Designing for Decommissioning: Opportunities for Marine Science

Workshop Proceedings

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Acknowledgements: Sarah Keynes and Lizzie Hinchcliffe, NERC
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1. Introduction and Background

Designing offshore structures for decommissioning allows engineers to learn from the issues encountered with current decommissioning plans, therefore potentially improving future efficiency, reducing costs, improving safety and reducing the overall decommissioning footprint.

A Joint Industry Programme (JIP) called Design for Decommissioning (D4D) was set up in 2016 in collaboration with 13 organisations. The aim of the JIP was to create a database\(^1\) that would provide practical guidance to engineers when designing new facilities or modifying facilities that would ultimately make the decommissioning process easier.

Building on this, there is the opportunity to take lessons learned from the environmental and marine science issues associated with decommissioning and determine how these issues may be overcome at the design stage.

The concept for this workshop was developed following interaction with the JIP through the Society for Underwater Technology (SUT) Decommissioning and Wreck Removal Committee. A topic paper was written (Appendix A) and circulated to committee members and to other Marine Alliance for Science Technology Scotland (MASTS) members that might have an interest, for comment and input.

The Natural Environmental Research Council (NERC) supported the workshop to discuss potential opportunities, bringing together marine scientists and engineers from academia and industry, as part of the NERC Innovation Programme in Oil and Gas (IPOG).

2. Aims and Objectives of the Workshop

The aim of the workshop was to bring together academic researchers and industry with the purpose to discuss potential challenges, opportunities and innovation within marine science, that if implemented and incorporated at the design stage of an installation, will enable better environmental management throughout the life cycle of the facility.

2.1. Presentations

The workshop initially consisted of a number of presentations. The first of which provided an overview of the industry D4D project, presented by Caroline Laurenson of Xodus Group (engineering consultant). This was followed by a joint presentation from Moya Crawford from DeepTek (industry solutions) and Joel Mills from the Offshore Simulator Centre (industry solutions and services), who presented an overview of recent industry innovations showcasing the use of simulators and virtual reality, which help reduce industry decommissioning costs and which may be applicable to non-engineering aspects – such as marine science, through collaboration with academics.

The second set of presentations were provided by project teams of the recently completed NERC Decommissioning and Innovation projects (awarded 2016-2017) – titles are provided in Table 1 and abstracts are outlined in Appendix B.

\(^1\) See PetroWiki – Design for Decommissioning for further information
Table 1: Workshop Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>09:00 – 10:00</td>
<td>Registration</td>
</tr>
<tr>
<td>10:00 – 10:05</td>
<td>Registration</td>
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<tr>
<td>10:05 – 10:25</td>
<td>Stuart Martin/Caroline Laurenson</td>
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<tr>
<td>10:25 – 10:45</td>
<td>Moya Crawford/Mark Lawrence/Joel Mills</td>
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<tr>
<td>10:45 – 10:55</td>
<td>Questions</td>
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<td>10:55 – 11:00</td>
<td>Neil Bateman</td>
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<td>11:00 – 11:15</td>
<td>Coffee</td>
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<tr>
<td>11:15 – 11:30</td>
<td>Daryl Burdon/Mike Elliot (PI) - Hull</td>
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<tr>
<td>11:30 – 11:45</td>
<td>Sally Rouse/Tom Wilding (PI) - SAMS</td>
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<td>11:45 – 12:00</td>
<td>Kate Gormley/Beth Scott (PI) - Aberdeen</td>
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<tr>
<td>12:00 – 12:15</td>
<td>Dan Jones/Andrew Gates/Brian Bett (PI) - NOC</td>
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<tr>
<td>12:15 – 12:30</td>
<td>Nienke Van Geel/Ben Wilson (PI) - SAMS</td>
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<tr>
<td>12:30 – 12:45</td>
<td>Lunch</td>
</tr>
<tr>
<td>12:45 – 13:00</td>
<td>Lunch</td>
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**NERC Decommissioning and Innovation project overviews**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>11:15 – 11:30</td>
<td>Oil and gas infrastructure decommissioning in marine protected areas: system complexity, analysis and challenges</td>
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<tr>
<td>11:30 – 11:45</td>
<td>Optimising decommissioning of oil and gas pipelines with respect to the commercial fishing sector on the UK continental shelf</td>
</tr>
<tr>
<td>11:45 – 12:00</td>
<td>Automation of marine growth analysis for decommissioning offshore installations.</td>
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<tr>
<td>12:00 – 12:15</td>
<td>Autonomous marine environmental monitoring for decommissioning</td>
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<tr>
<td>12:15 – 12:30</td>
<td>Capability of autonomous systems to match decommissioning monitoring requirements</td>
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**Break-out Discussions**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>13:30 – 15:00</td>
<td>45 mins per topic (2 topics per group):</td>
</tr>
<tr>
<td></td>
<td>1. Automated vs. In-situ environmental monitoring</td>
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<tr>
<td></td>
<td>2. Building and designing installations and infrastructure to remain in-situ or removal (from an environmental perspective)</td>
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<tr>
<td></td>
<td>3. Eco-engineering of structures</td>
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<tr>
<td>15:00 – 15:15</td>
<td>Coffee</td>
</tr>
<tr>
<td>15:15 – 16:00</td>
<td>Feedback from break-out sessions</td>
</tr>
<tr>
<td>16:15 – 16:30</td>
<td>Sarah Keynes (NERC) and Mamiko Ohno (EPSRC)</td>
</tr>
<tr>
<td>16:30 – 16:45</td>
<td>Thanks and Close, next steps</td>
</tr>
<tr>
<td>16:45</td>
<td>Finish</td>
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</table>

