INSITE Phase 2 Report

Understanding the INfluence of man-made Structures In The marine Environment

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Front cover image credit: Scottish Association for Marine Science/ University of the Arts, London

Executive Summary

From 2019 to 2024, the second phase of the INSITE (INfluence of man-made Structures In The Ecosystem) programme investigated the effects of man-made structures (MMS) on the marine environment. several areas of interest were explored, including marine predator foraging, capability of marine autonomous technology, fish aggregations, blue carbon benefits, efficacy of decommissioning strategies, influences on biodiversity connectivity, AI approaches to imagery analysis, and exploring risks from MMS-related subsea plastics.

This report summarises key findings from the nine INSITE research projects, six PhD cohort projects and the INSITE Interactive data initiative.

INSITE Phase 2 makes numerous recommendations for **nature-positive management of MMS,** from decommissioning of oil and gas structures to the future proliferation of offshore wind farms. **Scientific consensus for a case-by-case cost-benefit analysis of MMS aims to maximise the benefits of MMS when considering various decommissioning options.** From empirical data to consensus views, the body of work provided by the INSITE Phase 2 projects has produced diverse and crucial evidence that can undoubtedly make a significant contribution to the ongoing discussions and decision-making around management of MMS in the North Sea ecosystem.

CONNECTIVITY OUTCOMES

Under research challenge 1, findings suggested that MMS form inter-connected hard substrate networks across the North Sea, with settlement studies revealing similarities in communities across locations. MMS zones of influence of up to 20km exist for some fish species, with larger structures such as oil and gas platforms having greater influence than smaller structures, such as wind turbines. Clusters of turbines may create overlapping zones of influence, affecting fish populations and their distributions across the North Sea.

ARTIFICIAL REEF OUTCOMES

Under research challenge 2, projects explored the role of MMS as artificial reefs in the North Sea. Findings showed enhanced local biodiversity on MMS, supporting species of conservation value (e.g. cold-water corals) at some locations, and non-native species at others. Projects also showed MMS supporting local population increases for commercial fish and shellfish species such as sprat, herring, cod and scallops. However, less complex food webs are observed in sediments around MMS, highlighting issues with contamination.

TECHNOLOGY OUTCOMES

Under research challenge 3, research has shown that when combined with traditional techniques, **cutting-edge technology such as Autonomous Underwater Vehicles, Uncrewed Surface Vehicles, environmental DNA and machine-learning assisted analysis can play a crucial role in providing new evidence** on ecosystem structure and functioning variability around MMS. These findings highlight the opportunity for low cost, low risk monitoring in a standardised manner that can be strategically implemented across large spatial and temporal scales, as part of a coordinated effort.

Contents

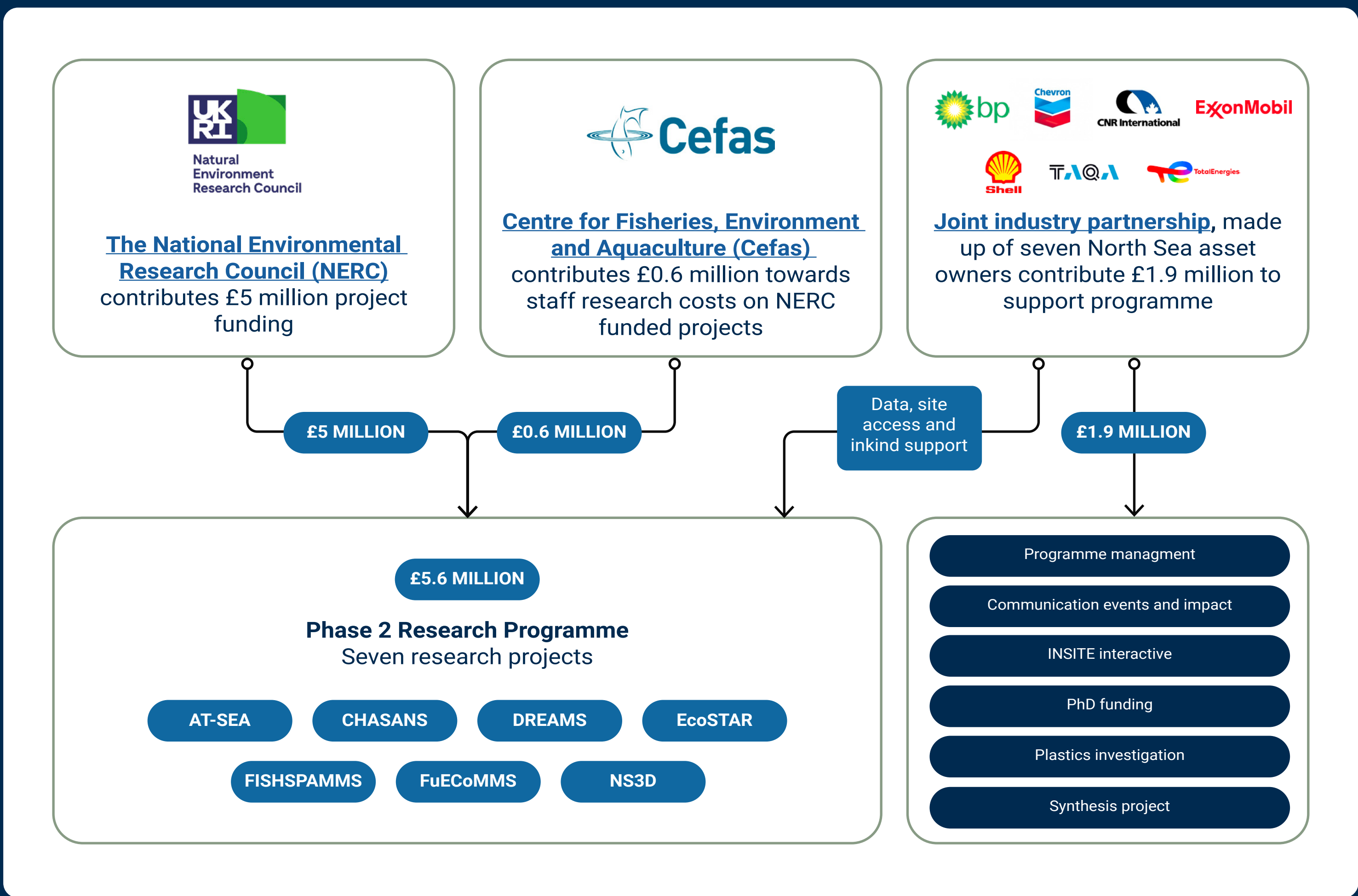
INSITE Programme Summary

The INSITE Programme (INfluence of man-made Structures In The Ecosystem) was launched in 2014 as the first joint industry partnership of its kind in the North Sea, setting out to deliver focused research to provide the independent scientific evidence base to better understand the influence of Man-Made Structures (MMS) on the North Sea ecosystem.

FUNDING

The **INSITE** Phase 2 programme is funded by the Natural Environment Research Council (£5 million) and the Centre for Environment, Fisheries and Aquaculture Science (£0.6 million), and is sponsored by an industry partnership of North Sea asset operators (£1.9 million).

Building on existing research under **INSITE** Phase 1 and other relevant global studies, the Phase 2 programme (2019-2024) has developed an advanced understanding and scientific consensus on the ecological and environmental implications of deploying MMS in the sea at scale, leaving non-operational MMS in situ, or removing non-operational MMS. Evidence gathered through **INSITE** supports the development of marine management and policy alongside nature-positive approaches to decommissioning that can underpin progress towards Good Environmental Status and the sustainable management of UK seas.



PROJECTS

Science advice is central to identifying, understanding, and addressing the policy and regulatory challenges faced by government. Those in government are invariably dealing with multiple and competing interests, and their decisions need to be made in a transparent, accountable, and proportionate way.

Science is necessary to identify alternatives and clarify the costs and benefits of particular courses of action so that policymakers can choose between them. Science plays a critical role in informing decision-making and enabling action, but ultimately, the role of the decision-maker is to decide what to do with the scientific evidence.

INSITE Phase 2 is made up of nine independent research projects, each led by principal investigators from different academic institutions. Areas of focus range from the practical application of Artificial intelligence (AI) and new technology to understanding the effects of MMS on benthic habitats and contamination. INSITE Phase 2 also has six PhD projects, funding the next generation of offshore ecologists working with MMS. Details of the fifteen projects as well as their key outputs and findings are outlined in the sections below.

CHALLENGE 1

Understanding the role of man-made structures as an inter-connected hard substrate network in the North Sea.

CHALLENGE 2

Understanding the role of man-made structures as artificial reefs in the North Sea.

CHALLENGE 3

Ecological monitoring and assessment of man-made structures as whole systems in the North Sea ecosystem.

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INfluence of man-made Structures In The Ecosystem

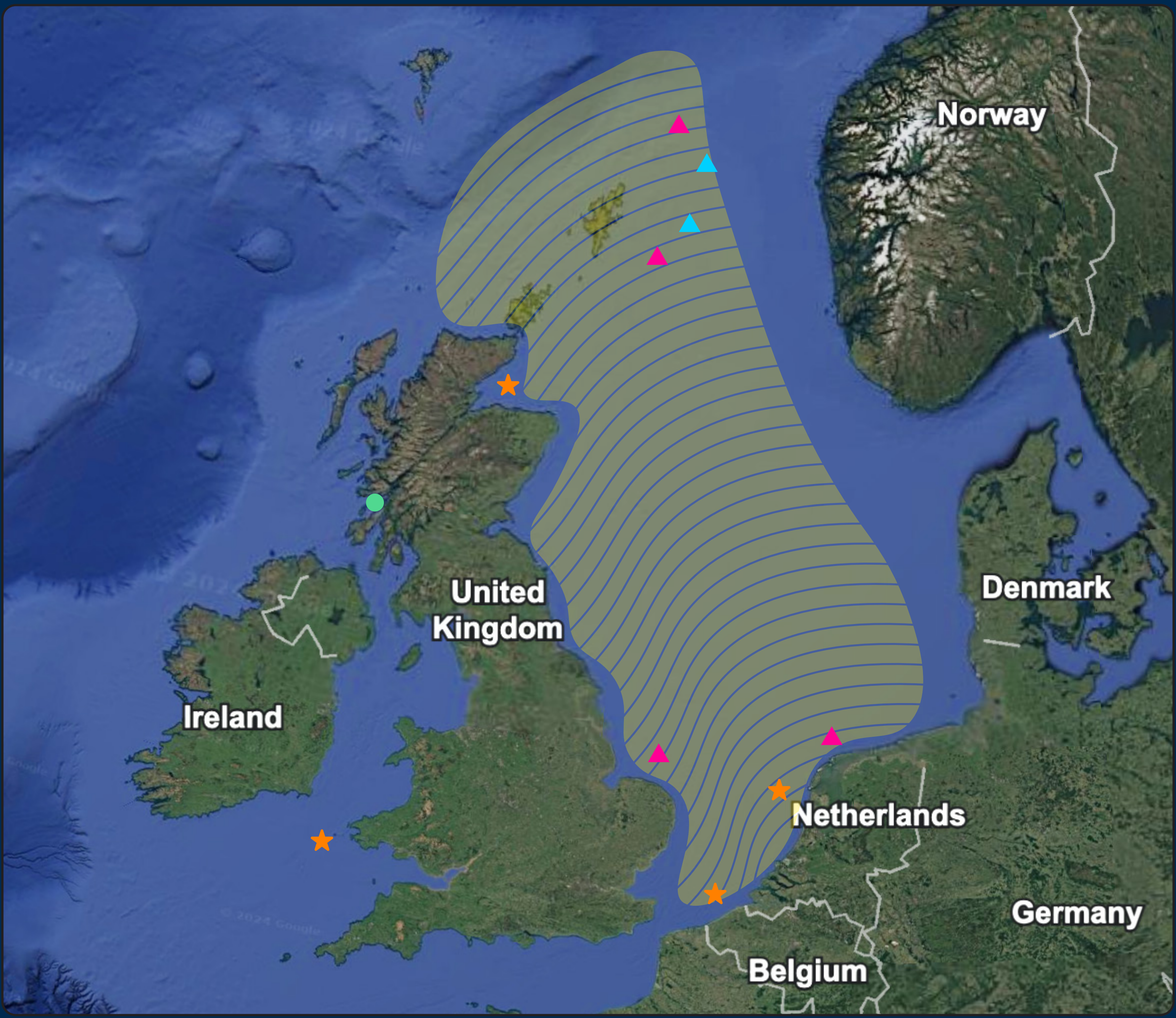
INSITE Phase 2 North Sea Research Locations

Offshore Wind Farm

Other sites i.e., protected sites, banks and reefs

Oil and Gas platform

Oil and Gas platform (sampled in more than one project)



Map of North Sea showing approximate locations for **INSITE** Phase 2 research activity, as indicated in image legend. Some locations have been sampled in multiple projects, as indicated by the blue triangles. A few projects have sampled areas covering the North, South or entire North Sea, as represented by the yellow striped polygon. Although research was primarily focused in the UK offshore waters of the North Sea, PhD research has occurred in the Dutch and Belgian North Sea, and literature reviews and scientific expertise for the **DREAMS** and **Synthesis** projects were global in scope.

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INfluence of man-made Structures In The Ecosystem

PROJECT 1

Autonomous Techniques for anthropogenic Structure Ecological Assessment (AT-SEA)

The **AT-SEA** project assessed the feasibility and efficacy of fully autonomous monitoring of multiple sites relevant to MMS decommissioning. This was done without the aid of a support vessel, using an existing shore-launched, long-range, fully Autonomous Underwater Vehicle (AUV) for marine environmental surveys. AT-SEA directly addressed Challenge 3 of the **INSITE** Programme.

Project Lead: Professor Daniel Jones (**National Oceanography Centre 'NOC'**) **dj1@noc.ac.uk**

Team: **NOC** - Dr Mike Clare, Dr Veerle Huvenne, Dr Anna Lichtschlag, Dr Andrew Gates, Dr Talicia Pillay, Dr Philip Bagley, Dr Alex Phillips. **University of Southampton** - Professor Blair Thornton and Dr Adrian Bodenmann.

Project partners: **BP**

Timeline: June 2021 - May 2024.

RESEARCH LOCATIONS

North West Hutton (Decommissioned Platform)

Miller (Decommissioned Platform)

Braemar Pock Marks (Special Area of Conservation)

METHODOLOGY

The AT-SEA team used a shore-launched AUV which travelled over 1000 km from Shetland over 21 days to collect a variety of data at the sites mentioned above. The data included millions of seabed photographs and measurements of water currents, chemistry, and physical conditions which were retrieved from the AUV and analysed at the **National Oceanography Centre** and **University of Southampton.**

OBJECTIVES

- Carry out the first fully autonomous environmental monitoring of multiple decommissioning-related oil and gas sites without the aid of a support vessel.
- Combine autonomously collected seafloor visual imagery, mapping and water column sensor-based measurements to produce an integrated environmental assessment at sites relevant to decommissioning.
- Directly compare the autonomously collected data with corresponding data obtained by current standard methods in the same areas.
- Demonstrate how a fully autonomous approach can lead to major advances in data quality, quantity, and cost savings over traditional approaches.

Image credit: Professor Daniel Jones and team with the AUV Boaty McBoatface, **National Oceanography Centre (NOC)**, Southampton.

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KEY FINDINGS

ENVIRONMENTAL AND ECONOMIC COST SAVINGS

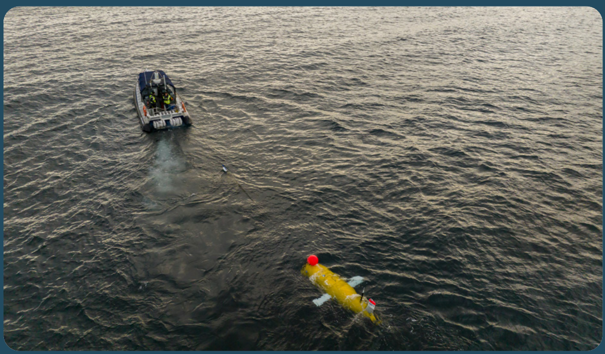

Image credit: National Oceanography Centre (NOC), Southampton.

AT-SEA have demonstrated that autonomous environmental data collection is a viable prospect for understanding the nature of the seafloor and its biological communities, linking these to aspects of the chemical and physical environment around decommissioned sites. Using autonomous systems allows considerable savings to be made in terms of financial cost, personnel time and carbon emissions and offers the potential for future reductions. These savings increase the feasibility of more regular monitoring over wider areas than would be practical using current standard approaches. **AT-SEA** deployments did not require any offshore personnel, met all safety at sea requirements, did not depend on the weather, and only used a total of 21.3 kWh of energy, roughly the same as 2 litres of diesel fuel. Just comparing the imaging surveys done with the AUV alone, any standard vessel-based image surveys would have taken at least 3 days of ship time using a relatively large (e.g. >50m length) vessel, requiring tens of offshore personnel and thousands of litres of fuel.

