Microplastic Monitoring in the Orkney Islands, Scotland

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Microplastic contamination of UK coastlines is frequently associated with heavily urbanised and industrialised areas. However, remote locations such as the Orkney Islands, Scotland appear to be equally as contaminated, likely due to complex tidal patterns redistributing marine litter. This study examines the susceptibility of local fauna across both benthic and pelagic realms. Green shore crabs (*Carcinus maenus*) are the third largest fishery in Orkney. As an indiscriminate active predator and scavenger, numerous routes of exposure to microplastics exist from sediment, incidental ingestion and trophic transfer from prey items. Microplastics were observed in the guts of 98.7% of individuals (n=77), predominantly fibres (74%) across nine locations in Orkney and one in Shetland. Orkney is also an internationally important breeding site for harbour (or common) (*Phoca vitulina vitulin*a) seals, however an ~80% decline in population was observed between 2000-2013. Whilst microplastics are not thought to be a direct factor, concerns have been raised regarding impacts of microplastic ingestion on overall general fitness of seals. Seal fish prey (n=123 from nine species) are currently being examined to determine microplastic loading in the gut (n=101) and gills (n=109) from five locations around Orkney. This study will help to build a profile of biota contaminated by microplastics in this remote region with potential implications for fisheries and conservation.

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Distribution of microplastics along the Scottish coastline using standardized sampling and extraction methods

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Approximately 13 million tons of plastic enters the marine environment each year globally. Microplastics are particles less than 5mm that are spreading due to the action of multiple land and ocean-based sources. Due to their specific characteristics, microplastics have currently been found in all marine environments studied, in both sediments and water. In addition marine organisms are also affected by microplastics, with 680 species registered as having ingested plastic. Current literature indicates that most of the marine plastic debris originates from the terrestrial environment, and is contributing to the widespread distribution of microplastic along shorelines around the world.

This study has developed and adapted standardised, cheap and simplified protocols to sample three different elements (coastal water, intertidal sediment and mussels) along the Scottish coastline. This research has focussed on several locations based on factors such as, the proximity of populated and heavily commercialised areas, hydrodynamics and tidal height, to understand better their role in the distribution and abundance of microplastics. To assess these factors, two extraction techniques are applied to samples. Firstly, a canola oil based extraction technique is used to recover plastic from intertidal sediment; while secondly, a trypsin enzyme digestion is adapted to look at microplastics quantity in mussels. These protocols are simple to reproduce, efficient, fast and cheap allowing the study of microplastic pollution in a range of samples.

From all the six locations, 127 potential microplastics from 15 litres of seawater have been observed with an abundance of 6 to 12.8 potential number of particles/L so 6000 to 12800 potential particles per m^3. Monofilament fibres seem to be the most abundant shape recorded from the coastal water samples with 74%. Next work will focus on the extraction of microplastics from wild mussels and intertidal sediments. These results will potentially highlight that microplastics distribution around Scotland is heterogeneous for the three elements based on the hydrodynamics and seasons. In addition, microplastic abundance is expected to be higher in sheltered and heavily populated areas compared to active hydrodynamic and low populated sites for at least water and sediment.

This research will fill the knowledge gap regarding microplastics in Scotland and help our understanding about factors that play a role in plastic distribution and life cycle. Results of this study will be used to develop mitigation measures for microplastic pollution and to communicate the potential impacts to stakeholders including industry and government.

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Spectral remote sensing of marine plastic litter

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3) Microplastics and marine litter

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Remote sensing has the potential to provide long-term, global monitoring but for marine plastic litter it is still in its early stages. We developed a theoretical reflectance model of sunlight interacting with a sea surface littered with buoyant macroplastics, based on geometrical optics and the spectral signatures of plastic and seawater in the visible (VIS) to short wave infrared (SWIR) spectrum (Goddijn-Murphy et al., 2018). We studied macroplastics because wind driven ocean mixing removes buoyant microplastics from the top of the ocean surface where water absorbs most light in the NIR and SWIR. We therefore do not expect our approach to be successful for the detection of marine microplastics, but by studying macroplastics we study a major and increasing source of microplastics. We could use the anticipated correlation between microplastics and macroplastics to derive microplastic concentrations from macroplastic concentrations.

Our model describes a mathematical relation between sea surface fractions of marine plastic and light reflectance measurements in air. In our presentation, we will show and discuss the results of our experiments designed to test the model with measurements using a field spectrometer (the ASD FieldSpec Pro). We analyzed a few common kinds of plastic debris of different chemical composition including expanded polystyrene (EPS), high-density polyethylene (HDPE), and polyethylene terephthalate (PET). We show that not only composition of the litter items controls light reflectance (through their light absorption spectra), but also their transparency, shape and surface roughness. This has significant consequences for spectral remote sensing algorithms for marine plastic litter.