2.2. Discussion Session Outline

The afternoon session of the workshop was dedicated to break-out discussions. The participants were invited to join a group of approximately 10 delegates and were presented with two of the three outlined discussion topics:

- Topic 1: Automated vs. In-situ environmental monitoring
- Topic 2: Building and designing installations and infrastructure to remain in-situ or removal (from an environmental perspective)
- Topic 3: Eco-engineering of structures
Participants were asked to consider the above three topics in the context of:

- Challenges;
- Opportunities;
- Innovation; and
- Knowledge Gaps

They were also asked to consider:

- If we were to move to less fixed platforms and more floating structures or subsea systems, do these points still apply? and
- Are the points applicable to renewables or oil and gas; or both? (What are the synergies between offshore energy developments; what are the plans or requirements for monitoring and design for decommissioning for the offshore renewables industry).

In addition, for each of the three topics, some “possible points to consider” were provided, in order to aid the discussion.

- **Topic 1: Automated vs. In-situ environmental monitoring**
  - Pros and cons of both systems
  - Challenges of installation and management
  - Challenges and opportunities for data collection and management
  - Current barriers (technology availability, industry buy-in etc.)
  - Which parameters should be monitored and why?
  - Differences and similarities of renewables and oil and gas industries
  - Research station potential – feasibility

- **Topic 2: Building and designing installations and infrastructure to remain in-situ or removal (from and environmental perspective)**
  - Materials
  - Repurposing - what needs to be done to accommodate other uses
  - Routes of disposal
  - Challenging environments, new areas of exploration (deep sea, Arctic)
  - Long-term impact of materials left in-situ
  - Environmental impact and footprint
  - Fixed platforms vs. subsea structures vs. floating facilities

- **Topic 3: Eco-engineering of structures**
  - Integrating ecosystems (how, why?)
  - What do we want to achieve from the structures long term (10, 20, 50 years)
  - What do we want to enhance (commercial fisheries, protected species/habitats)
  - What are the easy wins? (rock dump to enhance hard substrate vs. designing whole installations)
  - Ecology vs. engineering - where does the balance tip in terms of benefits - safety, cost, feasibility etc.

A designated facilitator for each group facilitated and provided notes on the discussion; and provided a summary of the discussion back to the whole group when the session concluded.
2.3. Participants

The workshop was held on Tuesday 6th March at Dynamic Earth, Edinburgh. The event attracted registrations from 78 participants (Figure 1), of which approximately 70% attended. Inclement weather and university industrial strike action had an impact on attendee attendance. A full list of registered delegates is listed in Appendix B.

