Quantifying the habitat complexity of the priority marine feature "maerl" using two-dimensional imagery

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Our study, suggests that maerl, an important 3D benthic habitat for diversity, can be quantified in terms of its structural complexity using 2D benthic imagery and 3D metrics of size.

Maerl is a collective name for calcareous coralline algae that support rich biodiversity with the complex three-dimensional (3D) structures they build on the seafloor. Maerl beds are a threatened and declining habitat in UK waters, and there is a drive to better understand them to manage them effectively (Barbera *et al.*, 2003; Steller *et al.*, 2003; Hall-Spencer *et al.*, 2006). This research explores the potential to use region-based Convolutional Neural Network (R-CNN) trained by NatureScot to classify live maerl, and attempts to quantify the structural complexity of maerl using two-dimensional (2D) images. We first assess whether the R-CNN is operational for the classification of live maerl using images of varying quality from different sites in Scottish waters. A manually annotated dataset of images of maerl was collated and R-CNN classified images of maerl were evaluated on this dataset. From a set of 18 images at 9 sites, the average score of similarity between annotated and R-CNN classified images was 27%, with the R-CNN predicting far less complexity of maerl across sites. These results strongly suggest that the R-CNN trained by NatureScot cannot accurately or precisely predict live maerl and requires further training before confirmed operational. This demonstrates the need for a high number of diverse images when training a deep learning model.
We propose a novel method for the quantification of the 3D structural complexity of maerl using 2D images. Maerl samples were analysed in terms of their 3D complexity using laser scanning techniques and 2D complexity using image analysis. The results show a strong relationship between 2D and 3D metrics of complexity across a diverse range of maerl branching structures. The relationship demonstrates that it is possible to make reliable estimates of 3D metrics for analysing complex branching structures of maerl. This replicable and scalable technique can be used to assist NatureScot with the monitoring of maerl beds in Scotland.

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North Sea 3D – Image analysis for measuring biofouling biomass from industry ROV footage

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Continued developments in marine infrastructure have given rise to an increasing number of Offshore man-made structures (MMS). This has become known as 'ocean sprawl'. These structures are quickly colonised, becoming artificial reefs.

To understand the role of these structure in marine systems, the colonising organisms need to be quantified, both by species and biomass. To date, this quantification has been limited by the difficulties in performing the studies on the scales needed.

In the North Sea 3D (NS3D) project we use existing footage collected by offshore energy operators with remotely operated vehicles (ROVs). This footage already exists in abundance since structures are routinely surveyed by ROV for maintenance purposes. We use recent advances in image/video processing - Structure from Motion (SfM) Photogrammetry and semantic segmentation by convolutional neural networks (CNNs) to generate 3D images of marine growth classified by taxa from standard 2D-video ROV footage (Figure 1). These are then calibrated and used for biomass quantification.

In this poster, the methodology of the associated image analysis is discussed, including the challenges of underwater photogrammetry and species auto identification, particularly when ROV footage is not taken specifically for this task. A 3D headset will accompany the poster, letting attendees 'walk around' the 3D dataset's we have generated.

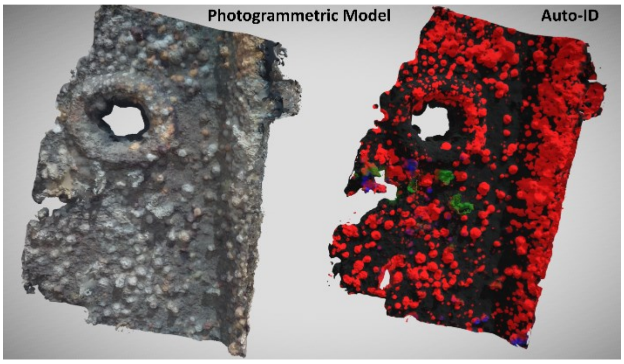

*Figure 1- **Pilot 3D model and Auto-ID annotation from North Sea ROV footage:** data supplied by Marine Scotland Science/Moray First Marine. Model of the bow of the wreck of the San Tiburcio, Moray Firth, Scotland.*

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Digital Condition Monitoring for Wider Blue Economy

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In the process of decommissioning energy systems, condition monitoring is crucial. It can make the health status of offshore oil and gas installations and pipelines, wind farms, etc., transparent to policymakers and stakeholders and aid them in creating a better repurposing plan for the assets that will be decommissioned to create a sustainable ocean economy. In most cases, condition monitoring calls for experienced engineers to perform on-site testing, which raises labour costs as well as commuter carbon emissions (J. Hasan & Kim, 2019; Rai et al., 2021).