NAVIGATING ENVIRONMENTAL COMPLEXITY

AT-SEA demonstrated that autonomous operations were possible in the complex environment of the northern North Sea. The North Sea is a challenging maritime area, with many users, including extensive fishing, shipping, and oil and gas operations. These represent hazards to autonomous deployments, which the team were able to manage using careful planning approaches, which are documented and will be made available to others interested in using these new technologies.

DATA

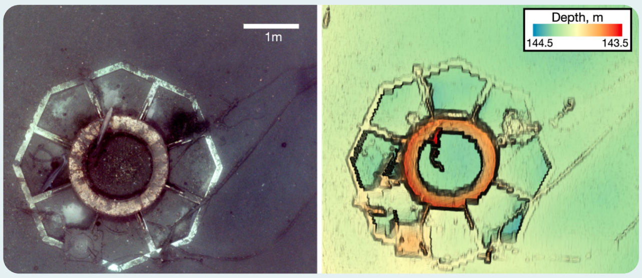

Image credit: University of Southampton & National Oceanography Centre (NOC), Southampton.

Autonomous platforms can collect some data types in a comparable way to current standard ship-based surveys. Some data types, e.g. **acoustic seafloor measurements** with multibeam, are very similar irrespective of whether the sensors are mounted on a ship or an autonomous platform. Other data, such as **digital imagery,** are broadly comparable but are often obtained in a different way, which may have different extents and resolutions. Using remote sensing rather than direct sampling isn't always a like-for-like replacement. There are some data, such as seabed macrofauna or water chemistry samples, which are not currently easily obtained using autonomous systems.

FUTURE MONITORING DEVELOPMENTS

With increased adoption of autonomous approaches, the accumulated learnings, innovation, and economies of scale will decrease financial costs, increase the value of these operations and lead to more capabilities being realised. Given the clear benefits of autonomous operations, and their ability to be carried out independently from and potentially in more challenging conditions than vessel-based operations, **the AT-SEA project advocates for a combined monitoring solution** that benefits from both approaches in an optimal combination, while collecting all the data required for effective monitoring. This combined solution would start with an autonomous survey, to map the site, and assess changes and anomalies using acoustic, optical and sensor-based measurements. This would provide a broad-scale context for the site, delineate different seabed features, zones or disturbance conditions and enable a greatly optimised sampling design for subsequent operations. Key features of interest or concern could be identified as sites for further investigation.

PROJECT 2

Connectivity of Hard Substrate Assemblages in the North Sea (CHASANS)

A key infrastructure management issue raised by the offshore industries focuses from the biological colonisation of their structures and how this might affect future development. This project described the connectivity between structures to understand the consequences for other sectors. The importance of colonisation arises both from the societal need to produce reliable sources of energy cost-effectively, and to ensure the developments are 'environmentally acceptable' e.g. maintaining healthy sea life, or avoiding conflicts with other sea users, including fishers who may have a prior claim on the development sites. CHASANS focused on addressing Challenges 1 and 2 of the **INSITE** Programme.

Project Lead: Joanne Porter (Heriot Watt University) j.s.porter@hw.ac.uk

Team: Heriot Watt - Dr Mike Bell, Dr David Woolf, Ms Bhavana Suresh, Dr Andrew Want, Mr Conor Gilmour. Aquatera Ltd - Dr Gareth Davies (GIS mapping lead), Duncan Clarke and Dr Raeanne Miller

Project partners: National Oceanographic Centre, Liverpool - Dr Michela de Dominicis (Particle tracking modelling lead) and Dr Ben Barton. Hull University - Professor Mike Elliot, Dr Krysia Mazik (management and policy lead) and Dr Anita Franco.

Other contributors: Dr Kate Gormley: Aberdeen University (July 2020 - March 2022) and Dr Andrea Waeschenbach (Genetic connectivity lead), Natural History Museum London.

Timeline: July 2020 – August 2024.

RESEARCH LOCATIONS

Settlement panels were deployed and retrieved from a series of coastal and offshore locations in the northern North Sea:

November 2023 – Orkney (EMEC)
Scientific evidence was gathered from scientific publications worldwide.

Image credit: Heriot-Watt University

OBJECTIVES

- Carry out field studies using settlement panel to validate larval settlement models by collecting data on larval behaviours, including transport, seasonality and life-cycling, and settlement succession from several epifaunal species.
- Assess genetic connectivity between hard substrata populations on settlement panels at sites across Northern North Sea.
- Use models to elucidate the expected consequences of larval dispersion following site-selective decommissioning and/or installation operations, as well as allow the projection of connectivity based on future climate-driven scenarios.
- Capture industry and policy opinions on marine energy scenarios at different spatial scales within the North Sea.

METHODOLOGY

The CHASANS project began with a review of the Northern North Sea evidence base for topography, hydrodynamics, ecosystem functioning and ecological connectivity, with a focus on species and habitats in both hard (including artificial) substrata and soft sediments. This informed the design of the settling plates study which used a Standard Monitoring System to explore and ground truth the colonisation of biofouling marine invertebrates at different sites. Finally, an online stakeholder questionnaire was designed to capture the opinions of industry and policy-related stakeholders on future scenarios for marine energy at different spatial scales within the North Sea.

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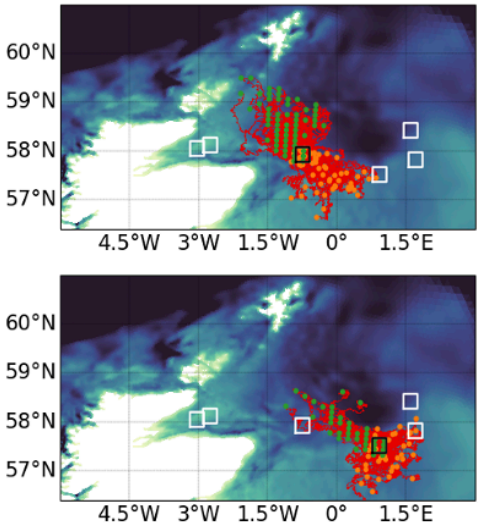
KEY FINDINGS

CONNECTIVITY



Locations of particles after 1 month that pass through the black box. Start (green)/ End (orange).

Image credit: Professor Joanne Porter, Heriot-Watt University.

Preliminary results of the species settling on panels at two Orkney sites suggest similar species composition and settlement ratios between the West Atlantic and more sheltered sites, with substrate types not appearing to have effects on the settlement of species. As saddle oysters *(Anomia ephippia)* were found in large enough quantities at each site they were selected for genetic analysis investigating interconnectivity between populations.

Settlement plates retrieved from the three North Sea sites revealed that 70% of the epifaunal colonisation across all sites was dominated by 23 species, many of which are commonly associated with artificial substrata. The commonly occurring epifaunal species *Metridium dianthus* and *Desmophyllum pertusum (Lophelia pertusa)* were absent from all plates which may have been a function of location depth of deployment and/or duration of deployment. Functional classification and analysis of the sensitivity of these species to habitat and climate change is ongoing (plate retrieval was April 2024). Preliminary indications are that the species present were largely epifaunal with a large number being gregarious or colonial. Most had a planktonic larval development phase with larval dispersal potential of over 10 km and a larval development period of at least 11-20 days, if not longer. The North Sea panels will also undergo genetic connectivity analysis at the Natural History Museum in London (results released 2025).

ENVIRONMENTAL AND ECONOMIC COST SAVINGS

Image credit: Heriot-Watt University.

This project emphasised the need to bring forward industry collaboration and agreements as early as possible in the project life cycle to identify research locations and ensure all permissions are in place. This **early collaboration not only allows more time to be allocated for data collection, analyses and project work but it also saves cost.** Linking this to other project research opportunities would provide even greater benefit.

STAKEHOLDER VIEWS ON FUTURE MARINE ENERGY SCENARIOS IN THE NORTH SEA

Survey responses clearly showed that stakeholders expect development of new oil and gas infrastructure will become less of a priority over time. Renewables remains a priority in the short-term (2023-2030) and medium-term (2030-2050) but there is a high level of uncertainty over what will happen in the long-term (>2050), when new challenges around recycling of renewable technologies during decommissioning and the development of new policy frameworks to cover multiple industrial activities further offshore are anticipated.

PROJECT 3

Decommissioning – Relative Effects of Alternative Management Strategies (DREAMS)

DREAMS was a highly integrated and innovative project designed to develop a new understanding of how MMS, and different strategies for decommissioning them, influence the structure, functioning and dynamics of marine ecosystems and ecosystem services. DREAMS directly addressed Challenges 1 and 2 of the INSITE Programme.

Project Lead: Dr Antony Knights (co-PI; University College Cork, Ireland; previously University of Plymouth) aknights@ucc.ie, Dr Michaela Schratzberger (co-PI; CEFAS), and the late Prof. Paul Somerfield (PI, Plymouth Marine Laboratory)

Team: University of Plymouth – Dr Anaëlle Lemasson (evidence synthesis and ecological effects). Plymouth Marine Laboratory (PML) - Dr Stephen Watson (stw@pml.ac.uk), Dr Nicola Beaumont, Dr Claire Szostek (ecosystem services), Dr Gennadi Lessin, Dr Michael Bedington, Dr Muchamad Al Azhar, Dr Molly James (ecosystem modelling), Joana Nunes, Christine Pascoe, Caroline Louise McNeill (ecological effects).

Project partners: Cefas - Dr Elena Couce, and Dr Murray Thompson.

Timeline: July 2020 - Jun 2024.

RESEARCH LOCATIONS

Scientific evidence was gathered from scientific publications worldwide.

METHODOLOGY

Using structured, systematic and meta-analytic approaches, as well as state-of-the-art ecosystem models, the DREAMS project explored the effects of MMS and different strategies for decommissioning them, on ecosystems and ecosystem services. This in turn provided information to decision-makers and stakeholders about the relative benefits and disbenefits of a variety of approaches.

OBJECTIVES

- Assess the clusters and gaps in our scientific understanding of the effects of structures on marine ecosystems (Lemasson *et al.*, 2021; Lemasson *et al.*, 2022).
- Assess and understand the linkages between the ecological effects of offshore wind farms and the provision of ecosystem services including interlinkages between the ecology and ecosystem services, using the Common International Classification of Ecosystem Services (CICES) framework (Watson *et al.*, 2024).
- Statistically assess the global ecological effects of structures (Lemasson *et al.,* 2024).
- Evaluate the relative effects of different MMS (oil & gas versus offshore wind farms) on whole-system marine productivity and biogeochemistry (Al Azhar *et al,* in prep).
- Understand the connectivity potential of structures in the North Sea (James *et al,* in prep).

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KEY FINDINGS

CONNECTIVITY

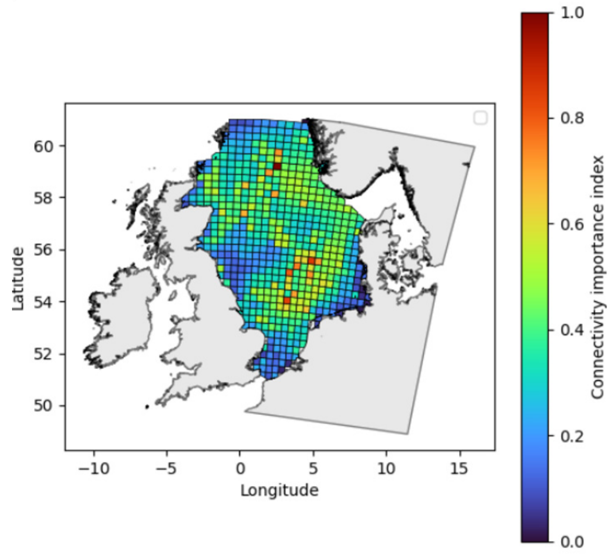

Image Credit: Plymouth Marine Laboratory and University of Plymouth.

Using a combination of high-resolution modelling techniques such as hydrodynamic, biogeochemical, particle tracking and graph network analysis, DREAMS generated a spatial Connectivity Importance Index which provides a generic overview of **maximum potential connectivity. Maximum connectivity between existing structures was found at 55N, 4E, with the Southern North Sea being identified as particularly important for connectivity under the existing structures scenario** *(red squares in image above)*. **An area of great importance for connectivity was also identified in the Northern North Sea at 59N 4E.** This methodology can be used to underpin decision-making around the placement of MMS at both the commissioning and decommissioning stages. At the North Sea scale, the extended biogeochemical-ecological model ERSEM showed that the effects of offshore oil and gas structures on primary productivity and biogeochemical fluxes are practically negligible at the scale of hundreds of meters to a few kilometres. The effects of oil and gas contrasted with that of offshore wind farm structures, for which placement density is much higher, leading to detectable impacts on primary productivity, chlorophyll and nutrients within the wind farm and adjacent areas. The extent of the simulated impacts is comparable to previous modelling estimates.

DATA

DREAMS used the wealth of studies on the effects of MMS to infer potential effects of decommissioning. Using robust meta-analytical techniques based on over 530 data points from 109 independent studies, **DREAMS found that offshore structures can enhance ecological function compared to natural sedimentary habitats, but not more so than natural rocky reefs.** The project also found clear differences between structure types demonstrating that not all structures have the same ecological effects. Overall, there are too few studies available to provide evidence that oil and gas or offshore wind structures would provide ecological benefits if decommissioned as artificial reefs or repurposed in situ (Lemasson *et al*., 2024). Some of the evidence suggests that **full removal of oil and gas structures and shipwrecks is overall negative for ecosystem services and that leaving structures in place or partially removing them is potentially more beneficial in terms of improved ecosystem services flows.**

NAVIGATING ENVIRONMENTAL COMPLEXITY

The systematic evidence synthesis work highlighted the lack of real-world case studies describing the ecological effects of different decommissioning options (Lemasson *et al*., 2022). This evidence gap makes deciphering the environmental effects of different decommissioning options a considerable challenge (Lemasson *et al*., 2023), which in turn hinders decision-makers in taking decisions regarding structures at end-of-life, and crucially, could also hinder potential support for policy change. The project catalogued a substantial amount of scientific evidence on the effects of various MMS (prior to decommissioning), particularly for purpose-built artificial reefs and the ecological effects on fish and invertebrates. **Clear knowledge gaps remain, for instance, associated with more recent or novel structures such as marine renewable energy installations or relating to effects on hydrography, sedimentary processes, nutrient cycling, or other groups such as algae, plants or mammals.** The project identified over 197 gaps in evidence related to ecosystem services (Watson *et al*., 2024), mostly in association with wind turbines. Despite the pace in this field, there are still large gaps in our current understanding of the linkages between MMS and ecosystem services (ES).

PROJECT 4

Ecosystem level importance of STructures as Artificial Reefs (EcoSTAR)

Both bottom-up and top-down processes could be mediated by Man-Made Structures (MMS) through impacts on prey distribution and abundance, and on predation pressure via impacts on behaviour and movement of top predators.

The **EcoSTAR** project aimed to fill some of the key knowledge gaps on the impact of MMS, addressing Challenge 2 of the **INSITE** Programme.

Project Lead: Debbie JF Russell **(Sea Mammal Research Unit 'SMRU', University of St Andrews)** **dr60@st-andrews.ac.uk**

Team: SMRU - Matt Carter, Sophie Smout, Phil Hammond, Janneke Ransijn, Claire Lacey and Gordon Hastie. **Cefas** - Christopher Lynam, Clement Garcia and Silvana Birchenough. Ecopath International Ltd – Jeroen Steenbeek. **The Royal Belgian Institute of Natural Sciences** - Steven Degraer. **Aarhus University** - Jonas Teilmann and Jacob Nabe-Nilsen.

Other contributors: Wageningen University & Research, La Rochelle Université, **University of Aberdeen, University of Veterinary Medicine Hannover**, **Marine Biological Association,** and **Flanders Research Institute for Agriculture, Fisheries and Food.**

Timeline: July 2020 – March 2025.

OBJECTIVES

- Map the existing oil and gas, and windfarm infrastructure in the North Sea (and collate associated metadata) (Martins 2023).
- Determine the drivers for, and at-sea distribution of the three most abundant marine mammals in the North Sea (harbour seals, grey seals, and harbour porpoises), which are estimated to overlap with presence of MMS.
- Utilise available animal-borne tracking data from the same three species to infer foraging behaviour and how this links to habitat and any potential relationships with MMS.
- Investigate how the diet for these species can predict how consumption of prey will vary with changes in prey abundance, including changes around MMS.
- Use available benthic data to determine the impact of MMS on benthic species composition and functioning.
- Use all work packages described alongside other data (e.g. on fish and plankton), to model the ecosystem of the North Sea to predict the impact of various MMS, fishery and climate scenarios on the species that make up the ecosystem and its key ecosystem services (i.e. fisheries).