The industry participants represented both the oil and gas and renewables industry, and included consultants (environmental and engineering) and service providers. Academic interests also varied from marine ecology and oceanography to engineering and policy/law. Delegates and particular sectors had been specifically targeted and the proportions of sectors that attended was as hoped.

Figure 1: Delegates by Sector

3. Discussion Sessions: Key Observations

From the notes gathered during the discussion session, a number of reoccurring subjects emerged. These have been summarised below. The raw notes from the discussion sessions are presented in Appendix D. These subjects may represent areas of opportunity in terms of new research or innovation/research translation\(^2\); or potential collaborative network development.

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\(^2\) For NERC, innovation/research translation is about enhancing the impact of NERC’s investments by transforming the knowledge, data, capabilities and skills of our community into new value-adding approaches, tools and solutions.
**Topic 1: Automated vs. In-situ environmental monitoring**

Note: automated monitoring was subsequently redefined as mobile monitoring (e.g. via for example automated underwater vehicles that might gather data on the fly); and in-situ monitoring was defined as any form of monitoring that involved fixed equipment in the water over a set time period.

- Combination of in-situ and mobile data recording stations needed to ensure a variety of data collected.
- Definite merit in building in monitoring systems to infrastructure – need to develop technologies to do this cost effectively and efficiently.
- Network of monitoring stations – taking inspiration from stations already functioning, how these could be developed further or over a larger spatial scale.
- New systems to monitor multiple parameters, or provide multiple uses – development of new equipment and methodologies.
- Collaborative industry/academic wide projects to trial and collect large scale datasets – e.g. AFEN (west of Shetland industry project 1996-1998).
- Network of autonomous monitoring equipment to enable access to new and improving equipment that would ordinarily be unavailable to smaller research or industry projects.
- Big data management and analysis methodology development.
- Setting clear objectives and methodologies for autonomous monitoring programmes.

**Topic 2: Building and designing installations and infrastructure to remain in-situ or removal (from an environmental perspective)**

- New research studies on what materials to use and where, this is particularly important when considering new frontiers and challenging environments (e.g. Arctic and deep water). This should also include stabilisation materials used for pipelines and structures.
- There is a requirement to develop full inventories or subsea equipment – both that are currently in the water, or new equipment going in. New methodologies to keep track of subsea inventory.
- Developing new methodologies or enhancing existing technologies for mapping and tracking of pipelines – particularly important for keeping track of equipment in dynamic environments, where changing sediments, for example, may make pipelines vulnerable to movement and/or exposure.
- Looking at resilience and design criteria for deep-sea (or challenging environments) infrastructure – where equipment is unlikely to be removed.

**Topic 3: Eco-engineering of structures**

- Engineering and installation methods to ensure pipelines (e.g.) remain buried, reducing risk to other users.
- Target species and objectives for engineering should be identified and used to inform design – for example fisheries enhancement.
- Engineering subsea structures to avoid interactions with other users (rather than for ecosystem development).
- Test sites and case studies needed to ascertain merit/value of eco-engineering. Maybe not applicable to O&G platforms in the North Sea – maybe more applicable overseas, eco-engineering for multi-use vs. ecosystem enhancement.

4. Conclusions

Overall, the workshop generated some interesting discussions on the three topics summarised above, and outlined some potential new areas of research and innovation/research translation.

There were, however, some challenges encountered during the discussions, primarily with the overall subject of designing for decommissioning. In general, it was perhaps difficult for delegates (particularly those involved in oil and gas decommissioning in UK waters) to see beyond the “status-quo” for decommissioning. That is, out with the OSPAR 98/3 environmental regulations for complete removal of all infrastructure (excluding pipelines) unless a derogation is granted. This could perhaps have been better explained to the delegates prior to the discussion sessions.

The general consensus was that there was more opportunity for “designing for decommissioning” within the renewables sector, because policy and regulations are evolving and may be more flexible at this stage.

A number of key barriers were identified by the delegates, and were reoccurring in the discussions, in terms of how designing for decommissioning may be accommodated by the oil and gas industry. These include:

- The restrictive nature of current environmental regulations (e.g. OSPAR 98/3 as described above) and can these environmental regulations really be challenged?
- Continued liability issues (who would be liable for structures if left in-situ, but not in use?)
- Lack of economic incentives to incorporate environmental monitoring/marine science into infrastructures.
- Historic practices and precedents within the oil and gas industry (making it difficult to impose new practices).
- Provision of “sound-science” needs to be defined (how is the timeline for providing “sound-science” defined, and how much evidence is needed).

