users. It consists of a large-domain model covering the entire Scottish shelf [1], and a number of sub-models which offer higher resolution in specific regions.

This e-poster presents two new sub-models that are nearing completion: One covering the Clyde Sea, and one for Shetland. The primary motivation behind these locations is supporting the needs of the aquaculture industry but they will be used for a variety of purposes, from modelling the drift of marine litter to estimating tidal energy resource. A previous model of the Clyde Sea [2, 3] was used as a prototype to inform the design of this one.

Both models are baroclinic and include wind and freshwater inputs in addition to forcing with tides, temperature and salinity at the open boundaries. Unstructured computational meshes are used, with maximum resolution of approx. 80 m.

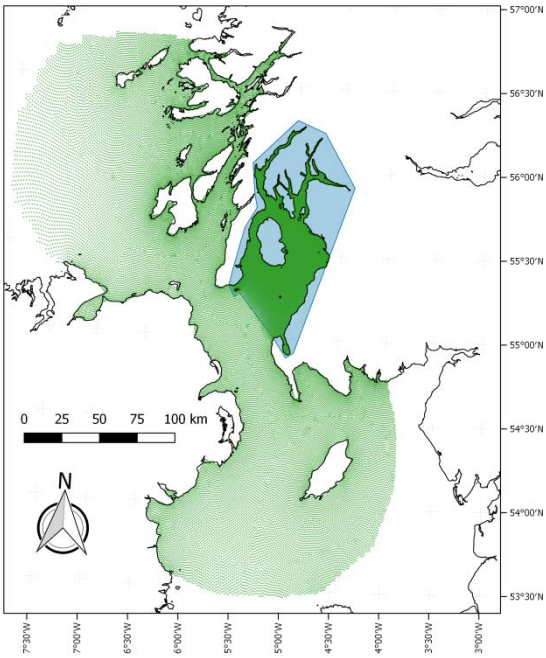

Figure 2: Domain of the Clyde model (green), with the area of interest in the Clyde Sea (blue)

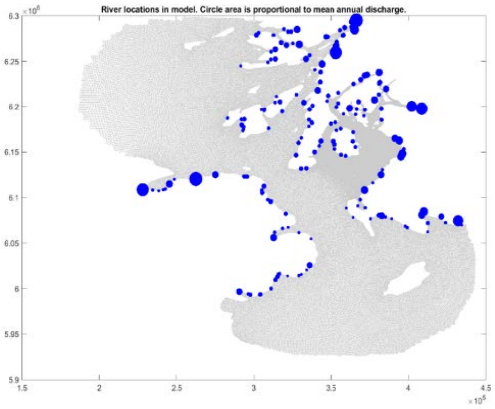

Figure 1: River inputs to Clyde model. Circle area is proportional to mean annual discharge.

The proposed e-poster will show the model domains and meshes, present sample outputs, and provide contact details for future users and collaborators to get in touch.

Acknowledgements

The following organisations are acknowledged for providing forcing and validation data: BODC; ECMWF; EU Copernicus Marine Service; Marine Harvest; SEPA; UKHO.

This work was funded by a NERC Innovation Placement, grant reference NE/R006903/1.

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Understanding litter decomposition in Scottish seagrass meadows

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The abstract should be submitted to masts@st-andrews.ac.uk, in an editable format, by 16:00 Friday 27th July 2018.

Seagrass meadows are natural carbon sinks, which could contribute significantly to global carbon sequestration. With increasing concerns over effectively mitigating greenhouse gas emissions, the profile of this habitat has attracted attention worldwide. In Scotland, research has shown seagrass meadows enhance carbon storage significantly compared with areas where seagrass is absent, but there are still large differences in carbon storage across sites that warrant the exploration of physical, chemical and biological factors.

This poster will explore plant litter decomposition in Scottish seagrass meadows. Plant litter decomposition plays an important role in the movement of carbon within a seagrass bed. To understand if decomposition is playing a role in the variation of carbon storage within seagrass meadows a common substrate – tea – has been buried and will be used as a measure to estimate rates of decomposition across multiple seagrass beds and adjacent bare mudflats. Further to this, microbial communities associated unburied tea (control), tea that has been buried for three months and sediment has been analysed across two seagrass meadows; the Solway Firth and the Firth of Forth.

Acknowledgements

Thanks to all the volunteers who have assisted with field and laboratory work to make this project a success.

Monitoring Scotland's offshore MPAs

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The Joint Nature Conservation Committee (JNCC) and Marine Scotland Science (MSS) collaborate to assess the condition of benthic Marine Protected Area (MPA) features in UK offshore waters (>12Nm from the coast). The data collected also enable the provision of management advice at the individual sites and across the wider MPA network. JNCC and MSS have completed 3 dedicated MPA monitoring surveys for 5 offshore MPAs on the MSS research vessel *Scotia* since 2015, and plan to conduct a benthic habitat monitoring survey at a further 3 offshore deep-sea MPAs in August 2018.

This presentation will describe the work completed to date, highlight data availability to the wider community and flag opportunities for future collaboration.