RESEARCH LOCATIONS

The whole North Sea basin.

METHODOLOGY

EcoSTAR focused on three key research areas. First, the research of marine mammals as flagship species, which have the potential to have substantial top-down impacts, as well as being good indicators of marine ecosystem health. This was done by using marine mammal tracking data to infer foraging behaviour and to quantify the relationship between foraging and aspects of the environment The second, filling the data gap in the understanding of the impact of MMS on the benthic structure and functioning. Finally, the extension of a North Sea ecosystem model, to predict the impact of various scenarios of MMS, climate change and fisheries on the ecosystem.

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KEY FINDINGS

CONNECTIVITY

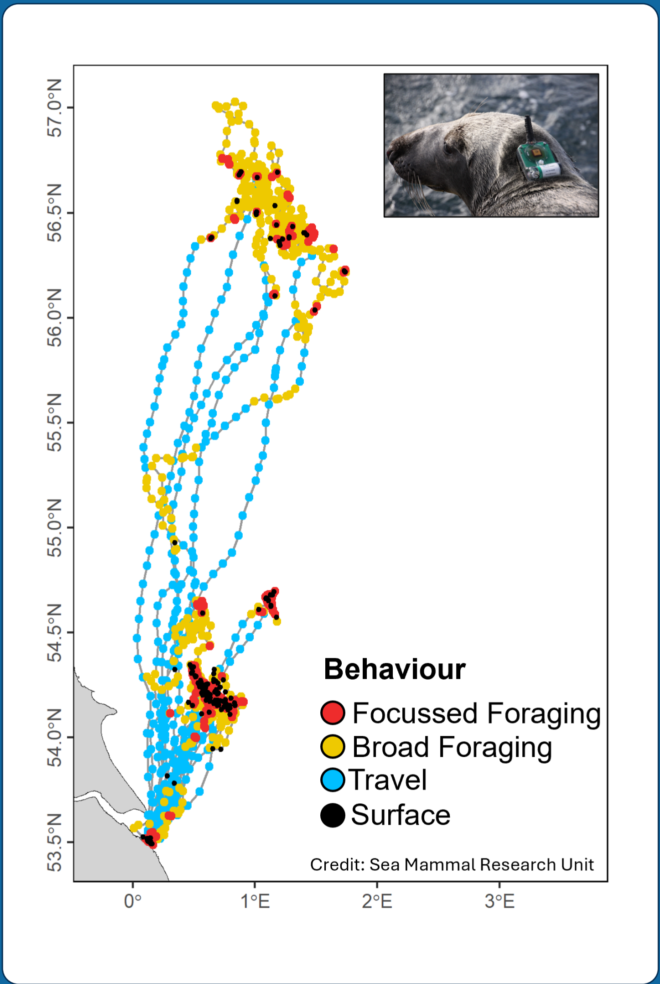


Image credit for new image is: Sea Mammal Research Unit (SMRU), University of St Andrews.

Building on Stadler *et al.* 2022, analyses revealed no significant relationship between MMS and the behaviour of porpoises tagged in Denmark. However, these findings are from the eastern North Sea, an area of low MMS density, and the temporal resolution of the data was low. **For seals, foraging behaviour and habitat varies regionally throughout the North Sea, driven by seabed geomorphology, substrate type and stratification regime, with MMS impacting the behaviour of some individuals.** Combining these findings with MMS spatial overlap improves understanding of the potential top-down effects of predators at MMS. Trait-based analysis of benthic species revealed that, for given environmental conditions, there was a significant relationship between benthic functionality and proximity to MMS platforms. However, the number of species expressing traits was fewer near platforms, indicating a higher functional vulnerability.

NAVIGATING ENVIRONMENTAL COMPLEXITY

At sea distribution of seals hauling out in the UK and Ireland was estimated (Carter *et al.* 2022) by combining animal-borne tracking and habitat data to quantify habitat associations, and by scaling predictions using haul-out counts. Harbour porpoise distribution was modelled similarly using data from a series of large-scale cetacean surveys - Small Cetaceans in European Atlantic waters and the North Sea (SCANS). Diet was also estimated via analysis of hard remains (such as fish bones) in stomach and faecal samples. By relating snapshots of diet in time and space to fish abundance within areas sampled for marine mammals, **the relationship between diet composition and prey availability was quantified and can be predicted** (this information will also be used to predict the impact of changes in prey abundance resulting from MMS on diet, and thus predation pressure).

DATA

A review of the available datasets on MMS highlighted that the current North Sea (via OSPAR) and country-wide databases contained inaccuracies, and lacked key meta-data. In response to this challenge, a comprehensive dataset (Martins *et al.* 2023; updated in 2024: 10.17630/1639540b-600e-42aa-8920-ac1890b78b5a) was generated by combining and cross-referencing information from databases, decommissioning reports, and operator websites. **As of June 2024, there were ~700 oil and gas platforms and >5000 wind turbines in the North Sea, highlighting the need to consider both structure types and associated decommissioning strategies.**

ECOSYSTEM SERVICES AND IMPACTS

Image credit: Sea Mammal Research Unit (SMRU), University of St Andrews.

The Ecopath with Ecosim model was refined and extended spatially using the Ecospace module. The model improved how marine mammals are represented, using outputs from EcoSTAR. With stakeholder engagement, potential scenarios for MMS, climate change and fisheries management have been developed and the ***relative impact of these different scenarios on the ecosystem (in terms of species biomass and ecological indicators) and fisheries will be modelled.***

PROJECT 5

Aggregation, Production and spillover: the cumulative effect of man-made structures on fish (FISHSPAMMS)

FISHSPAMMS used new and existing data on fish distributions around MMS, particularly oil and gas infrastructure, in combination with a novel spatial modelling approach to assess evidence for a) aggregation of fish at these structures, b) enhanced production of fish at these structures, and c) 'spill-over' of enhanced fish densities into the surrounding waters. The results were used to make inferences on the impacts of these structures and of their removal as part of decommissioning, on commercial fish populations. FISHSPAMMS addressed Challenges 1, 2 and 3 of the INSITE Programme.

Project Lead: Prof. Paul Fernandes (Heriot-Watt University, previously University of Aberdeen)
P.Fernandes@hw.ac.uk

Team: Heriot-Watt University - Dr Joshua Lawrence
University of Strathclyde - Prof. Michael Heath, Dr Douglas Speirs, Silvia Malagoli and Laura Thomson.

Project Partners: BP - Scott Campbell and Ross Nickson, Repsol Sinopec - Ciara McGarry, Ithaca - Paul Shearer and Tara Turner

Timeline: June 2020 - September 2024.

METHODOLOGY

The fisheries echosounder was used to conduct quantitative high-resolution sampling over large areas and to assess fish distributions around MMS. New data were collected using an echosounder deployed from a USV, a low-cost, low-carbon, low-risk alternative to a large, traditional research vessel. Due to its small size, the USV was allowed to operate within the 500 m safety zone around five oil platforms, collecting fish distribution data within ~20 m of these structures. For the modelling aspects, a highly modified implementation of the honeycomb model (Needle, 2014) was produced for the North Sea. The default models contained no effects of marine installation density but formed baselines for ongoing scenario experiments on possible effects on stock abundance and distribution.

RESEARCH LOCATIONS

Northern North Sea, and around the Moray Firth, Scotland.

OBJECTIVES

- Assemble and pre-process legacy acoustic datasets to provide consistent (calibrated) data on scattering around MMS and in the surrounding areas.
- Collect new acoustic data in and around MMS using an Uncrewed Surface Vessel (USV).
- Analyse the acoustic data to estimate the density of fish as a function of distance to MMS and estimate the abundance of fish at all MMS.
- Build a high spatial resolution fish population dynamics model and parameterise for saithe and cod, using all available acoustic data plus the archive of trawl survey data held by ICES.
- Conduct scenario experiments with the model to test the scale of effects of a) local enhancement of production, and b) local protection from fishing.

![INSITE]

KEY FINDINGS

CONNECTIVITY

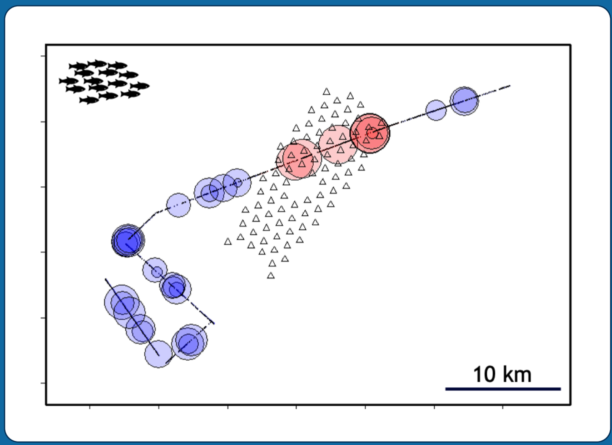


Image Credit: Professor Paul Fernandes, Heriot-Watt University.

During the USV survey, a transect was also completed through the Beatrice Offshore Windfarm. These data were analysed to examine fish densities within, and immediately outside, an operational wind farm. The **densities of both schooling and non-schooling fish were found to be significantly elevated inside the wind farm, relative to the surrounding 10km.** Non-schooling fish within the windfarm were also found to be significantly smaller than those outside the windfarm boundary.

FUTURE MONITORING DEVELOPMENTS

Analysis of the acoustic dataset collected with the USV provided data on fish distributions that were used to investigate the relative strength of trends in fish density at oil platforms of different sizes. This study also found **elevated fish densities close to platforms.** Additionally, stronger negative trends in non-schooling fish density were found at platforms (or multi-platform bridge-linked complexes) with higher substructure weight; i.e. the densities of non-schooling fish were higher and decreased more rapidly with increasing distance from platform at larger platforms than at smaller platforms (Lawrence *et al.* 2024b). This, along with the results of **INSITE** cruise data analysis, suggested that **structure size (and/or weight) is a potential driver of the strength of the influence platforms exert on local fish populations.**

DATA

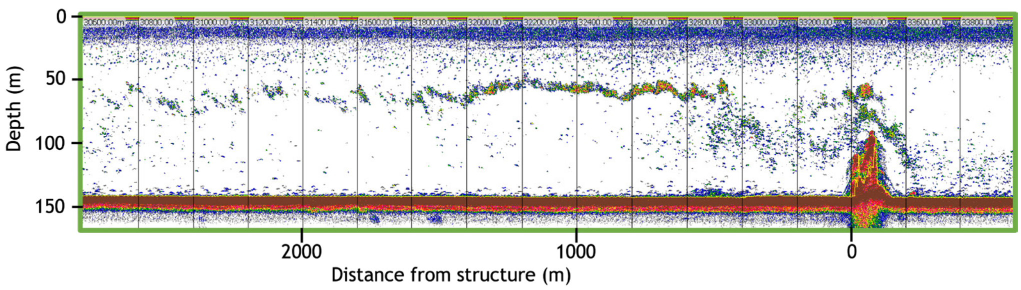
Acoustic data were analysed to quantify schooling fish (e.g. herring and sprat) and non-schooling fish (e.g. gadoids, such as cod, haddock, saithe and whiting), and investigate trends in fish density in relation to distance from individual MMS, local MMS density, and a baseline fish density far from any MMS. Three primary datasets were analysed; one existing dataset collected during a bottom-trawl survey of the northern North Sea in 2012 using a traditional research vessel; one new dataset, collected in 2021 as part of the 'INSITE cruise' on the same research vessel, focussed on the area around two decommissioned oil platforms, and; one new dataset collected using a USV which was permitted to enter the 500 m safety zones around four oil platforms.

Added to data collection, **a high-resolution spatial model of fish population dynamics and distribution has been fully implemented** and is capable of accurately recreating the population structure, distribution and catch-weights of mature saithe in the North Sea, referenced against stock assessments, and survey and landings data. This model will be used as a baseline for scenario experiments examining the potential influence of platforms on fish population and spatial dynamics (see 'Ongoing Research').

RANGE OF INFLUENCE

The 2012 ship-based survey revealed **elevated fish densities that extend kilometres beyond the 500 m safety zones around oil and gas platforms in the northern North Sea** (Lawrence *et al.* 2024a). The survey included 'visits' to 16 oil platforms (which were approached within 1 km). At these 16 platforms, local fish densities were compared to a relevant 'baseline', and trends with distance from the platform were investigated. Results were variable, but at 11 of the platforms, more fish were observed closer to the structures. The range of influence, i.e. the range to which fish densities were higher, was highly variable (from <1 to >20 km) between platforms. Both the **density of non-schooling fish and the probability of detecting a fish school were found to be higher in areas of higher platform density** when controlling for other relevant environmental variables (Lawrence *et al.* 2024a). Data from the 2021 research focussed on two decommissioned oil platform sites where only footings, up to ~40 m off the seabed, remain. Similar negative trends in schooling and non-schooling fish density were found, but these smaller structures showed a much shorter range of influence, with elevated fish densities persisting over a few 100s of metres (Yang et al. in prep).

Image Credit: Professor Paul Fernandes, Heriot-Watt University.



INSITE

PROJECT 6

Project Lead: Dr Natalie Hicks (University of Essex) natalie.hicks@essex.ac.uk

Functionality and Ecological Connectivity of Man-Made Structures (FuECoMMS)

FuECoMMS explored the impact of MMS on the seabed, detecting changes in benthic biodiversity and functioning as a result of MMS presence, placement or removal using analysis of existing industry data and collection of new field data from the North Sea. The project focused on addressing Challenges 2 and 3 of the INSITE Programme.

Team: University of Essex – Professor Corinne Whitby (microbial and molecular ecologist) and Dr Boyd McKew (microbial and molecular ecologists); Dr Eoin O'Gorman (food web and species analyses).
University of St Andrews - Professor David M Paterson (macrofaunal diversity analysis) and Dr Melanie Chocholek (macrofaunal diversity analysis).

Other contributors: Cefas - Dr Ruth Parker (benthic biogeochemist), Dr Clement Garcia (benthic ecologist), Dr Chris Lynam (food web modeller), Dr Tiziana Luisetti (natural economist), Dr Roi Martinez (scenario seabed management toolkit). Scottish Association for Marine Science (SAMS) - Dr Tom Wilding (benthic ecologist). VIA University College, Denmark - Dr Torben Skovhus (external sub-contractor and industry representative for sample collection).

Timeline: August 2020 – March 2025

RESEARCH LOCATIONS

Two Northern North Sea decommissioned oil and gas platforms:

- **North-West Hutton**
- **Miller**

OBJECTIVES

The overall aim of the FuECoMMS project was to determine how the removal or placement of MMS will affect marine biodiversity and ecosystem function (including services and economic value) of associated benthic habitats. The specific objectives included:

- Relate benthic biogeochemical parameters to microbial and macrofaunal biodiversity across sites.
- Measure the extent to which MMS are a contaminant source and the potential for in situ microbial communities to remediate contaminants.
- Use statistical and GIS modelling to predict the impact of MMS across sites and determine the ecological connectivity between structures in the North Sea.

METHODOLOGY

Existing information on installations and associated environmental data were sourced from UK Benthos and the North Sea Transition Authority. Field sampling conducted from RV Scotia collected replicate sediment samples along northerly and southerly transects, running 50 – 3200m from platforms, at set distances from the decommissioned sites. Sediment was collected using a grab for macrofaunal and eDNA analysis, and a multi-corer for geochemistry measurements such as carbon and particle size analysis. Sediment samples were collected for analysis of: macrofaunal taxonomic identification; analysis of microbial abundance, biodiversity and function (using eDNA, targeting phylogenetic markers and key functional genes); total, inorganic and organic carbon; particle size analysis; heavy metals analysis; hydrocarbons analysis (both alkanes and PAHs); and radioisotope dating for sediment accumulation rates (only performed at North West Hutton). Additional sediment samples from decommissioned sites were also sourced by project partner Shell, from Southern North Sea platforms Indefatigable J, K, and L.

INSITE

KEY FINDINGS

ECOSYSTEM SERVICES AND IMPACTS

Image Credit: University of Essex

Analysis of biodiversity and food webs showed clear differences in food web structure around nine platforms at pre-construction vs post-construction stages (Chen *et al,* 2024) **Closer to oil and gas platforms, with higher levels of hydrocarbons, food webs tended to be less complex, communities less diverse, species smaller in body size, with fewer predators/higher trophic organisms, but food webs are more connected.**

FUTURE MONITORING DEVELOPMENTS

Sampling around other types of MMS, such as wind farms, may not be best for traditional research vessels due to the size of the vessel and lack of dynamic positioning systems to allow the vessel to hold position, as well as issues with sign-off to enter operational sites. Clear communication was needed, between the research lead, the vessel operator, the engineering staff, and the contact within the industry partner, as this often involved more than one team within the industry organisation. **For the benefit of future environmental monitoring, key microbial taxa and genes were picked up, which link to the decommissioning legacy, and which could be used as indicators.** The legacy effects should be considered for seabed management policies, particularly around the practice of decommissioning.

