Citizen-science monitoring of harbour porpoises in Shetland

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Harbour porpoises (*Phocoena phocoena*) are frequently observed around Shetland but there are significant data gaps around the fine-scale use of sites which impedes the introduction of conservation measures for this species.

Harbour porpoise occur year-round in small groups around Shetland's coast but unusually large aggregations of 500 to 100 individuals have also been observed in some locations. However, porpoise sightings are under-reported and there is little data on the seasonal variation of sightings. Research into the social dynamics of this species is limited, partly due to difficulties in observing the surface behaviour of this species.

To address these data gaps, a citizen-science project was established to identify the temporal and spatial variability of harbour porpoise presence and use of coastal areas around the Shetland Islands, and to improve understanding of the behavioural interactions occurring when large aggregations are observed.

Shore-based observations were collected in collaboration with the Shorewatch programme[1] organized by Whale & Dolphin conservation at three sites where high numbers of porpoises have previously been reported (Mousa Sound, South Nesting Bay, and Quendale Bay). Behavioural footage was collected by local drone pilots with experience of videoing cetacean species.

Shore-based observations show that higher numbers of porpoises are observed in the autumn and winter months, with smaller groups observed over a wider area during the spring and summer months. Rushing behaviour was observed from the shore at multiple locations around Shetland, but for shore-based observations viewing distance and angle was insufficient to provide detailed observations of this behaviour. Drone footage has shown that this rushing activity includes mating behaviours which have been seldomly reported on in the literature. Belly displays can be seen in footage from October 2019, with rushing behaviour preceding mating attempts observed in footage from February 2022. This is the first known drone footage of porpoise mating collected, highlighting the importance of this area for porpoise populations in the northeast Atlantic.

Data from this project will contribute to informing marine planning and marine protected area designation and management to aid in developing conservation measures for this protected species.

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Native oysters: The balance between stress and benefit of wastewater when restoring oysters in the Anthropocene.

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Our native European oysters (*Ostrea edulis*) have been largely eradicated from our coastal waters for the last 100years (Fariñas-Franco et al., 2018). In this time the seas around the UK have changed. For better and for worse in different cases. For example, reported spill events from combined sewage overflows (CSOs) have doubled since 2016 according to data published by (DEFRA, 2022). With the current momentum behind restoration of oysters around the Europe, often in areas with dense populations and industry, it is very important to understand how oysters will manage conditions in the 21st century. It is often claimed that native oysters will improve water quality in areas with poor conditions, however, while evidence exists supporting this for other bivalves (Smaal et al., 2018, Dennison and Preston ,2001), there is a lack of research in this area for *O.edulis*. If a robust body of research in this area is generated it creates significant funding potential from industry around Europe for oyster restoration.

As part of the present project, novel techniques will be applied to the study of Ostrea edulis. These include measurements of stress markers for DNA damage and oxidative stress, proteomic stress markers and analysis of stable isotopes to determine feeding behavior. Experiments in laboratory aquaria and in the field will be carried out to address whether: 1) there are toxic effects of exposure to wastewater for the oysters; 2) whether there are nutritional benefits of wastewater that may enhance growth and proliferation of oyster reefs, and 3) whether there are exposure levels at which toxic effects and benefits trade-off against each other. In all these areas, there are significant knowledge gaps with respect to *Ostrea edulis* (zu Ermgassen *et al.*, 2020). Understanding these three factors will be critical to models of site suitability for restoration projects.

Research will be conducted in two main field locations in Scotland, The Dornoch Firth and, The Firth of Forth. Both sites hosted oyster beds which were fished out in the mid-1800s and have a starkly contrasting history of anthropogenic impacts. The Firth of forth has a long industrial history with many historical sources of pollution in its catchment. The Dornoch Firths only significant industry has been the Glenmorangie Distillery which produces very low impact wastewater due to the use of an anerobic digester pre discharge. (Fariñas-Franco et al., 2018; Smout and Stewart, 2012). These two sites have a rich variety of case studies to form experiments.