A revolution in decarbonized and sustainable decommissioning may result from further digitalization of condition monitoring to address this problem. We can gather and manipulate enormous amounts of real-time data and create a simulated representation of physical assets, then quickly predict their health conditions by combining artificial intelligence, the Internet of Things, and augmented, virtual, and mixed reality techniques (M. J. Hasan et al., 2019; Yan et al., 2018, 2020, 2021).

Digital condition monitoring has social and economic benefits, including:

1. Deliver a plausible innovation that can be successfully used in other UK industries.
2. Open a new high-tech talent demand market in the UK
3. Reduce carbon emissions in decommissioning missions, especially for the marine environment.
4. Reshape the offshore marine environment to benefit the blue economy.
5. Reduce costs across the decommissioning chain, from design and manufacturing to purchasing and maintenance.

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Sources, Sinks and Subsidies of Carbon in Coastal Saltmarsh Habitats

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Abstract

Saltmarshes are vegetated intertidal ecosystems that support unique biodiversity and provide coastal protection from storms and floods, alongside other ecosystem services[1]. They are extremely efficient organic carbon (OC) sinks which may contribute to mitigating climate change[1]. Their soils can store OC for up to millennia as low oxygen, sulphidic conditions limit organic matter (OM) decomposition[1]. Saltmarshes accumulate OC through *in-situ* (autochthonous) production by vegetation and benthic microalgae, and the accumulation of marine and terrestrial material (allochthonous) during tidal inundation[2].

A key blue carbon challenge is empirically understanding the sources of OC accreted into and respired from saltmarshes, to determine the proportion of the total OC pool which is additional (from *in-situ* sequestration) or prevented emissions (through increased preservation of allochthonous OM)[2]. Alongside ^{13}C and ^{15}N isotopes, radiocarbon (^{14}C) analysis/dating can be used to determine the sources of saltmarsh surficial soil OC[3]. 36 ^{14}C samples have been granted for this research by NEIF (NERC Radiocarbon Laboratory) for the bulk soil and allochthonous sediment from three contrasting Scottish saltmarshes: Skinflats (estuarine), Loch Laich (embayment), and Kyle of Tongue (loch-head). The objective of dating these samples is to gain an understanding of the age and sources of the autochthonous and allochthonous OM accumulating in these saltmarshes. The contributions of OC sources impact the response of the saltmarsh carbon cycle to pressures, such as increases in temperature induced by climate change[2]. Understanding which saltmarshes are the most efficient/resilient OC stores could, for example, inform protection/restoration measures for climate mitigation (see https://www.theccc.org.uk/publication/briefing-blue-carbon/).

This e-poster will highlight how a novel method for measuring ^{14}C of respired greenhouse gases (GHG) can help address this challenge, when compared to bulk soil and sediment ^{14}C. This will be done through Q_{10} incubation experiments to assess how saltmarsh soils may respond to abiotic factors such as temperature change. It is hypothesised that in ambient temperatures the younger, more labile, autochthonous OM will be preferentially decomposed, but at elevated temperatures the aged, allochthonous OM pool will increasingly contribute to the respired GHGs.

This work will contribute to a growing evidence base for emissions from saltmarshes, and the sources of OC accreting in their soils, which is vital for understanding how they cycle carbon and their ability to mitigate climate change. It has the potential to help build saltmarsh carbon cycle models and inform work to include saltmarshes in the UK's GHG inventory.