EVIDENCE USE AND GAPS

The lack of data prior to decommissioning was a crucial evidence gap, highlighted by the results of this research project. **Access to field sites, particularly exclusion zones around operating oil and gas infrastructure, was particularly difficult to secure, despite the support of project partner organisations.** Additional work to address some of the evidence gaps included a metagenomics study on the drill cuttings pile from North-West Hutton, further DNA sequencing of microbial communities and links to macrofaunal diversity, further characterisation of the sediment carbon and ecosystem modelling approaches to test impacts of different scenarios on seabed function such as carbon or biodiversity.

RANGE OF INFLUENCE

Data from North-West Hutton, and Miller decommissioned platforms revealed differences in macrofaunal and microbial diversity closer to the structure compared to further away. These trends were most noticeable 50 m from the platform, for both sites and across both transects and **microbial and macrofaunal communities became more similar as the distance from the platform increased. Elevated concentrations of heavy metals (copper, nickel, zinc, lead, chromium, cadmium) were found at 50 m for both platforms,** with the exception of lead at Miller, where concentrations were very low across all distances.

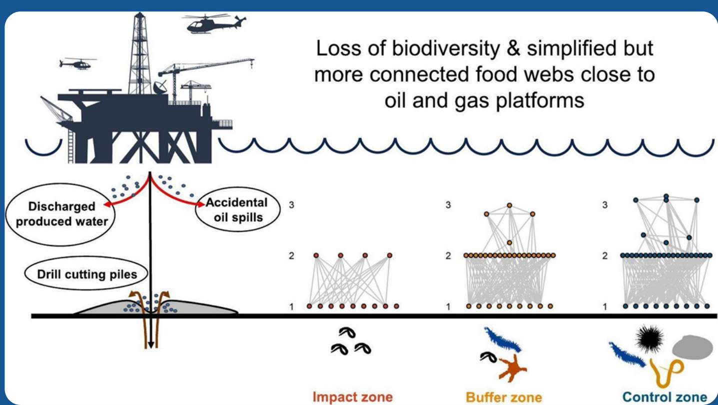


Image Credit: University of Essex.

PROJECT 7

North Sea 3D (NS3D)

NS3D sought to better understand the influence of MMS across complete ecosystems (e.g. North Sea) by both identifying organisms that inhabit structures and also quantify their biomass, rapidly and accurately. Until now, obtaining data on the biomass and identity of taxa associated with offshore structures has been limited by the time and cost constraints of conducting ecological surveys at the necessary spatial scales. NS3D focused on addressing Challenge 3 of the INSITE Programme.

Project Lead: Thomas Andrew Wilding (Scottish Association of Marine Science - SAMS)
tom.wilding@sams.ac.uk

Team: SAMS - John Halpin, Joe Marlow, Alan McDonald (PDRAs), Andy Crabb, Iona Harvey (outreach), Richard Dale (IT Support)

Project Partners: Orsted and Equinor

Other contributors: University of the Arts, London (UAL) - Rachel Pearl

Timeline: May 2021 – April 2025.

RESEARCH LOCATIONS

Industry ROV footage supplied from northern, central and southern parts of the North Sea. Cold water coral *Desmophyllum pertusum (Lophelia pertusa)* samples were collected from Dales Voe Decommissioning Centre in Shetland. Natural-reef footage and marine growth species samples were obtained from the Oban area using SCUBA-based sampling (wrecks, rocky reefs & mussel farms).

OBJECTIVES

- Take the ROV or diver imagery and identify important organisms growing on the structures, such as anemones, mussels, hard and soft corals and urchins, and digitally trace around them using a digital pen. These 'annotated' images are used, by deep-neural networks (convolutional neural nets), to train computer programs to identify marine growth taxa in imagery that has not been previously 'seen'.

- Use the same imagery to generate 3D models, based on either stereo camera pairs (like human vision) or from overlapping images that contain the same subjects.

- Combine the above to generate a 3D model (with automated identification informed by human annotation and machine learning) that isolates the taxa of interest, extracts it from the 3D model and enables us to determine its volume. Calibration curves enable this measurement to be converted into an estimate of biomass.

- Develop a standard operating procedure to maximise the utility of ROV-based underwater imagery for interpretation by computers.

METHODOLOGY

The project utilised underwater imagery, usually collected from inspection-class remotely operated vehicles (ROV) or diver-held cameras. Only the best quality imagery is suitable for the development of automated imagery analysis routines. NS3D also collaborated with Rachel Pearl, UAL to generate a virtual reality experience highlighting in an accessible way the role that MMS and associated activities play in the ecosystem to primary and secondary students and the general public. As part of the project, NS3D visited a decommissioning site in Shetland to obtain specimens for calibration). The calibration work was conducted using the SAMS aquarium and laboratory facilities and locally sourced animals. The ROV footage was collected by industry partners, which included Orsted and Equinor. NS3D also developed the technique using footage collected on local MMS and reefs, accessed using SCUBA, by the project team.

INSITE

KEY FINDINGS

DATA

NS3D have found that the optimal machine-based models for automating the identification of marine taxa are based on convolutional neural nets (CNN). The project trialled several CNN architectures and identified 'SegFormer' as optimal for the marine-growth identification task. **The optimal model achieved ~92% accuracy across the target taxa** (Marlow, *et al*, 2024). A pilot has been completed to train the project algorithm to complete identification tasks utilising multiple data types (e.g. acoustic data) and applying hyperspectral analysis to carbon sequestration around structures.

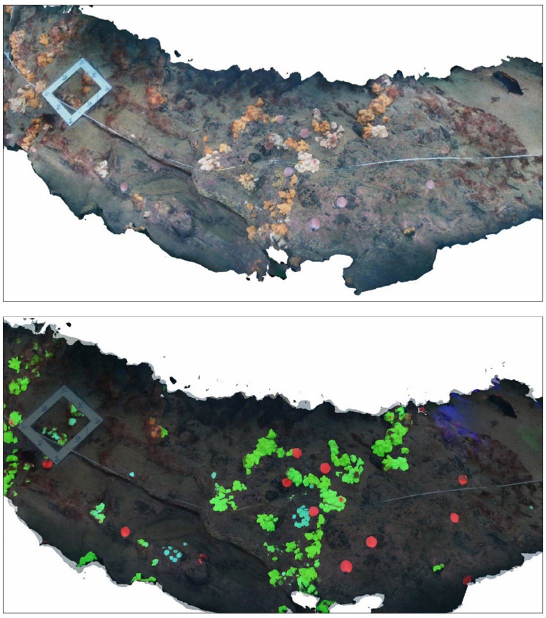


Image Credit: Scottish Association of Marine Science

SCIENCE-ART-VISUALISATION OUTREACH

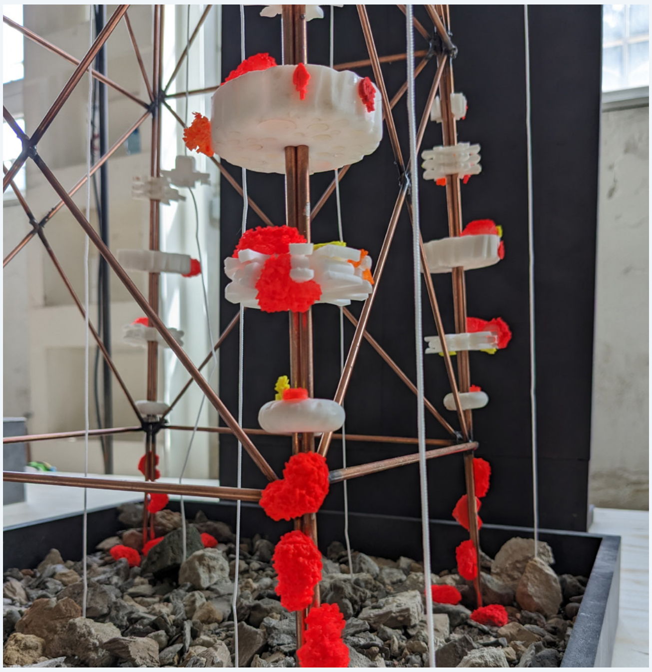


Image Credit: University of the Arts, London

NS3D have embedded 3D models into virtual environments, generating a visual and auditory seascape for exploration and education, as showcased at the Edinburgh and Glasgow Science festival 2024: Edinburgh Science Festival: Discover how oil rigs and offshore wind turbines are providing new homes for marine life in the North Sea (scotsman.com). Art collaborations with University of the Arts, London also produced **models of oil platform jackets with 3D printed coral colonies, scaled from actual survey data,** alongside novel nature-inclusive design additions, for public display at Milan Art Show 2023 and the Structures In the Marine Environment (SIME) conference 2023.

FUTURE MONITORING DEVELOPMENTS

NS3D have demonstrated that it is technically possible to generate 3D models from underwater imagery collected using ROVs, including from industry. It is then possible to automatically identify key taxa, extract biovolumes and predict biomass from those models. The project team found that only a small proportion of industry footage can be re-purposed to generate high-quality 3D models and that acquiring industry footage can be time-consuming. Extracting absolute volumes from 3D models required scaling and this was frequently lacking in non-bespoke underwater imagery which includes most industry data. Generating taxon-specific volumes from 3D models requires closure of the modelled surface meaning that information is needed on where the underlying structure is located in the model. This was not always easy to determine, particularly when modelling limited areas of a structure. This has implications for any future monitoring technique that seeks to use ROV footage to general 3D models and extract metrics relating to the community that is present.

Adopting the standard operating procedure (SOP) and engaging with modellers at SAMS ahead of future data capture would substantially improve the resultant 3D models, including auto-identification of taxa within those models. The project intends to extend the automated image analysis process to include other structures (e.g. cables and mooring systems and floatation cells in the 'Trophic effects of floating offshore wind' (TroFLOW) project) assessing vertebrate (e.g., fish) and invertebrate interactions, relationships and associations, extending the capability of the method to include images collected by autonomous underwater vehicles.

PROJECT 8

Decommissioning and subsea plastics project

Plastics are used above and below water, in coatings for pipelines and umbilicals to protect them from corrosion due to their durability, versatility, and low cost, and as thermal insulation for subsea infrastructure. However, plastics are recognised as a major pollutant in the marine environment and their potential to cause harm to marine life is well documented. To date, two studies have calculated degradation rates of subsea plastic in oil and gas pipelines and umbilicals; Oluwoye *et al*., (2023) and Testoff *et al*., (2022), which are thought to be in the region of 100s – 1000s years. This work suggested that there was sufficient evidence that the ecological risk from microplastics generated from the degradation of pipelines was negligible but does not consider the legacy of these plastics in the environment with other sources. Furthermore, recent expert evidence reviews concluded that on the balance of the available evidence, microplastics are harmful and measures should be put in place to minimise their accumulation in the environment (e.g. SAPEA, 2019).

Project Lead: Sarah Gall
(University of Plymouth)

Team: **University of Plymouth** - Professor Richard Thompson OBE FRS, Dr Freija Mendrick and Ami Northam.

Other contributors: **North Carolina State University** - Professor Anthony Andrady.

Timeline:

Phase 1:
October 2022 – March 2023

Phase 2:
Sept 2023 – Sept 2024.

RESEARCH LOCATIONS

Samples were taken from Brent Field (NE of Shetland Islands)

METHODOLOGY

Phase 1 established the extent to which plastic material associated with oil and gas infrastructure presents a source of plastic pollution, and Phase 2 determined how the risk from plastics associated with oil and gas pipelines and umbilicals should be incorporated into future policy and planning for decommissioning.

OBJECTIVES

This project explored the risks associated with plastics from the oil and gas industry in the wider context of plastic pollution to aid future decommissioning decision-making addressing these objectives:

- Provide best possible estimates of the quantity of pipelines, umbilicals, and associated plastics in the UKCS, including by polymer type where possible.
- Investigate timescales for degradation using pipeline/umbilical sections that have been recovered from the marine environment, considering the influence of some key environmental conditions such as abrasion, temperature, UV and depth.
- Review and evaluate the applicability of modelled degradation rates for a) fragmentation and b) mineralisation for pipelines and umbilicals in the UKCS.
- Identify factors to be considered in risk assessments for end state decision making.
- Develop decision-making support criteria to assess risk and make decisions regarding decommissioning of pipelines and umbilicals.

INSITE

KEY FINDINGS

EVIDENCE USE AND GAPS

The project revealed limited information on the processes and timescales for degradation of plastics in subsea environments particularly due to the lack of quantification of the influence of depth, pressure and burial on degradation processes. As a direct consequence, there is also a **limited understanding of the ecological risks associated with plastics in oil and gas subsea infrastructure and the risks associated with decommissioning in situ.**

FUTURE MONITORING DEVELOPMENTS

Acquiring samples of pipeline and umbilicals from the North Sea provided the project with an opportunity to look for evidence of degradation. However, this was restricted by availability due to the timeframe of the project, decommissioning schedules and also by the operational processes used during recovery. To answer outstanding questions regarding degradation, opportunity for further sampling would benefit from:

- Samples coming from areas with differing environmental conditions to enable comparisons to be made. To build a more complete picture of degradation **it would be helpful to get samples from areas with differing energy regimes such that adequate comparisons can be made of the effects of abrasion as a mechanical degradation method and the influence of factors such as temperature, UV and depth.**
- Use of the **cut and lift method for removal allows more precision** in removing sections of pipeline exposed to different environmental conditions, for example sections fully exposed to the water column, buried in sediment or protected under concrete mattresses.
- **Avoiding jet washing of pipelines to retain biofouling.** Analysis of biofouling would enable the identification of any microbes that may be associated with degradation.

ENVIRONMENTAL AND ECONOMIC COST SAVINGS

Image Credit: University of Plymouth

The key message from Phase 1 was that **there was unlikely to be an imminent environmental risk from plastics associated with oil and gas pipelines and umbilicals. While there was no urgent need for decisions to be made about removal, there was the potential to cause harm, particularly with the accumulation of legacy plastics driving increased concentration in the marine environment.** The analysis of samples as part of the second phase of this research aimed to provide additional information to help with the assessment of risk by increasing understanding of how degradation occurs in subsea environments.

Future research and engineering should focus on reducing the impacts of plastics associated with oil and gas as this could lead to better decommissioning policies. Consideration can be made of both economic and environmental costs of removal vs potential for compensation or mitigation if the material is decommissioned in situ. It may also help inform better decisions to be made prior to the introduction of new infrastructure into the environment.

PROJECT 9

INSITE Synthesis project

With both the decommissioning of oil and gas, and the installation of offshore wind, there is a need for a scientific consensus to provide independent scientific advice that may inform policy and regulatory decisions regarding MMS in the marine environment. The INSITE **Synthesis** project collated the views of scientific experts from across the globe to explore what scientists think about how we manage MMS in our marine environment. The **Synthesis** project revealed a range of views on the ecological outcomes of different decommissioning approaches, whether those approaches align with international conservation targets and the wider effects, both desirable and undesirable, that MMS have on our environment.

Project Lead: Dr Antony Knights (**University College Cork**, Ireland; previously **University of Plymouth**) aknights@ucc.ie and the late Prof. Paul Somerfield (**Plymouth Marine Laboratory**)

Team: **University of Plymouth** - Dr Anaelle Lemasson

Timeline: January 2022 – December 2024.

OBJECTIVES

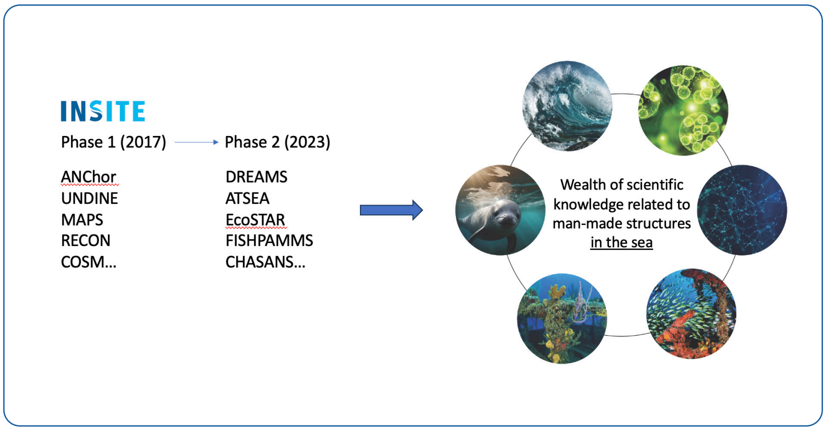


Image credit: Dr Antony Knights, University College Cork.