Acknowledgements

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Scottish Coastal Rubbish Aerial Photography (SCRAPbook): settling baselines for monitoring coastal rubbish.

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Increasing scientific, media and societal interest in coastal litter pollution, coupled with policy commitments such as the Marine Litter Strategy (2014) and the Marine Strategy Framework Directive (2008) highlight the importance of understanding our coastal litter problem. In response, the Scottish Coastal Rubbish Aerial Photography (SCRAPbook) project was established; a collaboration between the Moray Firth Partnership, the Marine Conservation Society and Sky Watch – UK Civil Air Patrol. The combination of these organisations provides a unique and novel skill set with the capability to deliver a comprehensive methodology for the identification, classification, mapping and cleaning of coastal litter.

Using aerial imagery collected from light aircraft, SCRAPbook will deliver a baseline overview of the distribution of coastal litter on Scotland's coasts for the first time. Continued monitoring will play a crucial role in developing our understanding of where, and why litter is accumulating and persisting on Scottish coasts. Such insight will play an important role in the realisation of clean, healthy, safe, productive and biologically diverse marine and coastal environments that meet the long term needs of people and nature (Marine (Scotland) Act 2010). Specifically, these data will inform more targeted, efficient cleaning activities for Scotland's beaches and coasts.

This presentation will summarise the methodology applied and present initial findings from the project. In addition, it will consider the potential to build upon the current scope of the project both in contribution to other scientific objectives and the longer-term scope and applicability of the methodology.

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Ingestion of plastic by fish: a comparison of Thames Estuary and Firth of Clyde populations

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Please note that abstracts should be broad and applicable to a wide audience.

This study compared plastic ingestion between pelagic and benthic fish populations from two UK watersheds: the Thames Estuary and the Firth of Clyde. Based on a preliminary study by McGoran et al. (2017), it was hypothesised that benthic flatfish would have ingested more plastic than pelagic species. The alimentary canals of 760 fish from twenty species were examined. Of these, fifteen had ingested plastic. In addition, the stomach contents of 116 *Crangon crangon* (brown shrimp), a key prey species of several of the fish in this study, were studied. Overall, 38% of fish ingested plastic, mostly fibres (88% of total plastics). Flatfish and benthic fish, however, did not ingest significantly more plastics than pelagic species (40% and 20%, respectively, compared to 28%). Despite no observed difference in plastic ingestion between fish groups, pelagic fish from the Clyde ingested significantly more plastic than similar Thames species (60% compared to 19% respectively). Microplastics were also found in the stomach of *Crangon*, but these had ingested far less plastic than predator species, such as the European flounder, *Platichthys flesus*. Only 6% of shrimp ingested plastic, with no individuals ingesting more than one piece of plastic. The most common polymers recovered were polyester and nylon, which are commonly used in the textiles industry. It is possible that many of the fibres in this study entered the estuaries through wastewater inputs and originated in domestic washing machines.

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Microplastics in marine mammals

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Plastic pollution represents a pervasive and increasing threat to marine ecosystems worldwide and there is a need to better understand the extent to which microplastics (plastic <5mm in size) are ingested by high trophic-level taxa, such as marine mammals, either via direct ingestion, or indirectly by trophic transfer from contaminated prey. Here we present the outcome of two linked studies investigating microplastics in marine mammals. Firstly, we sought to better understand trophic transfer by analysing sub-samples of scat from captive grey seals (*Halichoerus grypus*) and whole digestive tracts of the wild-caught Atlantic mackerel (*Scomber scombrus*) they are fed upon. Approximately half of scat subsamples (48%; n = 15) and a third of fish (32%; n = 10) contained microplastics (1–4). The use of captive animals allowed for increased contamination control and differentiation between directly and indirectly ingested microplastics. Our findings suggest trophic transfer represents an indirect, yet potentially major, pathway of microplastic ingestion for marine top predators. Following this, we sought to carry out a comprehensive assessment of microplastic ingestion in wild marine mammals by examining whole digestive tracts of 50 individuals from 10 species. Microplastics were ubiquitous with particles detected in every animal examined. The relatively low number per animal (mean = 5.5) suggests these particles are transitory. Stomachs, however, were found to contain a greater number than intestines, indicating a potential site of temporary retention. We investigated the relationship between microplastic abundance and factors, such as taxon, age-class, sex, length and cause of death. Further research is required to better understand the potential chronic effects of microplastic exposure on animal health.