The present work will present the rationale behind the project and the work planned, in the context of the UN Decade on Ecosystem Restoration and rapidly emerging oyster habitat restoration activities with their associated claims of Ecosystem Services.

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Man-made structures in the North Sea: potential blue carbon sites

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Continental shelf sediments sequester significant amounts of carbon and can thereby help mitigate global climate change. For decades, the North Sea shelf area has been modified through anthropogenic pressures including oil and gas (O&G) extraction, bottom trawling, and, more recently, renewable energy installations. Despite extensive research on the effect of man-made structures on the marine environment, there remains a research gap regarding their effect on shelf sediment carbon storage through their operation and following decommissioning. The presence of man-made structures, especially O&G platforms, provides de facto marine protected areas which could play an important role in carbon sequestration due to a lack of sediment disturbance once established. However, the majority of O&G structures in the North Sea are approaching mandatory decommissioning. It is therefore vital to quantify the carbon stocks and sequestration potential of benthic sediments located around man-made structures during their operational and decommissioning phases to (i) provide a robust 'baseline' for North Sea continental shelf carbon stocks, and (ii) determine if the sediments around O&G structures are a carbon source or sink. This study will evaluate the quantity, age, and origin of benthic carbon stocks surrounding man-made structures (O&G and renewables) in the North Sea, through organic and inorganic carbon analysis, 210Pb dating, and stable isotope sediment analysis. Outputs from this study could help inform future decommissioning legislation by highlighting potential carbon loss from destructive removal of structures and provide supporting information for carbon budgets of the North Sea.

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Bidirectional interaction between phytoplankton diversity and biomass in the San Francisco Bay estuary, USA

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Rapid biodiversity loss threatens ecosystem functioning and its ability to provide goods and services. Particularly, for system productivity, these losses have the potential to rival even the effects of global environmental changes such as elevated CO_2, drought and nitrogen deposition [1, 2]. Marine phytoplankton contribute to half of the primary production on Earth [3], but the overall effect of phytoplankton diversity on productivity, and vice-versa, remains poorly understood. Biodiversity can affect ecosystem processes via two main mechanisms: i) selection, where species with a particular trait are favored and become dominant; and ii) complementarity: where niche differentiation and/or facilitation between species enhances the community's productivity [4]. These mechanisms can affect the strength and direction of a system's productivity and are generally supported by both experimental and theoretical studies in terrestrial ecosystems [4, 5, 6]. In natural pelagic marine environments, information regarding diversity-productivity relationship is still limited and the shape of the relationship can vary according to spatial scale and diversity metrics used. Furthermore, natural planktonic systems are under physical and environmental forcing [7].

Our study aims to assess how phytoplankton trait diversity (i.e. size) affects biomass, as a proxy for productivity, in a highly dynamic estuarine region by analyzing a large data set (>25 years) in the San Francisco Bay (SFB, USA) area. Through its connection between land and ocean, estuarine ecosystems such as the SFB area, are under the effect of river discharge, urban and agricultural runoff, nutrient and environmental variability. As such, the SFB system provides a great setting to investigate the effects of environmental variability on ecosystem productivity, particularly coupled with the long period of observations. According to our results, size diversity and exponential Shannon index were the best diversity metrics to predict phytoplankton biomass. Also, nutrient supply alone did not explain the variability in biomass production in the region and using them as single predictors of productivity, may not be sufficient to explain the patterns of diversity and productivity. In the future, we will use these results to inform more complex models that are capable of accounting for the multivariate nature of natural phytoplankton communities under anthropogenic pressure.