Finally, more questions were raised during the discussions than perhaps solutions. This however highlights the importance for continued discussions around this topic area and the importance of using lessons learned from the existing oil and gas decommissioning, to inform new industries and the changing landscape of oil and gas in both the UK and worldwide.

5. Acknowledgements

The authors would like to thank NERC for funding and sponsoring this workshop. The workshop was also undertaken as part of a NERC (Oil and Gas) Knowledge Exchange Fellowship NE/M006859/2. Thanks also to the SUT Decommissioning and Wreck Removal working group committee for their support for the workshop and input into workshop topics.
Appendix A: Background Topic Paper

Designing offshore structures for decommissioning, allows engineers to take lessons learned from current decommissioning plans and learn from the issues encountered, therefore potentially improving future decommissioning efficiency, reducing costs, improving safety and reducing the overall decommissioning footprint (waste, environmental etc.).

In the same way, we can take lessons learned from environmental and marine science issues associated with decommissioning and determine how these issues may be overcome at the design stage.

Opportunities exist to:
- Reduce environmental impact/footprint of structure
- Reduce environmental monitoring costs
- Enable collection of top-quality environmental data (in particular time series data)
- Enhance biodiversity
- Creation of remotely operated research stations

Statoil’s LoVe Ocean Observatory and BP’s DELOS project are great examples of how offshore industries are engaging with marine science and contributing to the collection of important time series environmental data. Although this observatory collects ongoing environmental and ecosystem data, it is limited in its spatial context. In an ideal world, these types of observatories would be collecting data across the oceans. One way to contribute to this, would be through the incorporation of ocean observatory systems on man-made offshore structures.

One of the main challenges from a marine science and environmental perspective is the collection and collation of baseline/historic data, as well as finding ways of collecting appropriate ongoing monitoring data long term. A number of platforms being decommissioned at the moment are lacking consistent and comparable environmental data (primarily contamination related), therefore making it difficult to examine change to the environment over time, particularly in relation to any potential recovery. The ongoing collection of environmental data would ensure extensive environmental data was available at the decommissioning stage and enables any change to be detected and managed accordingly.

Innovation in offshore monitoring is crucial to reducing the overall environmental monitoring costs of decommissioning, with a move towards automation of data collection, through the use of sensors and AUVs/ROVs. The placement of sensors on offshore structures can be challenging at present, particularly where access to the structure is limited or unsafe, or where powering these sensors is difficult. Incorporating means by which sensors can be attached or powered will significantly reduce this challenge, again contributing to the collection of the best possible environmental data.

Although not yet appropriate in waters of the north east Atlantic, designing a structure for decommissioning could incorporate aspects of environmental engineering, to enhance the “reef” effect of the structures. For example using materials appropriate for organism settlement and structure design to encourage organism growth whilst maintaining structure integrity/function/reducing hydrodynamic loading; with the intention of leaving the structures in place at decommissioning, whilst contributing to ecosystem functioning and services (e.g. fisheries, tourism, MPAs etc.).
Appendix B: NERC Decommissioning and Innovation Project Abstracts