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Plastic substances contained in offshore chemicals used and discharged during offshore oil and gas operations

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There is an increasing level of awareness of the risks associated with the presence of plastics and microplastics in the marine environment. Concerns associated with plastics have predominately focused on marine litter but there is now a growing interest in identifying other sources of plastic entering the marine environment and understanding the risks associated with those sources. In the UK, the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) has been undertaking studies to improve our understanding of the presence of plastic substances contained in offshore chemicals that are used and discharged during offshore oil and gas operations. This work has been undertaken by the Centre for Environment Fisheries and Aquaculture Science (Cefas) on behalf of OPRED.

In the UK the use and discharge of chemical products is regulated under the Offshore Chemical Regulations 2002 (As Amended) ("the Regulations"). The Regulations implement OSPAR Decision 2000/2 on a Harmonised Mandatory Control System for the Use and Reduction of the Discharge of Offshore Chemicals (as amended by OSPAR Decision 2005/1). The Decision details an approach to the consideration of chemicals use and discharge in offshore activities. In addition to requiring the comprehensive testing of chemicals, the Decision requires the pre-screening, ranking and hazard assessment and risk management of chemicals, and the substitution of certain chemicals by permit holders for less hazardous alternatives.

Cefas, on behalf of OPRED, pre-screen and rank the chemicals in accordance with the OSPAR Decision, prior to including the chemicals in the list of notified chemicals, referred to as the Offshore Chemical Notification Scheme (OCNS). Chemical suppliers therefore must register their chemical product under OCNS before a product can be considered for use by an operator during offshore oil and gas operations. Once that product has bee registered an operator can apply to use and discharge the chemical product under a chemical permit and an operator is required to undertake a risk assessment as part of a permit application.

This presentation will provide an overview of our current understanding of plastic and microplastic substances contained in offshore chemicals and explores the next steps for addressing any potential risk. In addition, an overview of the work to date that the UK has contributed towards the OSPAR Offshore Industry Committee will be provided.

Acknowledgements

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Litter Dynamics on a Mid-Latitude, Macro-Tidal Beach

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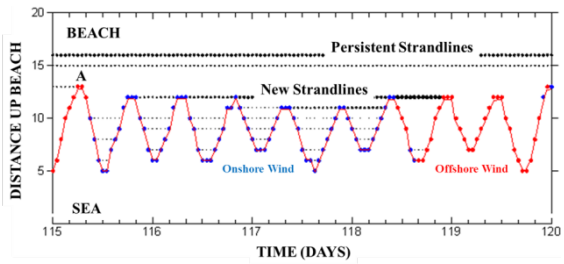
There is a growing realisation that plastic pollution in our oceans is a major concern. Globally efforts are being made to understand the sources, fate and impact of marine plastics (Galgani et al., 2015). Regionally, in Europe, the Marine Strategy Framework Directive (MSFD, 2008/56/EC) requires Member States to monitor the abundance and composition of marine plastics and litter in their waters (OSPAR, 2017). Within Scotland, efforts are underway to understand marine plastics within our own seas, and this study is a contribution to that effort.

Macroplastics (>2.5 cm) and microplastics (<5 mm) are now ubiquitous in the marine environment throughout the global oceans, and their impact on biodiversity and ecosystems is increasingly being realised (e.g. Derraik, 2002). Plastics have been found in the water column, in sea-bed sediments, in sea ice, ingested by many forms of biota and floating on the sea surface (Derraik, 2002; Galgani et al. 2015). Floating marine litter can be washed up on adjacent coasts, foreshores and beaches by winds and currents.

Macro beach litter is perhaps the element of the marine plastics problem that is most directly experienced by the general public who use our coasts. Beach litter stimulates concern in users of beaches, reduces their amenity value and creates economic costs to coastal communities who manage the litter. Surveyed quantities of beach litter have been used as indicators of environmental levels of plastic pollution, and globally there is a growing societal movement for beach cleans and litter-picking activities (e.g. Ryan et al., 2002).

A simple model of how floating marine plastic litter is blown onto a beach, and then moved on and off the beach by winds and rising and falling water levels is implemented in a computer simulation. When this simulation is driven using observed water levels and winds obtained close to a mid-latitude, macro-tidal shelf sea beach (Aberdeen beach, northeast Scotland, within the North Sea) it requires a realistic offshore plastic litter density in order to reproduce average quantities of observed beach litter. The simple conceptual model of how the sea and winds deposits and erodes litter onto a macro-tidal, mid-latitude beach illustrates aspects of litter flow that could not be quantified using presently available observations. The model leads to a new coastal litter budget for the western boundary of the North Sea and emphasises the importance of quantifying litter fluxes as well as standing litter densities.



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