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The resilience of wild UK amphibians to freshwater salinisation

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The salinisation of freshwater ecosystems is a widespread threat to global biodiversity and ecosystem health. Salinisation occurs when excessive salt, most commonly sodium chloride (NaCl), enters a freshwater ecosystem. The two main causes of salinisation of freshwater are road de-icers and seawater inundation, itself caused by climate change induced sea level rise and/or increased frequency of extreme weather events such as storms (Canedo-Arguelles et al., 2018). Freshwater vertebrates, including amphibians, typically experience negative impacts of salt pollution, with effects ranging from mortality to developmental delays and abnormalities. Apart from a couple of known salt tolerant species, laboratory exposures have demonstrated that many amphibian species are negatively impacted by salt pollution. However, despite sporadic reports of amphibians being found in coastal pools, resilience of most amphibian species in the field are not well understood, with the genetic mechanisms of this resilience being largely unknown (Hopkins & Brodie, 2015). Environmental DNA (eDNA) analyses were used to infer the distribution of UK amphibian species inhabiting saline or brackish environments. Species-specific primers for the detection of the six native amphibian species (common toad, *Bufo bufo*; natterjack toad, *Epidalea calamita*; common frog, *Rana temporaria*; great crested newt, *Triturus cristatus*; smooth newt, *Lissotriton vulgaris*; palmate newt, *Lissotriton helvetica*) and the invasive alpine newt (*Ichthyosaura alpestris*) were developed and optimised to detect the target species in a water sample. By extracting tissue and cross-testing primer pairs against each species, the specificity of each primer pair was verified.

Water samples from 56 different ponds in coastal Scotland, Northern England and Ireland were collected by volunteers. A citizen science approach was used whereby volunteers were recruited by through Froglife's volunteer network and through an advertisement in their newsletter. The volunteers provided three water samples, spaced three weeks apart, starting when they first observed spawn/adult amphibians in their respective water bodies. In addition to the eDNA analyses, the salinity of the water samples was also recorded in order to align species distributions with actual salinity levels. The salinity data was then used to characterise sites using QGIS and a cluster analysis in R. In total, 5 clusters were generated, and sites were grouped in accordance with their salinity, with pH, altitude, distance from the coast and TDS included as co-variates. Clusters grouped sites in salinity ranges of 0-0.05 PSU, 0.6-0.1 PSU, 0.1-0.5 PSU, 0.51-1 PSU and 1+ PSU. Species distribution data coupled with the environmental data will allow us to investigate the extent of amphibian occupancy of coastal water bodies in the UK as well as the tolerance of individual species to salinity *in situ*.

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Identifying the Chemical Triggers for Marine Snow and Oil Snow Formation

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The formation and subsequent sinking of marine snow (MS), and marine oil snow (MOS) following a marine oil spill has been widely accepted as a vertical transport mechanism of organic carbon and chemical pollutants to the seabed. MOS is of particular importance during accidental oil spills as a natural mechanism removing contamination from the water column. This mechanism removed an estimated 14% of the crude oil from the water column after the 2010 Deepwater Horizon spill. Recent studies have implicated microbially- produced extracellular polymeric substances (EPS) – a 'sticky' amorphous polymeric matrix - in which particulate matter and dispersed oil droplets can become entrained to form MS and MOS, however the physical and chemical qualities of EPS required for MS and MOS formation have not yet been fully elucidated.

EPS are a highly diverse class of molecules, and many oil- degrading marine bacteria are known to produce anionic EPS, which acts as a biosurfactant that breaks up oil droplets and thereby increase their relative surface area which enhances biodegradation. This is thought to be a trigger for MOS formation, however other characteristics of EPS, such as molecular size, protein to carbohydrate (P:C) ratio and acidic polysaccharide content have yet to be defined as potential triggers in aggregate formation in the ocean.

Using a roller- table microcosm setup containing microbial polymers or commercially sourced polysaccharides, we investigated the chemical characteristics, polymer concentration and other characteristics of EPS required to trigger MS and MOS formation. This included assessing the size and morphology of formed aggregates. These experiments involved incubations in the absence of biotic factors in order to eliminate biological influences in MS and MOS formation, and thus help identify the physical-chemical properties of EPS that triggers their formation. This work is expected to feed into models predicting carbon flux, including its sequestration, to the seafloor, and further improve our understanding of the ocean's biological pump.

Exploring the community structure of seaweeds attached to oyster reefs and how these two biogenic habitats interact with each other in terms of biodiversity.

