Seasonal Variations in Photosynthetic Efficiency of Polar Phytoplankton

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Area being submitted to 3) Marine Biogeochemistry

Preferred presentation medium (ii) e-poster format

Are you a student? Yes

While the strong seasonality of polar phytoplankton has been the subject of much study for over a century, many of the mechanisms behind spring blooms and over-wintering strategies are not fully understood. We used a combination of new in situ experiments, a general literature review, and new theory to determine how photosynthetic parameters evolve from season to season, and the likely controlling mechanisms.

Photosynthesis-irradiance (P-E) curves were determined experimentally for phytoplankton communities under winter sea ice and following ice retreat, in near-optimal spring bloom conditions, in the East Bering Sea, as part of the 2007-2010 Bering Sea Ecosystem Study (BEST). Under-ice samples were found to have lower values not just of maximum C and NO_3 uptake rate, but of photosynthetic efficiency α, the initial slope of the P-E curve. Past observations in polar marine systems showed many different photoacclimation patterns over short time scales, but a consistent positive correlation between α and photosynthetically active radiation (PAR) on a time scale of months or more. Spring and summer observations, especially in spring blooms, were associated with higher values of α than fall/winter values in the same communities. In at least some cases this pattern was a plastic species-level response, though in some cases it may reflect compositional shifts toward species with lower α.

These observations suggested a modification of the Platt model of phytoplankton growth that can be used to predict when it is beneficial for a species to decrease or increase α for the sake of growth. The revised model posits that higher values of α necessitate an increase in maintenance respiration R_M, which can be formulated as a function of α and the compensation point E_C, i.e. the light level where growth μ balances respiration. A threshold light level, E_{crit}, arises from this model, above which it is conducive to growth to have larger values for α, and below which smaller values are optimal. Predicted E_{crit} is consistent with the gap between clusters of under-ice, low α and open-water, high α points in the BEST observations.

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Molecular and Morphological Identification of Invasive Bullhead in Scotland

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

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

Are you a student? (Delete as appropriate): Yes

The European bullhead is a freshwater cottid that has been historically considered a single species with a European-wide distribution. Analyses of samples from a range of European locations has resulted in the redescription of European bullhead, traditionally classified as *Cottus gobio,* as a species complex (Kottelat 1997). Subsequently, a number of new *Cottus* species were established. The work of Freyhof *et al.* (2005) led to the reclassification of bullhead in English waters as the newly described *Cottus perifretum*, not *C. gobio* as traditionally reported in UK publications and policy documents. To date, no study has examined bullhead specimens from the two inhabited catchments in Scotland.

Bullhead is native to southern England, where it is protected under Annex II of the EU habitats directive, but considered invasive in Scottish waters. It was first recorded in Scotland in the 1960's (Maitland 1977), and has since been documented throughout most of the Forth and Clyde catchments. Its presence is likely a consequence of anthropogenic introduction, through use as live bait in recreational angling. The rich waters of the Forth and Clyde river catchments are now home to dense populations of resident bullhead. Shared habitat and dietary preferences between bullhead, native stone loach and native juvenile salmonids suggests a prospective niche overlap that could lead to competitive exclusion. Incidences of adult bullhead preying upon salmonid eggs have also been documented. Established bullhead populations outside of their native range are therefore considered detrimental to native fish.

Bullhead's current designation as invasive infers the need for careful monitoring of Scottish populations. Current protocol requires active eradication of individuals found in Scottish rivers, due to their perceived threat to native fish. However, the legislation that concerns management of bullhead throughout its natural range in England and Wales - and its invasive range in Scotland - is based on the presence of the now reclassified *C. gobio* species. An updated species management protocol will be needed to address this taxonomic shift.

The isolated bullhead populations established in Scotland have been neglected in the taxonomic overhaul of *C. gobio*. We therefore investigated the morphological and molecular characteristics of Scottish bullhead to establish whether the species located in the Forth and Clyde catchments is genetically and morphologically similar to *C. perifretum*. Phylogenetic analysis was conducted using DNA isolated from the muscle tissue of individuals from four rivers in the Forth catchment and one tributary of the River Clyde. We aligned and compared the obtained COI sequences with other *Cottus* COI sequences using maximum likelihood analysis. Morphological characteristics were also examined and compared with traits documented in the *C. gobio* species complex. These results allowed us to revise the taxonomic classification of the Scottish bullhead.