This project aimed to:

- Develop a view of the current consensus based on the existing evidence base being established under **INSITE** Phase 1 and 2 and other relevant global studies.
- Produce position-papers setting out the consensus view on the environmental implications of deploying MMS at scale, leaving non-operational MMS in situ, or removing non-operational MMS.

RESEARCH LOCATIONS

Scientific opinion gathered from leading scientists working worldwide.

METHODOLOGY

The INSITE **Synthesis** project used The World Café approach for building consensus in the absence of published evidence on the impacts of decommissioning MMS in the sea. A worldwide consortium of 39 scientists was built, each with international reputations in marine biology, ecology and physics, marine policy, ecosystem services and socio-ecological systems, from 30 academic and government institutions, four continents and seven countries:

INSITE

KEY FINDINGS

EXPERT VIEW ON ECOSYSTEM SERVICES AND IMPACTS

Experts concluded that most pressures from MMS could be classified as moderately severe and occur frequently, but that the effects were dependent on the spatial scale of the MMS. There was agreement that effects are more pronounced at local scales rather than across a regional scale. Regarding the nature of the effects, on balance, the **environmental effects of MMS** were considered marginally **undesirable,** as a result of pollution, disturbance, events, habitat loss, assisted dispersal and trophic interactions. However, some individual environmental effects were considered **desirable,** especially in certain geographic locations, where structures can support improved trophic linkages and population dynamics, habitat provision, locally enhanced biodiversity, ecosystem management and tourism opportunities. **Decisions may need to be decided on a case-by-case basis accounting for the trade-off in costs and benefits at a local level.**

EXPERT VIEW ON DECOMMISSIONING APPROACHES

Experts identified repurposing or abandoning individual structures, or abandoning multiple structures across a region, as the options that would most strongly contribute towards 37 international environmental targets, including UN Rio+20 'Future We Want', UN Sustainable Development Goals (SDG) and the OSPAR North-East Atlantic Environment Strategy 2030, suggesting that complete removal may not be best for the environment or society.

WORKSHOP CONTRIBUTORS:

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University of Western Australia
Todd Bond

California State Polytechnic University
Jeremy Claisse

Wageningen Marine Research
Joop W.P. Coolen & Ninon Mavraki

Pacific Northwest National Laboratory
Andrea Copping

Alfred Wegener Institute
Jennifer Dannheim

National Oceanography Centre (NOC)
Michela De Dominicis & Daniel O.B. Jones

Royal Belgian Institute of Natural Sciences
Steven Degraer & Jan Vanaverbeke

University of Hull; International Estuarine & Coastal Specialists (IECS) Ltd
Michael Elliott

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Paul G. Fernandes & Joanne Porter

Sydney Institute of Marine Science
Ashley M. Fowler

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Kieran Hyder, Michaela Schratzberger & Christopher P. Lynam

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University of Western Australia
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Texas A&M University-Corpus Christi
Paul A. Montagna

University of St Andrews
David M. Paterson, Debbie J.F. Russell & Brooke Shipley

University College London
Martin Perrow

The **Synthesis** team also hosted a series of online workshops with the consortium. Using structured questionnaires, the team elicited expert opinions on a variety of factors including:

- **Effects of pressures,** such as chemical contamination, food availability, electromagnetic fields, noise, disturbance to seabed/hydrodynamics/nutrients.
- **Resulting changes** on biodiversity, dispersal, habitat loss/provision, trophic effects, nutrient cycling.
- **Decommissioning options** ranging from fully decommissioned, partially decommissioned, toppled, repurposed in situ
- **Alignment of decommissioning approaches with international polices**

ONGOING RESEARCH AND POSTGRADUATE RESEARCH PROJECTS

INSITE also directly funds a cohort of six Ph.D. students listed in the page below (1-6). The **NS3D** project has three PhD programmes (7-9) linked to NS3D image analysis. These are not funded by **INSITE** but work with industry and regulators to feed directly into policy formulation.

NS3D

IMAGE ANALYSIS USING ARTIFICIAL INTELLIGENCE

NS3D are combining AI-machine learning image detection with automated navigational-decision making in 'intelligent surveys' to reduce costs whilst enhancing spatial/temporal capacity (in collaboration with the Robotics Academy at SAMS), also extending the image-analysis work (autoID) to benthic habitats and, working with SEPA and the aquaculture sector, are focussing on priority marine features of high-conservation value such as mussel and maerl beds. The SOPs and models enable cost-effective scale-up of data capture /analysis and transparency of data interpretation. **NS3D** are extending the image analysis techniques to mark-recapture experiments targeting flapper skate, using image analysis to re-identify, from archived images, skate images supplied by sport-fishers. Working with NatureScot, this image analysis enables a better understanding of the movements and site fidelity of this endangered species.

FISHSPAMMS

FISH PRODUCTION AT PLATFORMS

FISHSPAMMS has ongoing scenario experiments using spatial population models of saithe (expanding to cod) at oil and gas platforms, investigating local enhancement of production (maturity boost), aggregation and introducing spawning at sites of high installation density. The effect of the different scenarios will be evaluated by asking whether their inclusion significantly improves the correlation between modelled abundance and survey data. **FISHSPAMMS** will also generate yield curves for the scenarios to address the question of how large the possible effects would have to be to produce important changes in maximum sustainable yield for fisheries. This work is due to be completed by September 2024.
Future questions:

- Identify sources of inter-platform variability in fish density trends
- Establish means of determining spawning at MMS.

CHASANS

CONNECTIVITY OF BENTHIC TAXA ACROSS NORTHERN NORTH SEA SITES

Settlement plates from **CHASANS** undergoing biodiversity and genetic analysis (DNA) of the retrieved settlement panels are ongoing to determine connectivity across Northern North Sea sites.

FuECoMMS

MICROBIAL COMMUNITY ANALYSIS AT PLATFORMS

FuECoMMS analysing additional sediment samples from decommissioned Southern North Sea platforms (Indefatigable J, K, L) for microbial eDNA, for comparison with the Northern North Sea sites sedimentary microbial communities.

EcoSTAR

SEAL DISTRIBUTION MAP UPDATE

EcoSTAR's seal distribution maps are currently being updated to increase their spatial extent, include other North Sea countries and incorporate recent tracking and haul-out data. The next phase of analysis will incorporate MMS location and type into the habitat association models and quantify the impact on seal distribution.

EcoSTAR

CONTRIBUTION OF MMS ECOSYSTEM TO SEAL DIET

EcoSTAR will relate snapshots of seal diet in time and space to fish abundance to understand the relationship between diet composition and prey availability. This information will be used to predict the impact of changes in prey abundance resulting from MMS on diet, and thus predation pressure.

DREAMS

ECOSYSTEM IMPACTS OF DECOMMISSIONING MMS FROM REAL-WORLD CASE STUDIES

Continuing the evidence synthesis work undertaken as part of DREAMS and Synthesis, an update of the literature search used for the **DREAMS** systematic map (Lemasson *et al*. 2021, 2022) will include publications from 2021 onward, leading to the production of a systematic review of the effects of decommissioning oil and gas structures from reported decommissioning case studies.

EcoSTAR

IMPACT OF MMS SCENARIOS ON THE ECOSYSTEM

Testing is underway of potential scenarios for MMS, climate change and fisheries management to assess the relative impact of these different scenarios on the ecosystem in terms of species biomass, ecological indicators and fisheries (**EcoSTAR**). (Completion – Dec 2024).

PLASTICS

PLASTIC DEGRADATION RATES IN SITU

Estimation of degradation rates for plastics in oil and gas pipelines and umbilicals will be based on analysis of subsea plastic samples and literature review and will consider the influence of different environmental gradients. This will improve understanding of how decommissioning in situ may add to the standing stock of plastics in the marine environment and allow better assessment of any associated environmental risk. The findings will underpin the development of key decision-making support criteria for the decommissioning of oil and gas pipelines and umbilicals.

PhD PROJECT 1

Quantifying 'Blue Carbon' stores around Man-Made Structures

Research suggests that the soft surface sediments in the **North Sea** contain the largest store of carbon within the **marine environment**, and that this is likely representative of the global continental shelf systems. As a result of the exclusion zones surrounding the platforms, the sediments around structures have been protected from disruptive activities, contributing to 'secure' carbon storage. These sediments therefore provide an age profile 'baseline' for estimating carbon accumulation rates within the continental shelf sediments since the installation of the MMS. This PhD research directly addresses INSITE Challenges 2 and 3.

Academic Supervisor: Dr. Natalie Hicks (Natalie.hicks@essex.ac.uk)
Partners: Dr Ruth Parker, Dr Franck Dal-Molin and Professor Ursula Witte

Student: Hugo Woodward-Rowe

Institute: University of Essex

Partners: University of Aberdeen (National Decommissioning Centre)
University of St Andrews
Centre for Environment, Fisheries and Aquaculture

Timeline: January 2022 – June 2025

RESEARCH LOCATIONS

Northwest Hutton and Miller (decommissioned O&G platforms)

METHODOLOGY

Utilised sediment samples from distance gradients: 50 m close to the sites/ a control (3200m) sampling site.

CURRENT FINDINGS

Carbon stocks in sediment surrounding decommissioned oil and gas platforms are site-specific and can be described by sediment type, with no correlation in carbon content and distance from the platform. Carbon accumulation rates could only be determined for the control sites as heavy metals and anthropogenic discharge water disrupted the analytical procedures. New methodologies were developed as a result of measuring sediment and carbon accumulation impacted by O&G extraction.

ONGOING RESEARCH

- Determining the reactivity and source of the carbon within the sediment.
- Determining the potential impact of disturbance on carbon from decommissioning on anthropogenically impacted sediment.

Image credit: University of Essex

PhD PROJECT 2

Use of eDNA to assess the impact of decommissioning on marine sediment communities and the development of an industry-relevant environmental monitoring kit.

Environmental DNA (eDNA) sequencing is a powerful tool for monitoring biodiversity and allows for fine-scale analyses of ecosystems. This project investigated how such approaches could be applied to monitoring in the North Sea, to enable a more comprehensive and robust environmental monitoring approach; around MMS installation and through decommissioning, and specifically to ensure there are no adverse impacts on the surrounding sediment biota (e.g. from hydrocarbon leakage). This PhD research directly addressed INSITE Challenges 2 and 3.

Academic Supervisor: Professor Corinne Whitby, Dr Natalie Hicks, Dr Boyd McKew and Professor David M. Paterson, cwhitby@essex.ac.uk / dp1@st-andrews.ac.uk

Student: Haleigh Jorgeson

Institute: University of Essex

Partners: University of St Andrews Centre for Environment, Fisheries and Aquaculture, VIA University College, Shell

Timeline: January 2022 – June 2025

CURRENT FINDINGS

At both decommissioned O&G platforms:

- Denitrifier communities were similar in abundance.
- Fungal abundance was similar across the distance transect.
- Methanogen communities were generally in lower abundance than the methanotrophs, suggesting that methane oxidation was more predominant than methanogenesis.
- Ammonia-oxidizing bacteria (AOB) were more predominant and abundant than Ammonia-oxidizing archaea (AOA) and were the likely drivers of nitrification at these locations.

Found across all sites:

- Shifts in micro- and macrofaunal diversity close to the MMS, (particularly at Miller for macrofauna), were driven by an interaction of environmental factors including distance from MMS.
- Significantly higher concentrations of heavy metals (e.g. Cr, Fe, Ni) and hydrocarbons (e.g. PAHs, Alkanes) close to the oil and gas platforms, compared to the reference sites further away.

RESEARCH LOCATIONS

North-West Hutton, Miller (decommissioned oil and gas platforms)

Indefatigable Field

Offshore Wind Farm in the Irish Sea

METHODOLOGY

eDNA analysis on sediment samples at gradients from the different sites was used to examine the microbial communities involved in macronutrient cycling.

ONGOING RESEARCH

- Analysis of the microbial communities at Indefatigable Field and of micro and macrofaunal communities at the OWF.
- Characterise the impact of heavy metals on benthic microbial communities associated with OWF .
- Comparison of eDNA techniques to traditional taxonomic identification for the analysis of benthic macrofaunal communities from around MMS.

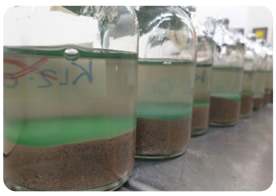


Image credit: University of Essex

PhD PROJECT 3

Changes in the distribution and abundance of marine top predators in the North Sea associated with present and future wind farm developments.

The development of large-scale wind farms and associated changes to near and far field habitats add increasing pressure to the distribution and abundance of marine top predators. This is added to the already observed impacts of increasing temperature on prey communities. The magnitude of such change is dependent on the scale, density and siting of wind farms. Whilst the overall range of important prey species is generally determined by temperature, the locations of enhanced prey availability within this range are determined by interactions between tidal currents, wind/waves and topography. All of which are affected by climate change and the presence of wind farms. This PhD research directly addresses INSITE Challenges 1 and 2.

Academic Supervisor: Professor Simon Neill and Dr. James Waggitt
s.p.neill@bangor.ac.uk/
j.waggitt@bangor.ac.uk

Student: Sophie Crouch

Institute: Bangor University

Partners: Deltares, Netherlands

Timeline: October 2021 – March 2025

CURRENT FINDINGS

Future offshore wind farms (OWFs) could impact North Sea hydrodynamics at regional scales, with localized, patchy effects. Models show future increased water column mixing and reduced stratification, particularly in the central to southeastern North Sea. Changes may affect prey species distribution, driven by factors such as bottom sea temperature, stratification, and lower trophic level processes, therefore, species within the Southern North Sea region are likely to be most impacted. While impacts at the North Sea scale may be minor, they could be more significant at localised scales for marine top predators reliant on areas of persistent prey aggregation.

RESEARCH LOCATIONS

Entire North Sea.

METHODOLOGY

Compiled national and international datasets to simulate models to develop a species distribution modelling approach and maps to highlight the location of critical habitats where prey is both abundant and exploitable.

ONGOING RESEARCH

Sensitivity analyses of key predator hotspots and protected areas are being investigated to assess the manner and magnitude of future OWF installation's impacts on key foraging hotspots.

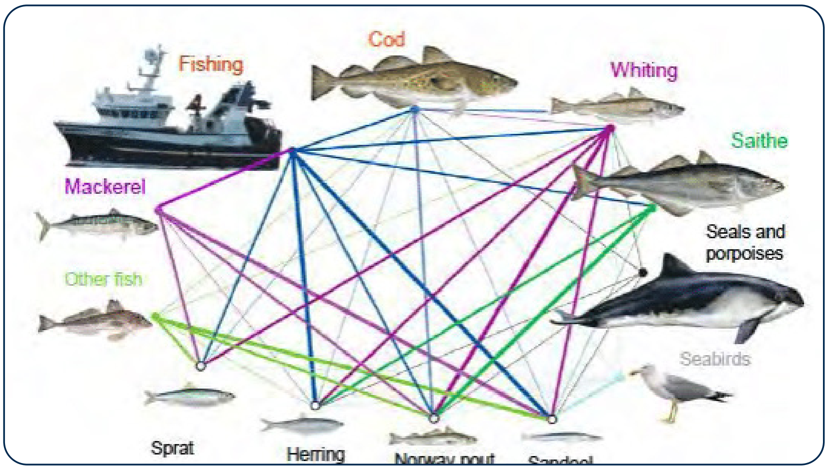


Image credit: Overview of the important predators on assessed North Sea fish species

PhD PROJECT 4

INSITE-OUTFLOW: Quantifying the cOntribUTion of Fouling fauna to the Local carbon budget of an Offshore Wind farm.

Man-made structures (MMS) in the North Sea provide new artificial hard substrates that are often rapidly colonized by various epifaunal organisms, predominantly suspension-feeding communities. These organisms filter suspended particulate matter, zooplankton, and phytoplankton, and also produce faecal pellets (FP) which are an integral part of the dynamics of organic matter (OM) and carbon sequestration in the sediment surrounding wind turbines.

To fully understand FP significance, this project aimed to develop isotopic tracers for the FP from dominant species, alongside other organic components such as phytoplankton and zooplankton, and use these tracers to quantify their contribution to the OM pool dynamics in OWF pelagic and benthic environment. This PhD research directly addressed INSITE Challenges 2 and 3.