### 2015 Decommissioning Projects (Projects Complete)

<table>
<thead>
<tr>
<th>Gormley, Kate/Scott, Beth</th>
<th>University of Aberdeen</th>
<th>Automation of Marine Growth Analysis for Decommissioning Offshore Installations</th>
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Permanent offshore structures form artificial reefs which provide attachment and settlement sites for marine organisms. In the UK, some of the oldest platforms have been in the water for over 40 years and have considerable colonisation of marine organisms. Marine Growth organisms generally include seaweeds, soft corals and mussels in the areas where light penetrates (photic zone) as well as anemones, hydroids and cold-water corals on the deeper sections of the platforms. One of the first marine growth studies published was on the Montrose platform back in 1982; and significant discoveries have been made during offshore installation marine growth assessments since then, such as the first discovery of the CITES Listed Lophelia pertusa coral growing on offshore platforms during the decommissioning of the Brent Spar storage buoy, the with results subsequently being published in Nature in 1999. L. pertusa has since been recorded on the majority of northern North Sea platforms - and therefore their presence on the structures may be contributing to the connectivity of the protect reefs in the UK and Norway. Marine growth causes issues for the oil and gas industry (operators) by adding additional weight to the structure which may cause damage and impair visual inspection of important equipment, both in routine and decommissioning scenarios. New areas of interest have also developed around platform marine growth, including the potential for marine invasive species, potential "stepping stone" habitats, artificial reefs for conservation (e.g. de-facto MPAs) or fish using the structures for food and shelter. In areas of the Gulf of Mexico, a "rigs-to-reef programme", (the conversion of offshore platforms into designated artificial reefs) is underway. However, in Europe, particularly in the North East Atlantic OSPAR region, there is a requirement to remove all offshore infrastructures from the seabed (although derogations may be granted). As part of the decommissioning plan, an operator may be required to assess the extent of marine growth on a platform to determine the additional weight added to the platform (for structure removal) or for potential organic waste disposal and especially if species of conservation importance (e.g. Lophelia and Sabellaria) are present. This project will use a pre-devolved method (CoralNet) to analyse images of marine growth on offshore structures. The method will allow for more images to be analysed, compared to traditional assessment methodology and will allow for a more consistent approach, potentially providing for a good long-term monitoring tool. In addition, finding new and innovative monitoring methods, is not only about collecting data in the field, but also about how the data should be analysed, with this project will contribute.

Wilding, Tom
Scottish Association For Marine Science
Optimising decommissioning of oil and gas pipelines with respect to the commercial fishing sector on the UK continental shelf

The oil and gas (O&G) and commercial-fishing sectors are among the two largest stakeholders that use the UK continental shelf (UKCS), particularly the North Sea. Evidence suggests that fishermen currently target pipelines, a poorly understood activity which has multi-sector implications for decommissioning. The challenge, as identified by the partners, is: the regulator and their advisers need to understand commercial fishing practices around pipelines in order to predict the consequences of various pipeline decommissioning options to both the O&G and fishing sectors. Such an understanding will enable the identification of the most cost-effective, legislatively compliant, safe and environmentally sustainable pipeline decommissioning option. This approach will reduce costs to all stakeholders and, ultimately, the UK taxpayer. To enable exploitation of UK Continental Shelf (UKCS) oil and gas (O&G), more than 45,000 km of pipelines have been installed since the 1960s [1]. Only 2% have been decommissioned and there has been little research on the consequences of decommissioning to other industries and the environment. Many of the pipelines are reaching the end of their useful lives and need decommissioning. Unlike platforms, pipelines are not covered by the OSPAR 98/3 ban on the disposal of installations at sea [2]. Pipeline decommissioning is considered on a case-by-case basis, by comparative assessment of the options. Operators must show that any proposed strategy meets international obligations to ensure the safety of navigation and fishing, and protection of the marine environment [1]. In the UKCS, fishing is an ecologically and economically important activity [3]. Due to the overlap of the O&G and fishing industries there is inevitably physical interaction between the two, including damage to fishing gear from pipelines [4] and to pipelines from fishing gear [5]. Vessels are banned from fishing within the 500 m exclusion zone around platforms [6], but no such restrictions apply to pipelines. Anecdotal accounts of vessels targeting pipelines as fishing grounds have always existed, with vessels thought to potentially benefit by targeting fish attracted to pipelines [7,8]. In 2014, analyses jointly undertaken by SAMS and MSS quantified the extent of this interaction and found that over a third of North Sea (NS) demersal trips fish occurred within 200 m of a pipe. The choice of decommissioning strategy of the ~2500 oil and gas pipelines will therefore have implications for the fishing industry and the environment. The proposed project brings together the regulator (Department of Environment and Climate Change), their advisers (Marine Scotland Science) and representatives of the fishing and O&G sectors (Scottish Fishermen's Federation and Oil and Gas UK respectively) to extend the 2014 analysis(see above) and translate it into predictions of the impact of a range of realistic decommissioning scenarios (e.g. 0 - 100 % pipeline removal, covering pipelines with rocks, pipeline-size dependent removal etc.) on the fishing industry. The first stage will be to collate data on pipeline attributes (size, protective material, date of installation) and fishing behaviour around pipelines and identify 'hotspots' of pipeline/fishing interactions by quantifying and characterising the location where pipelines are frequently crossed as fishermen move between grounds. The impact of realistic decommissioning options will then be determined. The final stage of the project is to embed this new knowledge into the relevant stakeholder community (e.g. regulators, their advisers and industry). This will
be achieved via knowledge-brokering events (e.g. multi-sector workshops), via industry-publications and, directly, via the project partners themselves.