Acknowledgements

We gratefully acknowledge MASTS for funding this work, the Forth Fisheries Trust for fieldwork assistance, and Dr William Yeomans of the Clyde River Foundation for providing samples from the River Clyde catchment.

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The Continuous Plankton Recorder (CPR) Survey: Indicators of change in Scottish 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.

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

Climate change and anthropogenic activities are exerting significant pressures on the marine environment at an unprecedented scale, affecting the functioning of our seas. Recognising these pressures and understanding their effects is essential in the development and implementation of effective environmental management, to promote healthy and ecologically diverse seas. Plankton, the base of the marine food web, offer important indicators of change; they are generally not a harvestable resource, have a rapid turnover and are highly sensitive to changes in their environment. The Continuous Plankton Recorder (CPR) Survey has been operating since 1931, using a mechanical sampling instrument to monitor near surface plankton communities across large geographic distances. The sampling and analysis methods have remained relatively unchanged, giving a long-term consistent database of plankton observations. The resulting multi-decadal time-series of plankton is a powerful tool in disentangling long-term changes, such as regime shifts, from shorter, seasonal cycles and natural rhythmic variation.

Data from the CPR Survey have revealed changes in the composition and abundance of plankton communities in Scottish waters and beyond. In the North Sea, one of the Survey's oldest and most consistent sampling route occurs, between Aberdeen and Shetland, where monthly samples have been taken almost without interruption since its inception. Here data collected from this area are presented, as an update to previous work using plankton data as 'Indicators', which investigates the changing distribution and seasonal timing of two species of copepod (*Calanus finmarchicus and C. helgolandicus*) from 1958 to 2015.

In addition to driving forward scientific understanding, SAHFOS is committed to applying knowledge gained to answer questions by end-users, providing valuable insight to environmental changes from a business perspective. Understanding and predicting which plankton occur where and the timings of the blooms are of interest to oil and gas companies operating in the North Sea, as these factors may influence the efficacy of their filters. By providing the industry with such knowledge, appropriate management action can be taken to maintain business production. Here we show an example of such work, with the identification of bloom-forming taxa, and the seasonality (and therefore the peak in abundance) of potential nuisance plankton.

One of the key strengths of the CPR is the consistent methodology, but in addition to traditional techniques, modern methods can also be applied. These can be in the form of novel instrumentation – the CPR is a stable platform that can support various instrumentation and sensors (i.e. Flurometers, Star Oddi's). In addition, cutting edge analysis techniques can be used on CPR samples, for example genetic analysis, flow cytometry and automatic recognition techniques. Here we highlight a recent advance in research capability through the introduction of the MacroCam. This state of the art instrument employs imaging analysis techniques to rapidly identify zooplankton samples, offering near real time, complementary data.

This e-poster presents findings from the CPR Survey in Scottish waters, highlighting the use of plankton as indicators of environmental change, and evidences how such knowledge can be translated into useful and applicable information to support partnerships with business and industry.

The ECOMMAS project: using passive acoustic monitoring to assess the distribution of harbour porpoises around eastern Scotland

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

E-poster abstract

An understanding of the distribution of marine species is essential to guide effort for their conservation. Offshore renewable energy developments pose a potential risk to marine mammals in Scottish waters, e.g. from injury caused by noise generated during the piled installation of wind turbines. European Union member states are required to establish Special Areas of Conservation for harbour porpoise *Phocoena phocoena*, but identifying important regions for these small and elusive marine mammals poses considerable challenges. Due to their size and behaviour, visual monitoring of porpoises is difficult and is restricted to daytime and calm conditions, so Passive Acoustic Monitoring (PAM) offers an alternative method of study.