Academic Supervisor: Professor Dr Jan Vanaverbeke, Professor Dr Tom Moens and Professor Dr Pascal Boeckx, jvanaverbeke@naturalsciences.be / tom.moens@ugent.be / pascal.boeckx@ugent.be

Student: Cepeda Gamella

Institute: Royal Belgian Institute of Natural Sciences

Partners: Marine Biology Research Group, Ghent University, Isotope Bioscience Laboratory (ISOFYS), Ghent University

Timeline: May 2021 – April 2025

METHODOLOGY

Field sampling, laboratory analysis and utilisation of long-term datasets (10 year+) of fouling fauna and soft sediments in OWFs in the Belgian North Sea.

RESEARCH LOCATIONS

OWF Belgian North Sea.

CURRENT FINDINGS

Preliminary fieldwork indicates that wind turbines enhance carbon accumulation in surrounding sediments, with levels 10-13% higher than in reference sites, varying seasonally.

ONGOING RESEARCH

Isotopic tracers will be selected to help quantify the contribution of faecal pellets (FP) to the pelagic OM pool which will help in tracking OM sources, enhancing our understanding of OWF impacts and informing marine conservation efforts. Data from a pulse-chase experiment will then assess carbon accumulation potential in offshore wind farm (OWF)

Image Credit: Esther Cepeda Gamella together with Gent University and the Royal Belgian Institute of Natural Sciences.

INSITE

INfluence of man-made Structures In The Ecosystem

PhD PROJECT 5

Artificial Structures and the functioning of the North Sea EcoSyStem (ASSESS).

This research studied the effects of fouling communities on MMS on natural processes, and dynamics by characterizing the local food web structure, nutrient cycling, and community respiration rates, as well as their effects on carbon cycling in the immediate vicinity. The project also explored the role of seasons in these dynamics. Information for this project was obtained from old production platforms, which was used as an indication for future developments in processes around the rapidly expanding offshore wind farms. This PhD research directly addresses INSITE Challenges 2 and 3.

Academic Supervisor: Joop W.P. Coolen, Ninon Mavraki, Marjolijn Christianen and Jaap van der Meer

Student: Leandra Kornau

Institute: Wageningen Marine Research Institute, The Netherlands

Partners: Royal Netherlands Institute for Sea Research, The Netherlands
Heerema Marine Contractors

Timeline: June 2022 – November 2026

RESEARCH LOCATIONS

Food web sampling OWF site:
K12-CC

Offshore WF incubations:
Halfweg, L10-B, L10-AR, K12-CC

Settlement plates:
Watersportvereniging Texel

METHODOLOGY

- Collect and analyse stable isotope samples around an old production platform and compare these to data from a younger structure.
- Monitor three community types under incubation conditions (for a year) to calculate oxygen and nutrient content per gram of incubated biomass. Then model outputs to estimate the effects of marine growth on nutrient concentrations and productivity in the North Sea.
- Extract pieces of the seafloor close and further away from a platform and add labelled organic material.

CURRENT FINDINGS

The project has developed a working method for offshore incubations and has conducted 20 offshore incubations for which the data on species and biomass still needs to be generated in the lab. The settlement plates have all been placed, and measurements have been collected for more than a year.

ONGOING RESEARCH

The experiment investigating carbon cycling in the sediment surrounding a production platform is in preparation and will be conducted in spring/ summer 2025.

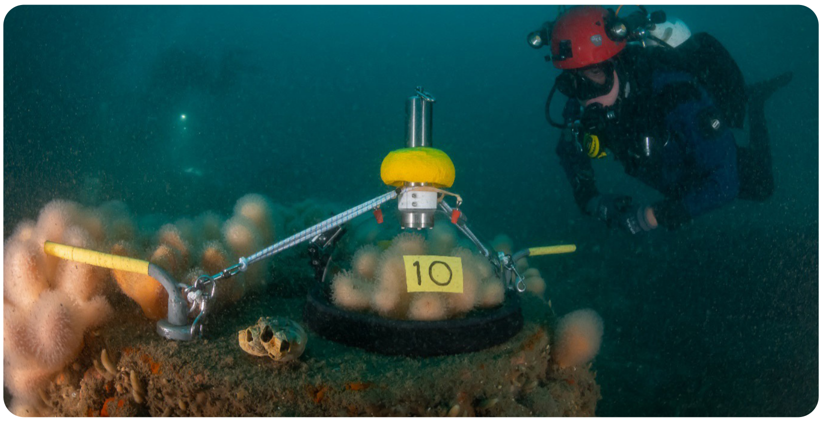


Image Credit: Joost van Uffelen. Incubation of the fouling community using an incubation chamber.

PhD PROJECT 6

Artificial Structures and the functioning of the North Sea EcoSyStem (ASSESS-2).

Structures implemented in soft-sediment-dominated marine environments, are shown to enhance benthic biomass and potentially alter energy flows, and function at the base of marine food webs. Such changes to substrates might also lead to altered stocks of species relevant to sustainable food production (e.g. seaweed and mussels), but these effects are relatively unknown. Modelling the current and forecasted numbers of hard substrates in the North Sea can help prepare for the socio-ecological challenges and opportunities imposed by the renewable energy transition. This PhD research directly addressed INSITE Challenges 2 and 3.

Academic Supervisor: Jaap van der Meer and Joop W.P. Coolen, jaap.vandermeer@wur.nl / joop.coolen@wur.nl

Student: Tan Tjui Yeuw

Institute: Wageningen Marine Research Institute, The Netherlands

Partners: Wageningen University and Research, Aquaculture and Fisheries Group

Timeline: December 2022 – November 2026

RESEARCH LOCATIONS

Entire North Sea basin.

METHODOLOGY

This project used an innovative modelling approach to understand how offshore developments such as offshore energy structures, seaweed farming, and mussel cultures, affect the mass balance of the entire food-web and carrying capacity of the North Sea, including hard substrate, soft sediment, and pelagic systems.

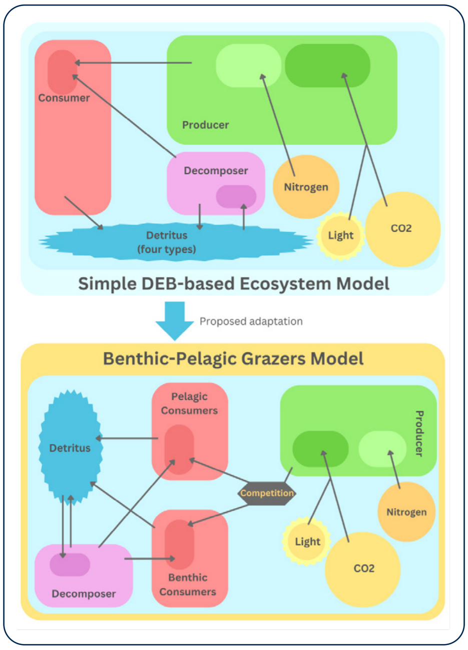
CURRENT FINDINGS

The underlying bioenergetic traits observed in benthic and pelagic grazers reveal differences that go beyond body sizes. Pelagic grazers' relative metabolic dissipation rates are orders of magnitude higher than benthic ones. This remains true for species commonly found around wind turbines and oil and gas platforms in the North Sea. Such high rates might indicate that pelagic grazers play an important role in nutrient availability and align with well-known copepod contributions to vertical carbon export.

ONGOING RESEARCH

Development of a method to express multi-species community traits in terms of their aggregated bioenergetic (i.e. Dynamic Energy Budget theory) parameters and modelling competitive trade-offs between grazer groups.

Image Credit: Wageningen Marine Research Institute Dynamic Energy Budget ecosystem model extended to include competing benthic and pelagic grazers.



NS3D PhD projects

PhD 7

"Optimising marine image capture and analysis from autonomous underwater vehicles" – Thomas Morgan (**NS3D; University of Highlands and Islands**)

PhD 8

"The application of machine-learning to establish baselines and assess change in sensitive marine habitats" - Alejandra Mejia Saenz de Tejad (**NS3D**; **University of Highlands and Islands**)

PhD 9

"Incorporating ecological modelling into 3D simulation of marine growth on man-made structures" – Megan Squire (**NS3D; University of Aberdeen**)

INSITE Interactive Metadata Portal

INSITE Interactive was an interactive GIS tool developed to facilitate data sharing between oil and gas operators and **INSITE** programme researchers. Developed by the **Xodus Group**, this proof-of-concept portal contained metadata relating to surveys completed close to oil and gas platforms and pipelines, as well as offshore renewables infrastructure and marine aggregates extraction sites. The metadata could be combined with other data sets such as those for Marine Protected Areas (MPA) locations, and offshore oil and gas licence areas. Scientists could search for and then request data from **INSITE** Interactive to use in their research under **INSITE**.

Project Lead: **Xodus Group**

Partners: **AT-SEA**, **DREAMS**, **FuECoMMS**, **EcoSTAR**, **CHASANS**, **FISHSPAMMS** & **NS3D INSITE projects**

Timeline: October 2020 – June 2023

Following the test phase between 2021-2022, the effectiveness of the **INSITE** Interactive portal was assessed, both from the perspective of the data requests and transfers process, and the quality of the data provided to end users. Key learnings from this trial are:

- The functionality of the portal had a great deal of potential, however the value of the current data holdings to **INSITE** projects it was difficult to evaluate due to data access issues. Of those data that were received, it was found that the interpreted and summarised data sets available through survey reports in pdf format were not as useful as raw imagery data from Remotely Operated Vehicles (ROVs), or samples that could be processed for further analysis.
- The data request process was onerous and the data that was received from operators via INSITE Interactive (often pdf format survey reports) was often not of great value to the **INSITE** projects.
- A valuable resource for **INSITE** researchers would be a system which is able to easily provide searchable and downloadable raw data from industry operators to interested parties.
- The **INSITE** programme director team recommend that the valuable experience and learning from **INSITE** Interactive is taken forwards in a programme of work to better understand the perspectives of the data owners and to work towards including oil and gas industry data in **The Crown Estate's Marine Data Exchange.**

The **Marine Data Exchange** is a world-leading collection of offshore marine industry data, containing data from marine aggregates, subsea cables, tidal and wave energy, offshore wind and wider research and evidence projects. Investing in a single, centralised, searchable raw data portal for offshore marine industry in the UK will make accessing industry data easier and more cost effective for those who wish to use it, harnessing its value in a wider context.

POLICY CONTRIBUTIONS

The **INSITE** Phase 2 projects addressed scientific challenges related to key UK marine policy areas.

UK Marine Strategy (UKMS)

Technologies such as Autonomous Underwater Vehicles (AUV) hold significant value for monitoring the Good Environmental Status (GES) descriptors and for rapid assessments of detailed high-resolution data collection (**AT-SEA**).

Both active and decommissioned oil and gas structures can enhance pelagic ecological function by acting as suitable habitats for marine growth (**NS3D**), increasing local fish abundance and attracting foraging seals (**EcoSTAR, FISHSPAMMS**, **CHASANS**). Fish abundance may also be elevated inside wind farms (**FISHSPAMMS**).

However, these effects are not greater than would be seen with natural rocky reefs or purpose-built artificial reefs (**DREAMS**) and all networks of hard substrates have the potential to act as stepping stones for non-indigenous species (**CHASANS**). There are clear benthic legacy effects of decommissioned oil and gas platforms, documented in sedimentary food webs which are less complex and diverse closer to structures (**FuECoMMS**).

It is unlikely that plastics associated with oil and gas pipelines, and umbilicals pose an imminent threat to the environment, but their persistence and accumulation over long timescale is of concern. Plastics from all sources have the potential to cause harm in the marine environment and oil and gas activity could be a significant contribution to the overall concentration in the marine environment (**PLASTICS**).

POLICY BACKGROUND

The UK Marine Strategy Regulations 2010 provide the three-part framework for delivering marine policy at the UK level and sets out how UK Government will achieve the vision of clean, healthy, safe, productive and biologically diverse oceans and seas.

PART 1

UK Assessment and Good Environmental Status (GES).

PART 2

UK monitoring programmes.

PART 3

UK programme of measures.

Achieving GES is about protecting the marine environment, preventing its deterioration and restoring it where practical, whilst allowing sustainable use of marine resources. The framework applies an ecosystem-based approach to the management of human activities, to keep collective pressure within levels compatible with the achievement of GES.

The UK Marine Strategy (**UKMS**) covers 11 descriptors and 6 ecosystem components grouped into 15 indicator categories (Table 1), as well as four areas of interest:

- **Biodiversity, food webs and marine protected areas**
  (Fish, Seals, Marine protected areas, Food webs, Benthic habitats, Pelagic habitats, Birds, Cetaceans),
- **Pressures from human activities**
  (Non-indigenous species, Commercial fish and shellfish, Eutrophication, Hydrological conditions, Contaminants, Contaminants in Food, Marine Litter, Underwater Noise),
- **Ocean processes and climate**
  (Sea temperature, Salinity, Ocean acidification, Turbidity),
- **Uses of the marine environment**
  (Evaluating public perceptions, Predominant pressures exerted by human activities, Social and economic analysis, Cumulative effects of human activities).

RELEVANCE OF PROJECT FINDINGS

As summarised in Table 1, several projects from INSITE have generated new data directly relevant to the **measurement of GES:**

AT-SEA generated **benthic species** diversity and spatial extent data.

ECOSTAR generated data on **marine mammal** abundance and trophic linkages.

CHASANS recorded the occurrence of **non-native species** on structures

FISHSPAMMS assessed **fish** size and abundance, and distribution around structures.

FuECoMMS documented high levels of contaminants alongside less diverse and complex **food webs** near platforms comprising of smaller individuals and fewer higher trophic organisms.

DATA

Data were also generated on the environmental and societal effects of MMS which can feed into reporting on pressures from human activities as part of UKMS assessments:

AT-SEA generated **distribution data of disturbance pressures** on the seabed.

PLASTICs will contribute to understanding of the **quantities of plastics and microplastics in the marine environment.**

DREAMS generated a coded **database of the ecological effects of structures,** containing raw data on fish and invertebrate abundance, biomass, and diversity, with links to ecosystem services.

SYNTHESIS proposed a general **framework for assessing pressure and effects from structures** as well as costs and benefits from decommissioning options which can be tailored to specific contexts, such as specific structures sited in UK waters.

TECHNOLOGIES

Other projects have developed techniques, generated databases, produced frameworks, or used technologies which hold significance to the UKMS, particularly in monitoring (part 2) and implementing measures (part 3). For example:

AT-SEA generated high-resolution data on **bathymetry, chemistry, and biology using AUVs.**

FISHSPAMMS used Uncrewed Surface Vehicles (USVs) to collect consistent, low-risk and low-cost acoustic information. These technologies could be used to standardise the monitoring of the descriptors, as well as undertake rapid environmental impact assessments.

NS3D developed technologies that enable large-scale **assessment of marine growth on structures, including biomass estimation and automated species identification,** contributing to assessments of ecosystem health and ecosystem-based monitoring.

GES / Projects	AT-SEA	CHASANS*	DREAMS	EcoSTAR*	FISHSPAMMS	FuECoMMS*	NS3D*	PLASTICS	Synthesis
D1 & D4			Indirect	High					Indirect
D1 & D4 Seals			Indirect	High					Indirect
D1 & D4 Birds			Indirect						Indirect
D1 & D4 Fish	Medium		High	Indirect	Medium				Indirect
D1 & D4 Pelagic		Indirect *	Medium						
D1 & D6 Benthic	Indirect	Medium	High	Medium		Medium *	High	Indirect *	Indirect
D2 Non-indigenous Species	Indirect	High	Indirect				High		Indirect
D3 Commercial Fish (and Shellfish)		Medium	Indirect	Indirect	Medium				Indirect
D3 Food Web				High		Medium *	High		Indirect
D5 Eutrophication			Indirect						Indirect
D7 Hydrographical condition change	Medium		Indirect			Medium *			Indirect
D8 Contaminants	Indirect					Medium *		Medium	Indirect
D9 Contaminants in food									Indirect
D10 Litter	Indirect		Indirect					High	
D11 Input of				Medium					Indirect

Key (cell shading): High = Direct findings/ High relevance; Medium = Direct findings/ Medium relevance; Indirect = Indirect findings/ Medium -low relevance; empty = No relevant data

Relevance of INSITE Phase 2 project outputs for the different Good Environmental Status (GES) Indicators (Table 1).

These technologies could be adapted to assess not only MMS but also the surrounding seabed which could contribute to a wider marine environmental monitoring framework, such as the UK Marine Monitoring and Assessment Strategy

POLICY CONTRIBUTION

POLICY 2

British Energy Security Strategy (BESS)

The infrastructure needed for offshore wind energy should be designed to provide environmental benefit both during and after its operational life (**SYNTHESIS**)

Fish abundance was found to be higher inside an offshore wind farm than in the surrounding 10km (**FISHSPAMMS**)

New oil and gas infrastructure is becoming less of a priority for stakeholders, while offshore wind is increasing in priority and as a source of opportunity, but not without challenges and potential conflicts (**CHASANS**).