### 2016 Decommissioning Projects (Project completion early/mid 2018)

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<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Project Description</th>
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<tr>
<td>Elliott, Mike</td>
<td>University of Hull</td>
<td>An evidence-based approach for the effects of decommissioning options on Marine Protected Area conservation and ecosystem services (DECOM-MPA). Project Description: DECOM-MPA will develop a Decision Support Document (DSD) and strengthen the evidence base to support decision making for decommissioning oil and gas infrastructure on the qualifying features and integrity of Marine Protected Areas (MPAs). The DSD will meet the current requirements of the regulatory regime, but provide flexibility to evolve in response to changing regulations. Stakeholders as partners is considered essential to a successful project and significantly increases the likelihood that outputs will be applied to real-world decision-making. Objectives: (1) To develop a user-friendly DSD to facilitate decision-making for understanding the impacts (positive and negative) of decommissioning operations on the condition of MPA qualifying features and site integrity; (2) To gather and assess (providing confidence scores) the best available scientific evidence to underpin the assessment of impacts of decommissioning options on major marine habitats and species, including taking an innovative natural capital focus; (3) To engage end-users (incl. industry, industry bodies, SNCBs, regulators &amp; academia) throughout the project to provide proof of concept, identify sources of evidence and provide case studies; (4) To assess potential short and long-term impacts of decommissioning options on MPA qualifying features and site integrity using industry-led case study examples from the North Norfolk Sandbanks and Saturn Reefs cSAC/SCI, and (5) To provide end-users with an innovative and user-friendly evidence-based approach to better understand the risks, opportunities and impacts of decommissioning on MPAs and the wider marine environment. Impacts: Although it is unlikely that the full impacts of DECOM- MPA will be measurable within the project timescale, expected impacts will provide the best combination of: Environmental benefits: - maintained or enhanced MPA integrity; - reduced impact on marine ecosystems; - maximisation of ecosystem service provision; - improved scientific evidence base to support sustainable decommissioning (as well as renewable energy and other construction activities within MPAs). Economic benefits: - support a transparent decision process, decreasing the likelihood of challenging the method selection and reducing associated additional time and cost of regulatory reviews of decommissioning programmes; - early insights into risks and opportunities presented by decommissioning operations; - strengthened links with academia to influence the future research agenda to deliver industry-relevant knowledge, and - enhancing transferability potential of decision support products to other areas. Societal benefits: - enhanced sustainability and societal acceptability of selected decommissioning options; - translating existing knowledge to make it useable and accessible to users; - improved knowledge gained through research (cognitive benefits); - identifying unrealised benefits from decommissioning options within and out with MPAs; - identified knowledge gaps improving efficiency of public research spending, and - enhanced reputation by exporting UK scientific excellence to inform global decommissioning solutions. Keywords: Decision Support Document, stakeholders, Marine Protected Areas, decommissioning, oil &amp; gas, evidence, assessment, case studies Key Stakeholders: BEIS, JNCC, NE, SNH, Oil and Gas Industry, Oil and Gas Industry Representatives, Marine Scotland, MMO.</td>
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<tr>
<td>Bett, Brian</td>
<td>National Oceanography Centre</td>
<td>Advanced monitoring of marine infrastructure for decommissioning projects. Many oil and gas fields are reaching the end of their lives. It is estimated that over 50 of the 475 structures that eventually will have to be decommissioned will be decommissioned by 2018. While most structures will be removed entirely, some larger platforms and pipelines currently cannot be removed without causing serious environmental harm. The structures that remain in place are cleaned and made safe and then they are regularly monitored by the oil and gas company that owns them to ensure that they are not causing any adverse impacts on the environment. Currently this monitoring is done using a survey ship, which at tens of thousands of pounds a day, becomes very expensive. This is not conducive to regular monitoring, which in turn increases the risks of any impacts going undetected. This project aims to introduce a new approach for monitoring of decommissioned