Since 2013, Marine Scotland Science has deployed cetacean click detectors (CPoD, Chelonia Ltd) at 30 locations between Latheron, Caithness and St Abbs, Berwickshire, covering a large portion of the east coast of Scotland. These devices are moored near the seabed and autonomously record dolphin and porpoise echolocation clicks during deployments of up to four months. These PAM data produce a record of presence/absence of dolphins and porpoises during the deployment, although they cannot distinguish between dolphin species. The aim of this work is to characterize the habitat preference of harbour porpoises, the most abundant cetacean species in the North Sea.

CPoD data have also been collected at sites in the inner Moray Firth by the Lighthouse Field Station, Cromarty (University of Aberdeen) since 2008. Our collaboration and sharing of data extends the scope of our analyses to better identify oceanographic drivers of porpoise distribution, using data collected at over 100 sites.

Following four years of data collection we present some preliminary results to describe the distribution of porpoises around the east coast of Scotland. In due course we hope that these data can be used to inform marine spatial planning, for example to identify potential protected areas for the species, as well as informing environmental impact assessments for industrial projects such as port construction and marine renewable energy developments.

New Accessible Devices for Aquatic Particle Motion Measurements in Bioacoustic Studies

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Anthropogenic noise has profoundly changed the acoustic environment of aquatic habitats, with growing evidence that even a short exposure to man-made noise sources can negatively affect organisms. To generate a more complete understanding of the ecosystemic effects of this noise, animals from all trophic levels must be investigated, and the sound field they are exposed to characterized.

To accurately describe the noise experienced by marine organisms, two components need to be measured, the sound pressure and the particle motion. The latter is detected by many fishes and all marine invertebrates. Although devices for measuring the particle motion in water exist they have a number of constraints, e.g. their size, cost, availability, that have prevented their use in most aquatic bioacoustical studies to date. The lack of particle motion data (i.e. accessible devices) has recently been highlighted as a major shortcoming in aquatic sound research (see reviews by Hawkins *et al.* 2014, Nedelec *et al.* 2016)

The aim of this work was therefore to create a new compact and low cost particle motion sensor to allow both water borne and sediment borne particle motion measurements during laboratory and field studies. Three commercially available accelerometer models were chosen representing a range of price points (Here labelled type 1, 2, and 3). Each accelerometer was mounted into a custom-made waterproof housing. These sensors were calibrated, and their performance (accuracy, precision, noise floor, frequency response), relative to that of a reference accelerometer, assessed on a shaker table. Finally the sensors were compared in terms of cost-benefit.

The most accurate accelerometer for measuring the particle motion was the Accelerometer Type 1 (£1200, Piezoelectric, 5.4gm, 10.2mV/(m/s^2), 49 (µm/s^2)/√Hz @100Hz) which was also the highest cost accelerometer tested. Aside from the price however, this sensor had an ease of use constraint, since it requires coupling to a computer through costly and less readily available systems, such as the Brüel & Kjær Pulse, or National Instruments capture cards.

Accelerometer Type 3 (£3.50, MEMS, 0.04gm, 67.32mV/(m/s^2), 490 (µm/s^2)/√Hz @100Hz) was the second best sensor tested, and comes in at the lowest cost. It was also able to accurately measure the particle motion, although not as precisely as Accelerometer Type 1. This low cost sensor can easily be attached to an M-Audio interface and the signals analysed in Matlab.

Accelerometer Type 2 (£125, Piezoelectric, 3.0gm, 5.1mV/(m/s^2), 624 (µm/s^2)/√Hz @100 Hz) failed to measure the particle motion of underwater noise. It was unfit for purpose since this accelerometer was originally designed to work with large forces rather than the smaller particle motion movements. It should however be noted that other models of this accelerometer with different sensitivities may perform better.

Following our construction details, both the high- and low-cost sensors can be replicated by anyone working in the field of aquatic noise, allowing the inclusion of this important noise metric in forthcoming research. More accurate presentations of sound fields, and the ability to compare noise exposures across studies can then be made, enabling advancement in this field of research.

Acknowledgements

We would like to acknowledge the MASTS Coastal Zone Forum for their financial support, PCB Piezotronics for their support with equipment purchase, and the Robin Mackenzie Partnership for advice and equipment loan.