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Using Machine Learning to identify Pecten maximus (King Scallop) and Aequipecten opercularis (Queen Scallop) in their natural habitat

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The main objective of this study is to develop an algorithm, which will reliably detect King and Queen scallops in their natural habitat. This will aid the development of more efficient and timely fisheries management with minimal interference to seabed communities. Scallop fisheries hold significant importance in the UK as the third most valuable shellfish species. Around 50,000 tonnes of king scallop (Pecten maximus) were landed in 2019. Scallop fisheries traditionally utilise dredging for fishing but this method is also used as an exploratory method to locate new fishing grounds. Dredging causes damage to benthic flora and fauna. Machine learning (ML) techniques are increasingly used to automate image analysis allowing for the potential to apply artificial intelligence (AI) algorithms which could be used as part of a more efficient and non-destructive sampling method for scallops. This study investigates the possibility of using low-cost camera tow footage and convolutional neural networks (CNN) to automate abundance estimations of King (Pecten maximus) and Queen (Aequipecten opercularis) scallops in their natural habitats. The Video and Image Analytics for Marine Environments (VIAME) software is being used to train a detection model to detect the two species. The abundance of live scallops per frame is then estimated. The model was trained, then evaluated using a test set of 1885 images (28% of ground truth images).

The model's ability to detect scallops in the imagery is currently 0.32 mean average precision (mAP). Detected scallops are then classified into king, queen, and dead with accuracy of 0.82. Despite low mAP figures, the results suggest there is strong potential to utilise these methods in estimating scallop abundance following additional annotation of images for training and further fine-tuning. We will explore the challenges of training a detector for King scallops and how this is informing our strategy for fine tuning the detector. If successful, the resulting CNN detector will be deployed in further validation field studies with a view to its use being operationalised.

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Application of Deep Learning technology to satellite monitoring of whales

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Very-High-Resolution (VHR) satellite imagery is increasingly being used to monitor terrestrial (Duporge et al. 2021) and marine wildlife (Fretwell et al. 2014; Cubaynes et al. 2018). In the marine environment, the key advantages of using satellites as a survey "platform" are that large, and potentially inaccessible areas can be surveyed in a very short space of time. The method is well suited to surveying whales because of the relatively large size of some species and it being less affected by some of the challenges faced by traditional methods (observers on boats or aircraft) in the offshore environment. To date, the processing of satellite survey images to identify whales has largely been carried out manually (e.g. Cubaynes et a. 2019; Clarke et al. 2021) but this is time consuming and inevitably will incur human error. Consequently, artificial intelligence methods are underpinning progress in this field. Project SPACEWHALE is a service offering surveys using VHR satellites (~30-50cm resolution) to conduct surveys and a semi-automated process to detect whales in the imagery. Our approach has been to build an "object detection algorithm" (Borowicz et al. 2019) that was recently updated from a single Convolutional Neural Network (CNN) (Ren et al. 2015) to a two-stage Faster Region-based CNN; this enables more precise locating of "small" whales relative to the large expanse of open water within images. The algorithm was trained using 2cm resolution digital aerial survey images of minke whales (*Balaenoptera acutorostrata*) down-sampled to 31 cm to match the resolution of WorldView 3 satellite imagery. The algorithm automatically detects whales in the images and then a team of reviewers verify and identify the whale to species. SPACEWHALE surveys have now been conducted in multiple locations world-wide, and a wide range of species have been successfully detected from smaller whales (long-finned pilot whales *Globicephala melas*) to the largest, the blue whale (*Balaenoptera musculus*). The approach has also proved successful in remote, sub-Antarctic waters off the Aukland Islands; here, we detected, mapped and counted southern right whales (*Eubalaena australis*). Importantly, in comparisons between manual and automatic processing, the SPACEWHALE algorithm outperformed the manual method in terms of processing time by a factor of eight and in terms of the number of whales detected. The use of deep learning technology has greatly improved the performance of satellite surveys and enables survey data to be rapidly available for a broad range of uses. As the use of the marine environment's natural resources continues to diversify and expand, improving our understanding of the distribution and abundance of marine wildlife is essential to inform conservation efforts.

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Site Selection and Validation for Native Oyster Restoration in the Firth of Forth

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Native oysters (*Ostrea edulis*) in the 1800's were a common commodity, sold as fast food by the side of the road, an accessible food with a rich cultural history. The Firth of Forth in Scotland had native oyster beds which spanned 20 miles wide and 6 miles in length, producing 30 million oysters a year at the fishery's peak. Overfishing and disputes about bed ownership swiftly brought about the fishery's decline and by the early 1900's the native oyster beds in the Firth of Forth were declared extinct (Smout and Stewart, 2012). This waterbody is a busy hub of industrial activity, giving easy access to population centres such as Edinburgh, Dunfermline, Linlithgow, and Stirling, it has been vital to Scottish import and export activity for hundreds of years.