Pathways to Influence: How formalised groups mediate knowledge exchange and influence across the offshore renewable energy sector

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Area being submitted to (delete as appropriate): 1) General science session

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

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Marine governance and meeting the requirements of environmental policies and regulation are frequently cited as persistent barriers to development in offshore renewable energy (ORE), alongside finance and technology development challenges. The processes of developing appropriate governance structures and meeting environmental requirements are not always straightforward. Actors within the ORE sector, including technology developers, site developers, engineers, environmental scientists, and policymakers have varying degrees of influence on the development of policies, regulatory frameworks, and monitoring requirements.

It has also been suggested that a failure to adopt renewable energy technology could, in part, be explained by poor connectivity within the sectoral network, reducing innovation (Geist, 2015; Jacobsson and Johnson, 2000). The objective of our work was to understand the pathways through which individuals, with differing environmental interests/perspectives, are inter-connected and to consider how those connections may infer influence on regulators and future policy. We used a survey approach to identify formal groupings that bring together individuals in the ORE sector, thereby connecting them in a social network. Over 300 individuals from 24 nations responded to our survey, identifying more than 100 advisory boards, export forums, steering committees, and working groups across academic, industry, policy, and societal sectors.

We used a social network analysis approach to understand the conditions that facilitate the transfer of knowledge across the network, and how the positioning and connections of specific interest groups increased or decreased their influence in the network. While survey respondents from all backgrounds identified academics as the group they most frequently communicated with, the most influential organisations as illustrated by their position in the network were consultancies and funding agencies, who represent the most rapid routes for information to travel across the network. We suggest that understanding the structure of the ORE research and innovation network can enable individuals working in the field of ORE, and particularly those in the research community, to identify the most effective pathways for knowledge exchange in order to generate the greatest impact from their work.

Acknowledgements

RGM and TW acknowledge the support of the ICES Working Group on Marine Renewable Energy and the ICES Working Group on Marine Benthal and Renewable Energy Development in developing the study survey. RGM was supported in this work by NERC Knowledge Exchange Fellowship NE/M006999/1

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A zooplankton perspective on high latitude, spring phytoplankton blooms: Insights from the Southern Ocean

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Area being submitted to: 5) The changing Arctic Ocean: identifying and quantifying the Arctic response to climate change

Preferred presentation medium: (i) oral

Are you a student?: Yes.

Polar oceans have highly pronounced interannual variability in primary production and sea ice cover. Zooplankton such as calanoid copepods and euphausiids exhibit a wide range of life history strategies in response to the variability in their environments with large adult sizes, long generation lengths and slow development rates all being typical adaptations. The spring phytoplankton bloom is vital for zooplankton development in the high latitudes and many species time key life events around it. However, defining appropriate bloom timing metrics remains elusive, posing the question: What prey indicators are important to zooplankton?

The Coltrane copepod life history model (Banas et al, 2016) is applied here to resolve *Calanoides acutus* in the Southern Ocean testbed of South Georgia. By modelling the progression of a cohort of individuals spawned on the same yearday, Coltrane resolves individual life history traits and population-level dynamics. Further, an ensemble of model runs with a range of internal, biological parameters allows Coltrane to resolve community composition. Using satellite chlorophyll-*a* data to force the model and calculating commonly-used metrics defining bloom initiation, duration and magnitude, we look for a relationship between these metrics and key copepod traits such as development time and egg-replacement rate. If a coherent relationship exists between a certain bloom and copepod metric, we carry out further model runs to identify whether a 'threshold' value of the bloom metric exists, above which copepod populations are successful and below which they cannot complete their life cycle.

In future work, the Coltrane model will be adapted to resolve a wider range of zooplankton species, particularly Antarctic krill (*Euphausia superba*). The waters around South Georgia provide a useful testbed to investigate whether the response to phytoplankton metrics are consistent across the zooplankton spectrum or whether there are interspecific differences.

Primary production in polar regions is expected to look very different in the future. Changes, not just in biomass but also in timing and/or duration of production, impact species throughout the food web. Our work provides a basis to investigate the impacts of such changes across the zooplankton spectrum and whether they will be uniform or vary across zooplankton taxa.

Acknowledgements

Work by Euan McRae is partially supported by the Natural Environment Research Council, through the Changing Arctic Ocean programme, and by the University of Strathclyde.

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Chronobiology of Changing Arctic Sea Ecosystems (CHASE project)

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Area being submitted to 5) The changing Arctic Ocean: identifying and quantifying the Arctic response to climate change

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The Arctic is changing rapidly, with ice retreat resulting in an ocean of warmer, fresher and lighter water. This is resulting in the earlier arrival of the spring bloom, the later arrival of autumn freeze, and the increasing length of the main growing season. Such climate change effects are driving marine zooplankton to extend their habitat ranges polewards[1] resulting in exposure to new and more extreme day-length (photoperiodic) climates with unknown consequences[2]. Using individual copepods (*Calanus* spp.) and krill (*Thysanoessa inermis*), the aim of the CHASE project is to understand individual responses to photoperiod at different latitudes to better predict large scale ecosystems consequences to change. Presenting behavioural, physiological and genetic data collected from recent research cruises, we reveal unexpected variability between individuals and habitats, suggesting adaptation potential within the population. We further show expression of the circadian clock in *Calanus* which provides a mechanism to gain temporal information in the absence of environmental cues[3]. We suggest that this may underpins zooplankton diel vertical migration, centrally important in high latitude biogeochemical cycling[4].

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