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This study sets out to determine the relationship between oyster reefs and their associated marine native seaweeds. Within that remit, this paper compared seaweed community structure attached to oyster beds across three sites (Isle of Mull, Isle of Skye, and Loch Ryan). It also looked at both seaweeds and oysters associated fauna assemblage as an indicator of biodiversity. Several field surveys were undertaken between May and June 2022. Biological data were collected by snorkeling during low tide at each site. Once in the laboratory, seaweeds were weighted, and their biomass was used as proxy of abundance, whereas fauna communities associated to both seaweeds and to oysters were counted and sorted to family level. The seaweed community structure was significant different between Loch Ryan and Isle of Mull with Loch Ryan yielding the highest biodiversity ($p \leq 0.05$). Biodiversity was significant higher in oysters with higher biomass of seaweeds attached ($p \leq 0.05$). Finally, these two biogenic habitats combined (oysters and algae) had a significant greater biodiversity than seaweeds attached to a non-biogenic habitat ($p \leq 0.05$). The findings in this study highlighted the importance of actively restoring these two biogenic habitats since they can promote biodiversity through acting as ecosystem engineers.

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Exploring environmental chemical exposure in seabird chicks at two European breeding sites using a non-targeted analytical approach

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Marine habitats are affected by anthropogenic chemicals which are released from various point (e.g., factories, sewage treatment plants) and non-point (e.g., agriculture, urban runoff) sources. The accumulation of these environmental chemicals and biomagnification through food chains can pose serious threats to long-lived organisms that feed at higher trophic levels like seabirds (Furness and Camphuysen, 1997). Many seabird species are suffering from population declines (Dias et al., 2019) and therefore it is important to understand such threats in more detail.
Negative effects of certain chemicals on seabirds have already been shown and exposure can be particularly harmful during early life stages when many important developmental processes take place. However, most studies that address the effects and/or monitoring of environmental chemicals in wildlife only examine a specific set of chemicals using a targeted analytical approach.

The aim of this project is to establish the first comprehensive environmental chemical profiles of seabirds in a Scottish and a Belgian marine feeding seabird colony using a non-targeted analytical approach. The work focuses on early postnatal exposure of Arctic and common terns. The non-targeted approach used will help to identify unknown and overlooked chemicals and to reveal exposure variation within and between populations. The non-invasive collection of faecal samples will provide information on chemical exposure through diet.
In exploring chemical exposure profiles in Arctic and common terns new baseline knowledge will be generated to help assess possible sublethal effects of environmental chemical mixtures. These insights will contribute to protecting these important populations and allow action to be taken to mitigate negative impacts. In addition, this information can also help predict risks to other species foraging in the same habitat.

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ElasmoPower: Investigating the effects of EMF on elasmobranchs

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Electromagnetic fields (EMF) generated by subsea power cables from Marine Renewable Energy Devices (MRED) have been shown to be disruptive, both behaviourally and physiologically, to several benthic and pelagic marine species. However, to date, very little is known about the impacts of EMF on elasmobranchs, despite their commercial importance and key ecological role in benthic ecosystems.

The ElasmoPower project aims to determine the impacts of EMF exposure on several species of elasmobranchs native to the North Sea.

ElasmoPower is a multi-year project led by Wageningen University, and one of its phases is conducted at St Abbs Marine Station. That phase of the project aims to determine, in controlled laboratory conditions, the impacts of EMF exposure on several species of elasmobranchs (catsharks and rays), investigating both behavioural and physiological parameters.

A custom made generator and cable were developed in order to create an EMF comparable in strength to values measured around live cables in the North Sea. This state of the art equipment exposes one designated area of a 15m tank to alternating or direct current (AC or DC) EMF, therefore replicating the different types of export cables from MREDs. An array of cameras fixed above the tank allow for an uninterrupted observation of the animal's behaviour. Blood sampling and analyses of known stress parameters in elasmobranchs will give insights into potential effects on a physiological aspect.

The results from these laboratory experiments are hoped to contribute baseline data on how these species behave around artificial EMF, and will provide key information for future stages of the ElasmoPower project.