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The people who want to facilitate new marine industries; Agents for Change and the development of wave energy in Scotland.

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Area being submitted to: 1) General science session

Are you a student? No

The Highlands and Islands Region of Scotland has the potential to add to Scotland's renewables portfolio due to its high energy marine environment which led to the expansion of the wave and tidal industries in recent years. Nevertheless, to date, there has been limited research conducted on the social systems around marine renewable energy development, excluding offshore wind. In answer to this deficit, this study explores the well-established concept of agents for change (AFCs), within the context of the wave energy sector in Scotland. AFCs are people who can co-ordinate and facilitate change through their skills, power, and leadership (Lunenburg, 2010).

This project looks at the role of AFCs by examining their behavior, motivation and the consequences of their actions in relation to the development of wave energy to over a 3 year time period. Two case studies, Lewis in the Outer Hebrides, and Orkney, were chosen based on their localities and the interest that they have garnered from wave energy developers due to their high energy marine environments. A grounded approach was taken data collection and a social power analysis conducted in order to find AFCs working within or closely with the wave energy industry that were not part of structured or hierarchical organisations. Emergent themes revealed the barriers that the AFCs faced, and the reasons behind their drive to establish wave energy in the case study sites.

The most noteworthy barrier to wave energy development at the case study sites and to the work that the agents for change were doing was in the form of a complex dynamic between private financial investments in the sector, the national grid, national energy policy, and the technology itself. Financial investment in the wave energy sector was found to be limited by the national grid infrastructure and the slow rate of technology advancement. In turn, technology developments and public investments in national grid infrastructure were restricted by the lack of private investment. These complexities were found to be exacerbated by the changeable nature of UK energy policy and the political climate around the Scottish Independence Referendum in 2014.

On the other hand, the AFCs were found to act as catalysts for the wave energy industry through their skills, perseverance and visionary approach to facilitating wave energy development, despite significant barriers. Their roles included progressing initial ideas into actual projects, developing local supply-chain, and promoting positive community involvement through open dialogue and effective communication. The motivations of the AFCs are explored by examining their core beliefs and values. These were found to relate to their psychological dispositions of self-efficacy, self-determination, and optimism as well as their relationship with place.

The role of the AFCs in the projects that they were working on transformed as the projects progressed – shifting from visionary leaders and facilitators to advisors. These steps are described and compared to organisational change process models, namely Lewin (1958) and Kotter (1995) showing that these models can be applied outside of organisational change management. The results of this study contribute to understanding how individual AFCs operating outside of the formality of hierarchical organisations can play a role in the development of novel, marine energy technologies.

Acknowledgements

Funded by the European Social Fund. Many thanks to the participants in this research and to Lews Castle College, UHI; Charlie Greenwood, Arne Vögler, and James Morrison.

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The Lyell Centre - a new research centre for earth and marine science and technology

Area being submitted to (delete as appropriate): 1) General science session
Preferred presentation medium (delete as appropriate): (ii) poster
Are you a student? (Delete as appropriate): No

Heriot-Watt University and the British Geological Survey (BGS) have joined forces to create a new research centre for earth and marine science and technology. Based at Heriot-Watt's Edinburgh Campus, the Sir Charles Lyell Centre (the Lyell Centre) will become one of Europe's leading centre´s for research and expertise in the earth and marine sciences. Jointly funded by UK and Scottish funders; Natural Environment Research Council (NERC), Scottish Funding Council (SFC) and Heriot-Watt, The Lyell Centre will promote innovative research at the core of geoscience, marine and terrestrial ecology, computing, mathematics and engineering. The Lyell Centre's research themes are clustered into two main areas: Applied Geoscience (e.g., conventional exploration, enhanced oil recovery, subsurface monitoring, petroleum basin analysis, geophysics) and Ecosystems Science (e.g., marine ecosystems in a changing ocean, marine pollution and ecotoxicology, terrestrial ad freshwater ecosystems and biogeochemistry). This poster will present the main research focus areas, and the existing and future facilities at this new centre for earth and marine science and technology.