The Restoration Forth project aims to restore native oyster and seagrass beds to the Firth of Forth. This community-driven project is a large collaboration across multiple organisations, which aims to restore 30,000 native oysters over a three-year period with training and support given to local communities. Scientific support will be delivered through three main factors, site suitability assessments, monitoring and biosecurity measures.

Initial site suitability assessments were undertaken in August and September 2022 to compare the physical characteristics and biodiversity of the now extinct, historical native oyster beds in the Firth of Forth with native oyster beds both naturally occurring (Loch Ryan) and restored elsewhere (Dornoch Firth). Data was collected using SCUBA transect surveys and consisted of an analysis of biodiversity, benthic characteristics, temperature and salinity parameters and shell coverage. Each site surveyed will be spatially plotted and compared with geo-physical characteristics such as water movement and tidal flows, depth and sediment type with a view to modeling these characteristics throughout the system.

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Incorporating differences in socio-economic values between Scottish marine regions for strategic-level suitability mapping

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Sustainable siting of offshore renewable energy must consider multiple objectives, including ecological, socio-cultural and economic interests, and this can be informed by spatial decision support tools such as suitability mapping. Socio-economic activities at sea, such as recreational use, fisheries or shipping, are typically represented with heat maps for inclusion in suitability maps.

Socio-economic space use depends on many different factors (e.g. weather conditions, time of year), therefore there will be a degree of uncertainty as to the relationship between the socio-economic value of an area and how that translates to spatial suitability levels for novel developments. Depending on the scale of the suitability mapping exercise, this uncertainty carries a spatial dimension, in that certain regions may be overvalued or undervalued compared to others. At a national scale, this could lead to the risk of locally high value areas in areas further away from population centres to be overlooked, where protection of sites of national importance may be prioritised over sites that have important local values[1].

This study proposes a standardisation technique to be used for suitability mapping that standardises socio-economic values per marine region instead of standardising the entire study area using the same overall range of socio-economic values, based on the technique developed by Malczewski, 2011[1]. This allows differences in values within regions to be better represented at a national scale.

The technique was applied to the spatial data collected through the Scottish Marine Recreation and Tourism Survey in 2015[3]. Comparing the novel technique with a more conventional standardisation approach demonstrates it selects different suitable areas, indicating it can make a difference in site selection outcomes. This technique can be used to integrate local values into national-level suitability mapping and therefore decision-making outcomes.

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The effects of 660nm line laser exposure on the eye of white legged prawn (*Litopannaeus vannamei*)

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Novel laser scanning technology is being used as part of a prototypic device designed to automatically acquire morphometric data from commercially important invertebrates. The intension is to use the device to cost effectively acquire data needed to inform stock assessment, recognizing that data for many commercially fished shellfish species is deficient.

The technology uses two 660nm line lasers to quickly obtain a point cloud map of morphological characteristics.

The effect of lasers on non-human eyes is understudied, particularly in invertebrate eyes. The lasers used by the technology have the potential to exceed maximum permissible exposure (MPE) for human eyes (Schulmeister and Jean, 2010). It is important to note that MPE is defined under the ANSI Z136.1 as the maximum exposure an eye can receive without sustaining eye injury — in the context of the human eye and the human blink response.

The potential impact of lasers used in the scanning device on the crustacean eyes is unknown. Similar wavelengths have been found to result in distortions, swellings, and fusions of the fundamental units of the crustacean eye (Viljanen et al., 2017). This may result in abnormalities in responses to photic stimuli which may reduce survival rates.

As part of using the device for stock assessment data collection, the expectation is that many of the animals sampled at sea would be released after exposure to the lasers. It is therefore essential to assess whether exposure to results in temporary or permanent visual impairment which could influence their subsequent survival. Further, that the device will align with forthcoming sentience legislation related to the welfare of crabs and lobsters (Animal Welfare (Sentience) Act 2022 (c. 22).

This study seeks to analyse the eye structure and photic response behaviours of *Litopannaeus vannamei* pre- and post-exposure to the lasers to identify potential abnormalities and quantify recovery times.

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