Autonomous and remote technologies offer quick and standardised data collection for preliminary assessments and monitoring, contributing to the development of a transparent, efficient and robust consenting process for the roll out of offshore wind (**AT-SEA**, **NS3D**, **FISHSPAMMS**)

Offshore wind farms can have both beneficial and detrimental effects to biodiversity, the provision of other ecosystem services, and human community groups (**DREAMS**).

POLICY BACKGROUND

The British Energy Security Strategy (**BESS**) is a 10-point strategic plan which aims to "Secure clean and affordable British energy for the long term". BESS aspires for the majority of British energy to come from wind, solar and hydrogen production, as well as nuclear.

The BESS has key objectives that are relevant to **INSITE** projects around scaling up the UK's renewable energy capacity, accelerating licencing and consenting approaches, and granting additional leases to UK North Sea fields so that domestic gas production may be maintained and remain a core part of UK energy security.

INSITE project findings can contribute to two of the 10 strategic points: Advancing offshore wind (while still renewing leases to O&G field in the North Sea) and Protecting our natural environment. Further contributions to BESS can align with these targets:

- Introducing **environmental considerations at a more strategic level** to speed up the consenting process while improving the marine environment.
- Introducing **strategic compensation environmental measures** for projects already in the system to offset environmental effects and reduce delays to projects.
- Implementing an industry-funded **Marine Recovery Fund** and **nature-based design standards** to accelerate deployment whilst enhancing the marine environment.

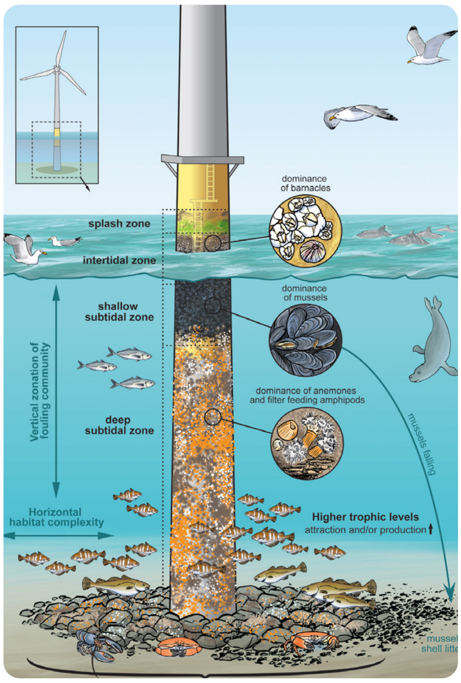


Image Credit: **Illustration by Hendrik Gheerardyn**

RELEVANCE OF PROJECT FINDINGS

Quick, simple, consistent and standardised data collection and monitoring, such as that offered by emergent AUV and USV technologies, as developed in **AT-SEA**, **NS3D** and **FISHSPAMMS**, can provide the necessary information needed to contribute to the development of a transparent, efficient and robust consenting process for the roll out of offshore wind. Incorporating the use of such technologies and methodologies at regional scales will foster and simplify strategic regional cooperation and coordination, leading to environmental considerations being achieved at a more strategic level.

AT-SEA, **NS3D** **and** **FISHSPAMMS** provide simplified and consistent exploratory and **monitoring practices** that contribute data and **methodologies suitable for Environmental Impact Assessments** and **Habitats Regulations Assessments**. These may be used to gather crucial in situ information and assist consenting assessments. For example:

FISHSPAMMS data collected at an OWF site showed that inside the **OWF site densities of fish are higher than in the surrounding 10km.** Additional data will be available from **FuECoMMS** by the end of 2024 on the impacts of OWF and contaminants on seabed biodiversity; Regional analysis approaches by **EcoSTAR** estimated seal and harbour porpoise densities across the North Sea;

PLASTICS has gathered evidence on the nature, legacy and occurrence of plastics in oil and gas subsea cables and umbilicals;

DREAMS has provided evidence on the global ecological and ecosystem service effects of offshore wind;

NS3Ds AI-assisted AutoID technology and 3-dimensional modelling techniques can analyse imagery data collected by industry to produce **biomass and abundance estimates** from ROV collected data from MMS.

Both the **DREAMS** and **SYNTHESIS** projects have shown that there is a clear consensus that the roll-out of offshore wind structures provides an important strategic opportunity to implement design that not only reduces ecological impact but also provides net environmental benefits and therefore enhances the marine environment, in order to generate legacy benefits beyond their operational life. For example:

DREAMS discusses the importance of **designing offshore wind structures that are easily removable** (decommissioned), or if they are to remain in the sea, ways of integrating **nature-based designs** (**DREAMS**; Knights *et al*., 2024c; Lemasson *et al*., 2024).

The science-art collaboration in **NS3D** shows how **nature-based design standards** may be supported through user-interactive 3D virtual environments showcasing marine growth on MMS supported by 3D printed coral and other taxa.

"Eco-engineering concepts, such as those already tested for coastal artificial structures […] could be applied either prospectively or retrospectively to maximize ecological benefits and contribute to environmental net gain."

Lemasson et al. 2024
DREAMS

"Governments should require companies to ensure that their structures provide added environmental and societal benefits […] If designed properly, the marine infrastructure that is needed as the world moves towards renewable energy could benefit the environment — both during and after its operational life."

Knights et al. 2024 **SYNTHESIS** *(3)*

POLICY CONTRIBUTION

POLICY 3

Marine Net Gain (MNG)

Oil and gas structures and wind farms can host locally increased fish abundance. This effect may be reduced at smaller structures, e.g. following decommissioning (**FISHSPAMMS**)

Structures can support biodiversity through the colonisation of species of conservation value, but also generate risk from non-native species (**CHASANS**)

Decommissioning oil and gas structures or wind farms to become artificial reefs will deliver environmental benefits (including enhanced biodiversity) towards achieving MNG, however, not as much benefit as compared to purpose-built artificial reefs and natural ecosystems (**DREAMS**)

Where MNG and environmental restoration are the objective behind decommissioning there is international scientific consensus that partial abandonment or fully leaving structures in place at end of life is preferable (**SYNTHESIS**).

POLICY BACKGROUND

Marine Net Gain (MNG) builds on Biodiversity Net Gain (BNG), which applies to terrestrial areas down to the mean low water mark in England. MNG is a concept that aims to support recovery of the marine environment by requiring that future developments leave the environment in a measurably better state than before that development took place, embedding environmental improvement into infrastructure planning and delivery.

This emerging policy area offers a real opportunity to deliver marine nature recovery through industry involvement. MNG is only applicable to developments below the mean low water mark and is intended to cover new marine developments in English waters only. A similar initiative is under development in Scotland referred to as the Marine Nature Enhancement Programme.

MNG has biodiversity at its core but also allows for inclusion of wider environmental benefits. Each development would need to produce a level of gain proportionate to the losses related to it. MNG incentivises both active interventions and appropriate pressure reduction measures to achieve recovery.

Although specific requirements for MNG are still being decided MNG does not supersede existing environmental requirements but is a new requirement that developers of new oil and gas, or offshore wind installations will need to adhere to.

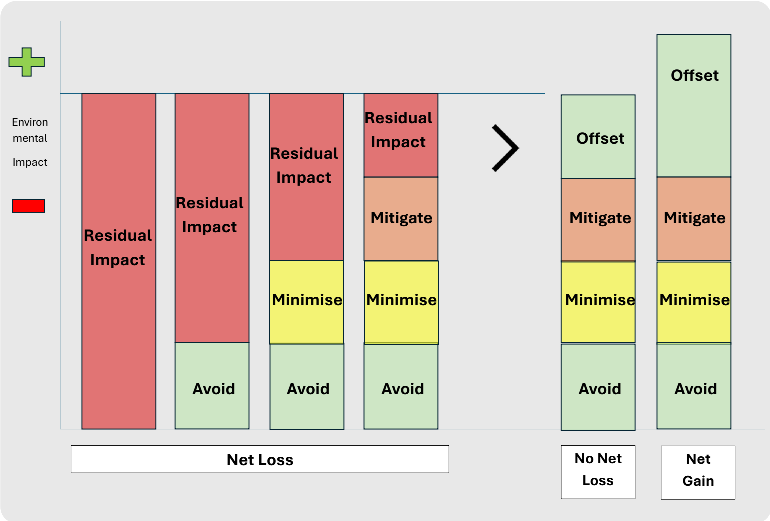


Image credit: Adapted from MNG, **Defra Consultation report.**

RELEVANCE OF PROJECT FINDINGS

Six INSITE Phase 2 projects directly generated biodiversity data that can contribute significant information and evidence for MNG assessments:

CHASANS gathered information on **larval diversity and settlement preference at structure sites.** Understanding what species are likely to be in the species pool of a location as larvae, as well as the preferences of materials that they can grow on, can **inform the design and choice of materials used for infrastructure development.** This in turn can support MNG or accelerated recovery as part of restoration programmes.

ECOSTAR produced marine mammal distribution estimates which can contribute to identifying specific areas and habitats to **guide MNG project placement and design.** Work on benthic trait indicators related to the impact of offshore structures can help understand the wider change in **environmental benefits such as ecosystem function and services.**

NS3D generated taxon-specific **biomass estimates** from ROV footage collected at MMS, while FuECoMMS has this data from the sediments, the latter also measuring seabed biodiversity changes from microbial to macrofaunal level. Sediment biodiversity is particularly important as it drives much of the wider environmental benefits derived from the seabed, such nutrient cycling, pollutant or contaminant remediation, carbon sequestration. AT-SEA measured surface seabed biodiversity of macrofauna and fishes.

FISHSPAMMS provides supporting evidence for MNG metrics in the form of fish densities and spatial distribution patterns. It also demonstrated the **potential for wind farms to locally support biodiversity** through increased fish densities.

INDIRECT PROJECT FINDINGS

DREAMS and SYNTHESIS evaluated the relative environmental and societal benefits and limitations of the presence of structures and the different strategies for their decommissioning of use to MNG assessments.

DREAMS highlights that **leaving all or part of offshore wind structures in place** and potentially adding protective layers to the structures, **might be beneficial** for ecosystem services and environmental net gain.

DREAMS also suggests that using decommissioned structures as artificial reefs by leaving all, or part, of the structure or repurposing them at sea may not deliver enhanced biodiversity, compared to purpose-built artificial reefs and natural ecosystems.

SYNTHESIS emphasised a collective viewpoint from experts on the overall effects of structures on marine biodiversity. General consensus was reached that **if MNG and environmental restoration is the objective partially or fully leaving all structures in place was the preferred option.**

BIODIVERSITY AND ENVIRONMENTAL BENEFITS

INDIRECT EVIDENCE

SYNTHESIS (collective viewpoint on structures effects on biodiversity + net gain effects of various decommissioning options)

DREAMS (fish and invertebrate abundance, biomass and diversity, changes in ecosystem services provision)

DIRECT EVIDENCE

EcoSTAR (marine mammal distribution, benthic trait indicators)

CHASANS (larval diversity, species sewttlement preference)

FISHSPAMMS (fish density and distribution)

FuECoMMS (biodiversity on structures and in sediments, from microbes to macrofauna, seabed services)

TECHNOLOGY/ METHODOLOGY

NS3D (ROV and 3D model assesment and monitoring of biodiversity)

FISHSPAMMS (modelled fish spillover)

ECOSTAR (modelled future biodiversity and ecosystem services)

FuECoMMS (eDNA)

FuECoMMS (autonomous platform for biodiversity assesment)

POLICY CONTRIBUTION

POLICY 4

Fisheries Management

Decommissioned oil and gas structures, and wind farms can locally increase populations of important commercial fish and shellfish stocks such as sprat, herring cod and scallops, creating opportunities for more fish to be caught with less effort, but also challenges due to increase competition for space due to fish aggregating around these structures (**FISHSPAMMS**, **DREAMS**, **CHASANS**).

When considering OSPAR 2030 strategy targets, the only decommissioning option found to have any enhancement on fishing catch and efforts was partial removal and addition of protective structures (**SYNTHESIS**).

POLICY BACKGROUND

The **UK Fisheries Act (2020)** seeks to ensure UK fisheries are environmentally sustainable in the long term, and managed to achieve economic, social and employment benefits, and contribute to food supplies. The Joint Fisheries Statement (JFS) (2022) sets out how the 8 objectives of the Fisheries Act will be met by the UK's four national fisheries policy authorities.

The JFS recognises the importance of protecting and restoring blue carbon habitats, and the importance of a healthy and resilient marine environment as the foundation for a prosperous seafood sector and thriving coastal communities. It also recognises that sustainable use and conservation of the sea is central to any fisheries management approach.

RELEVANCE OF PROJECT FINDINGS

Two projects generate evidence directly relevant to UK fisheries policy (Table 2):

- **FISHSPAMMS demonstrated the potential of O&G infrastructure and wind farms to support locally increased fish densities,** with consideration of catchment areas and the potential for structure networks to have large-scale influence.
- Mammal distribution estimates produced in **EcoSTAR contribute towards better understanding of the bycatch potential of sensitive species** (Environment objective).

Objectives / Projects	Sustainability	Ecosystem	Scientific Evidence	Bycatch	Climate Change
CHASANS			de facto		
DREAMS			de facto		
EcoSTAR			de facto		
FISHSPAMMS			de facto		
NS3D			de facto		
SYNTHESIS			de facto		

Direct emperical data

Indirect data or information

de faco relevance to the Scientific Evidence objective

No relevant data

Relevance of INSITE Phase 2 project outputs for the different UK Fisheries Act 2020 objectives (Table 2).

Five projects generated indirect evidence of relevance to the UK's Fisheries Act 2020 and its objectives.

ECOSYSTEM OBJECTIVE:

- **NS3D** has developed **image-analysis techniques** that can be further developed to identify pelagic and benthic fish species, including individual endangered flapper-skate, and **can offer capacity to reduce the impact of fisheries surveys,** reducing costs and environmental impacts, whilst increasing their scope.
- The **DREAMS** meta-analysis showed that **offshore structures** (oil and gas, offshore wind, shipwrecks, artificial reefs) have the ability to **promote fish abundance locally** when placed on natural sedimentary habitats (Ecosystem). Some appear to also **boost fish diversity** (artificial reefs), and **provide increased fish biomass** (oil and gas), compared to natural sedimentary habitats.
- **CHASANS** focussed on the epifauna assemblages associated with structures, which can **provide food and refuge for juveniles of commercial fish and shellfish** such as the Queen Scallop, thereby contributing information to the Ecosystem objective.
- **INSITE point of view:** Whilst commercial fishing is not permitted directly adjacent to structures, such areas of refuge can provide important habitats and protection for juveniles of stock species leading to **potential 'spill over' providing stocks for fisheries.** This information could also be used towards establishing MMS as multi-use areas where aquaculture and fish farming could be explored.

CLIMATE CHANGE OBJECTIVE:

- The modelling scenarios in **EcoSTAR** provide insights into how **different fishing scenarios** (e.g. fisheries exclusion around structures) will **impact both the ecosystem and fisheries,** providing information for **more effective Fisheries Management Plans.** These scenarios also explore how the ecosystem is likely to respond to climate change addressing the climate change objective.

SUSTAINABILITY OBJECTIVE:

- **SYNTHESIS** considered how different decommissioning strategies for offshore structures could indirectly support fisheries objectives. For instance evidence on **restricting spatial access** through buffer zones or by creating navigational hazards support the ecosystem objective and showing the extent to which **structures can support aggregation of fish biomass that could lead to greater stock resilience** to fishing pressure supports the sustainability objective.
- The ecosystem service assessment from **DREAMS** showed that the only decommissioning option to have any **enhancement effect** (increased landings) for commercial fishing opportunities was to **partially remove and add protective structures.**

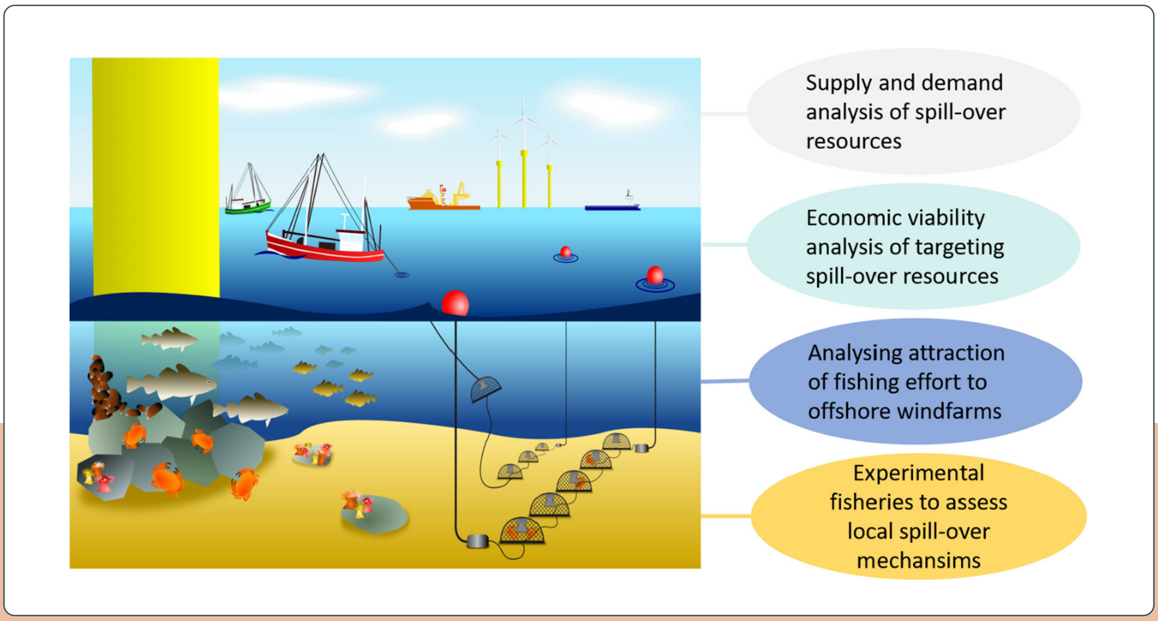


Image Credit: *Sustainable co-location solutions for offshore wind farms and fisheries need to account for socio-ecological trade-offs. Thünen Institute of Sea Fisheries.*

POLICY CONTRIBUTION

POLICY 5

UK 25 Year Environmental Plan

Updated harbour porpoise distribution in the North Sea provides long-term trends as well as snapshots in time over large scales. Further spatial population modelling to update density for multiple fish species, including cod, underway (**EcoSTAR**).

The assessment of priority marine features of high-conservation value, such as specific benthic habitats (mussel beds and maerl beds), is supported by new imagery analysis techniques developed by **NS3D** and **AT-SEA**.

POLICY BACKGROUND

The 25YEP sets out the UK Government's vision for action to help the natural world regain and retain good health. The **Environmental Improvement Plan (EIP) 2023** for England is the first revision of the 25YEP and sets out ten goals and interim targets to measure progress for improving nature. **INSITE** projects are of particular relevance to the Apex Goal (Goal 1) as described in the EIP.

GOAL 1: THRIVING PLANTS & WILDLIFE

- **Restore nature and halting biodiversity loss**
- **Establish a network of marine protected areas**
- **Protect 30% of our sea**
- **Designate the first Highly Protected MPA**
- **Create, enahance and restore habitats**
- **Achieve GES (link to UKMS)**

The EIP uses an Outcome Indicator Framework which sets out a comprehensive set of 66 indicators arranged into 10 broad themes to describe the environmental change that relates to the 10 goals. Of particular relevance to **INSITE** projects is theme C on Seas and Estuaries and its related indicators.

RELEVANCE OF PROJECT FINDINGS

As the majority of the 11 indicators used in theme C, Seas and Estuaries, are closely linked to those used to assess Good Environmental Status (GES), as part of the UK Marine Strategy (UKMS), these are dealt with in the UKMS section on page xx. Here we will only relate INSITE findings to the C6 indicator on Diverse seas: status of threatened and declining features:

- EcoSTAR estimated distribution of **harbour porpoises,** a listed mammal species under C6, and;
- FISHSPAMMS collected density and distribution data for various listed species of **fish,** including cod;
- CHASANS is identifying the larval connectivity at different oil and gas sites while FuECoMMS and AT-SEA described **sedimentary macrofauna species,** with some of those species likely listed as part of the C6 assessment.
- DREAMS catalogued all the scientific literature around the ecological effects of marine offshore structures and marked which species were investigated in each study, including listed species such as the **black-legged kittiwake, the harbour porpoise, and the cold-water coral Lophelia pertusa.** This has provided a **catalogue of information on species affiliated with offshore structures.**

TECHNOLOGIES

NS3D and ATSEA showcased how the application of technologies and methodologies could support the assessment of C6, through standardised, quick and consistent biodiversity data collection and automated species identification from imagery analysis.

- AT-SEA demonstrated that **autonomous environmental data collection can be used to evaluate the nature of the seafloor** and its biological communities. NS3D used **image-analysis techniques** to identify individuals of endangered species from photographs as well as **monitoring priority benthic habitats and marine features of high-conservation value.** These endangered species and habitats include the flapper skate/common skate and mussel and maerl beds, all of which are listed in C6.
- NS3D applied machine learning to help establish baselines and assess change, including that of fishing impacts, in sensitive marine habitats. The **technology holds the potential to be adapted for the automatic assessment of indicators other than C6, such as litter, condition of the seabed, and fish/shellfish populations.**

Image credit: RSPB

Image credit: Whale and Dolphin Conservation

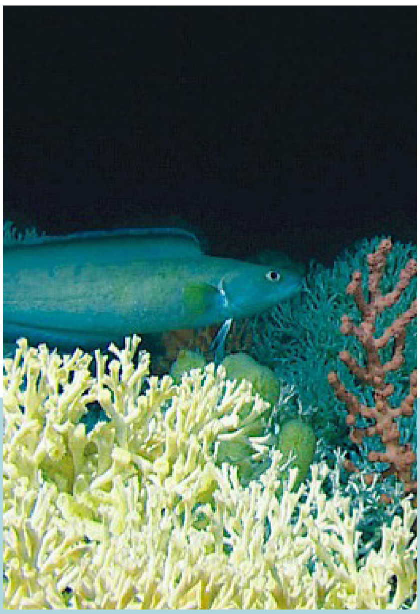


Image credit: OSPAR commission

An INSITE into OSPAR 98/3

Since 1998, OSPAR Decision 98/3 has prohibited the dumping, and the leaving wholly or partly in place, of disused offshore installations within the North Sea and wider northeast Atlantic maritime area, unless a derogation has been granted.

As a result, oil and gas infrastructure must be fully removed from the marine environment at end-of-life unless there are sufficient reasons for not doing so. There are limited instances where derogations have been granted, typically leaving concrete gravity bases and heavy steel footings on the seabed due to difficulties in their removal, rather than on environmental grounds.

As oil and gas infrastructure reaches end-of-life in the UK, there are plans to decommission over 2100 wells, 260 topsides and sub-structures, and 3800 km of pipeline by 2032. Alongside this need for decommissioning of oil and gas infrastructure, the UK's ambition for large-scale deployment of offshore wind infrastructure to achieve up to 50 GW of renewable power generation by 2030, as set out in the British Energy Security Strategy (BESS), will also require large-scale future decommissioning strategies.

Options other than complete removal of structures do exist and are being implemented elsewhere in the world, e.g. Gulf of Mexico, California, Gulf of Thailand, where the benefits of MMS are being explored. Such **benefits include the provision of artificial reef habitats for marine life.** However, there is currently no legal provision for this consideration in the OSPAR maritime area. As the **debate over the suitability of Decision 98/3** continues amidst the modern climate and biodiversity crises, **INSITE** Phase 2 shares new scientific findings to best inform OSPAR.

TESTING NOVEL TECHNOLOGIES

In alignment with the OSPAR principle of using the most up-to-date Best Available Techniques and Best Environmental Practice, INSITE projects have showcased the use of innovative technology and methodologies. For example:

- The use of eDNA and radioisotope analyses show that **microbial community diversity differs in sediments adjacent to structures** relative to controls 3km away **(FuECoMMS).**
- Innovative modelling techniques in various projects **(EcoSTAR, DREAMS, FISHSPAMMS, CHASANS, NS3D)** have helped to inform potential **effects of decommissioning scenarios upon food-webs.**
- The use of autonomous or remote monitoring technologies have collected thousands of images, generating **new evidence of seabed condition around MMS** that was not previously available when Decision 98/3 was published **(AT-SEA, NS3D).**
- **NS3D** used remotely operated vehicles to collect imagery of organisms growing on structures and, with the help of **machine learning, identified biodiversity** and fed the information into **3D models of biomass.**
- The prospect of fully autonomous monitoring of multiple production and decommissioning sites without the aid of a support vessel was demonstrated by **AT-SEA** through shore-launched, long-range AUVs and by **FISHSPAMMS** which used USVs to survey the densities and spillover of fish around structures. This data was used to parameterise a **high spatial resolution model of fish dynamics and movements.**

INSITE has shown that when combined with more traditional techniques, **cutting-edge technology and methodologies play a crucial role in providing new evidence** that was once beyond reach. They also offer the opportunity for data gathering and monitoring in a standardised manner that can be **strategically implemented efficiently across large scales and multiple structures as part of a coordinated effort.**

GENERATING NEW ECOLOGICAL DATA

Much like the OSPAR commission is guided by the ecosystem approach, several INSITE Phase 2 projects have helped shed a fresh light on ecosystem dynamics around MMS, highlighting both desirable and undesirable effects across local and wider ecosystems:

- EcoSTAR showed **benthic communities may be more functionally vulnerable near platforms** than away from them, results echoed by **FuECoMMS**, which showed **less trophic complexity in seabed communities** closer to decommissioned platform bases;
- Conversely, AT-SEA and NS3D identified **highly diverse and functional communities living on the structures themselves,** including cold water corals, now functioning as artificial reefs.
- FISHSPAMMS shows the potential **range of influence** of oil and gas installations on fish abundance to be between 1 to 20 km. around MMS that was not previously available when Decision 98/3 was published **(AT-SEA, NS3D).**
- Decision 98/3 equally applies to offshore renewable energy installations. **FISHSPAMMS** shows the potential impact of offshore wind farms on the densities and behaviour of fish, showing **local aggregations of different fish species within an offshore wind farm.**
- EcoSTAR also showed how **MMS affected the behaviour of some seals,** who may be attracted to the structures, but this project is still investigating wider seal distribution patterns where they vary across sites, showing no clear overall attraction to the structures.
- Upon completion in 2025, **CHASANS** will enhance our understanding of the genetic connectivity of populations of marine fauna colonising artificial substrates across the North Sea, indicating to what extent structures are serving as a network of stepping stones across the North Sea, echoing results from **INSITE** Phase 1.

SUPPORTING DECISION-MAKING FOR DECOMMISSIONING

To complement new empirical and modelling data, several INSITE Phase 2 projects generated information that can play a key role in decision-making and the on-going debate around the suitability of OSPAR Decision 98/3:

- EcoSTAR generated a robust and comprehensive dataset of North Sea MMS to address spatial inaccuracies in the existing national databases, that in one instance showed the position of a MMS to be inaccurate by 50km. This **new dataset catalogues 700 oil and gas platforms and >5,000 wind turbines in the North Sea** (June 2024) and is essential to the effective spatial management of the marine environment across the North Sea basin.
- DREAMS showed that, overall, oil and gas structures and offshore wind farms have very different effects on species diversity, abundance and biomass compared to purpose-built artificial reefs. **While offshore energy structures may provide some ecological benefits compared to sedimentary habitats, there were not enough studies available, with empirical data, to make comparisons across alternatives** such as natural reefs. There is a need for more evidence to assess claims that these structures can “act as artificial reefs” if decommissioned in the sea.
- The **PLASTICS** project estimated timescales for **degradation of subsea plastic in oil and gas pipelines and umbilicals to be in the region of 100s – 1000s of years.** Consequently, whilst there is unlikely to be imminent environmental risk, the potential for cumulative impacts from plastics accumulating in the environment over time cannot be ignored, particularly in light of scientific consensus that plastics are harmful, both to marine life and to human populations. Steps should be taken to minimise their accumulation in the environment, for example, as a key element of consenting in any new developments.
- The **SYNTHESIS** project concluded that there was a diversity of impacts, costs and benefits associated with extant structures, some of which were desirable (e.g. locally enhanced diversity) and others were undesirable (e.g. pollution). Despite this, consensus was achieved with limited disagreement that **leaving structures in place in some form was considered a better option than complete removal with respect to environmental targets**, such as those set in the OSPAR North-East Atlantic Environment Strategy 2030, UN Rio+20 ‘Future We Want’ and UN Sustainable Development Goals (SDG).

OSPAR 98/3 Summary

Collectively, INSITE research shows the environmental and societal benefits from structures vary greatly depending on the decommissioning options but also depending on the local context.

As such, the benefits of leaving structures in place rather than removing them depends on the priorities of stakeholders in a given region and decisions should be made on a case-by-case basis.

Indeed, many researchers in the **SYNTHESIS** project called for **Decision 98/3 to be revised to allow a more flexible approach to decommissioning of structures in the North Sea, in which decision-making can be applied on a case-by-case basis by undertaking a robust cost-benefit analysis of various decommissioning options.** Perhaps this could be achieved via the existing Comparative Assessment process established by OSPAR Decision 98/3. In this way, **regional decision-makers should have the power to consider alternative decommissioning options which may be better suited to their local context, if the cost-analysis process leads to the conclusion that alternatives to full removal are preferable.**

From empirical data to consensus views, the body of work provided by the **INSITE** Phase 2 projects has produced diverse and crucial evidence that can undoubtedly make a significant contribution to the ongoing discussions and decision-making around OSPAR Decision 98/3. Some evidence gaps still remain, but this new knowledge will support future research directions and help shape **INSITE** Phase 3.

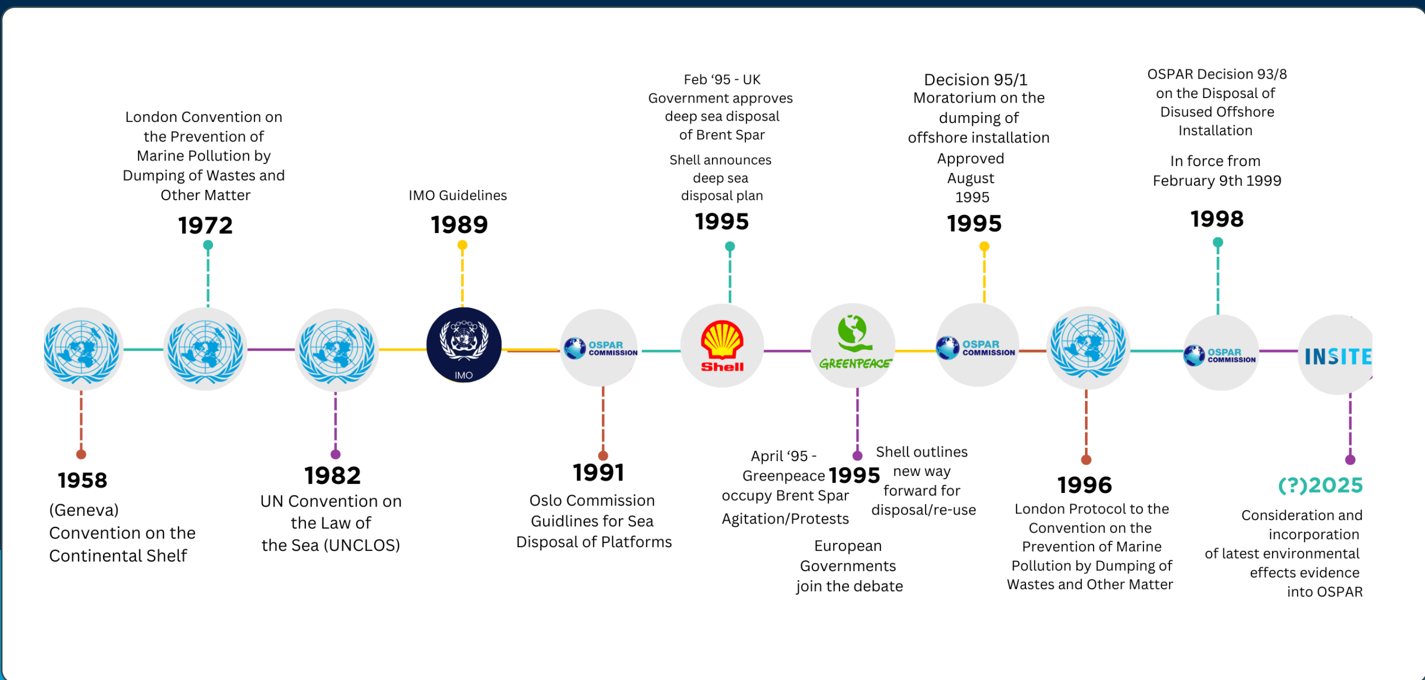


Image Credit: Adapted from 'A Rigs-to-Reefs Pilot Project in the OSPAR Region -Why should we pursue the option?', University of Aberdeen.

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