structures - autonomous submarines. These vehicles are becoming more widely adopted by industry. It has been demonstrated that these vehicles can be launched from shore and carry out complex missions underwater, collecting information on the seabed type and biological environment, while also monitoring pollution. However, so far they have not yet been applied to decommissioning and existing sensors and protocols need to be reconfigured to collect the data that is required for environmental monitoring around decommissioned structures. Working with our project partners, Shell, BP, BEIS, Gardline and SeeByte, this project will address these challenges and develop approaches for collection of appropriate monitoring data to regularly assess the impact of decommissioned structures with autonomous vehicle. The approaches will be integrated within the standard practices of oil companies to ensure that they are realistic and widely adopted for monitoring. The integration of this new information with existing baseline information on the areas will also be considered. This will ultimately reduce the costs associated with monitoring and improve the quality and quantity of data that can be obtained, which will reduce the risk of environmental damage from decommissioned structures.</td>
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<tr>
<td>Wilson, Ben</td>
<td>Scottish Association For Marine Science</td>
<td>Strategic Review of Autonomous System Capability for Long-Term Decommissioning Monitoring. STREAM will provide a comprehensive strategic review, looking at the capabilities of robotics and autonomous systems for Long-Term Monitoring (LTM) pre-decommissioning and in perpetuity. The main impacts from this project will be the embedment of new knowledge within the industry sector, taking account of the lessons learnt within the academic community regarding the true capabilities of autonomous systems for LTM. The industry project partners are SLR, BMT Cordah, Gardline, and Marine Scotland. They will steer the strategic review, providing context with regards to the current practise and data expectations of the decommissioning community. Reviewing our current technological capabilities, this project will, in-turn, identify the knowledge gaps that restrict the adoption of autonomous technology within the sector. This valuable outcome will inform policy on</td>
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Background As part of the exploitation of UK Continental Shelf (UKCS) oil and gas (O&G), more than 27,000 km of pipelines have been installed since the 1960s. To date, only 2% have been decommissioned and there has been little research on the consequences of decommissioning to other industries and the environment [1]. Over the next 6-8 years, approximately 5,600 km of pipelines will require decommissioning on the UKCS [2]. Pipeline decommissioning is considered on a case-by-case basis, by the comparative assessment of the available decommissioning options [3]. As part of the comparative assessment, operators must demonstrate to the regulator (the Department for Business, Energy and Industrial Strategy - BEIS) that any proposed strategy meets international obligations to ensure the safety of fishing and protection of the marine environment. In order to do so, a comprehensive evidence-base and a strategic framework for assessing pipeline decommissioning with respect to fishing and environmental interests is required. The commercial fishing industry is one of largest users of the UK continental shelf (UKCS), and it is known that there is substantial spatial overlap between pipeline infrastructure and fishing [4]. The presence of decommissioned pipelines on the seabed, without rock dump, presents a potential snagging risk to fishers, according to the type of pipeline, seabed type, fishing intensity and gear-type. The UKCS also contains a number of internationally important conservation features (habitats and species), such as those listed in the EU Habitats Directive (e.g. cold-water corals) and those that are included within designated marine protected areas. These conservation features/species (CF/S) are potentially sensitive to pipeline decommissioning as a result of physical impacts, sediment disturbances and the removal of hard substratum which provides additional habitat for the CF/S and/or protection from trawling damage. Objective This project will result in the quantification of the risks/benefits of all pipeline decommissioning options to both fishing and the environment and the integration of these risks to find the optimal decommissioning solution for each pipe (from the fisher/environmental perspective). This will be achieved by: 1. Combining and collating knowledge of species-pipeline associations gained from analysis of video footage of pipelines (collected routinely by the industry for integrity monitoring), spatial data on fishing patterns and snagging incidents, and data on the distribution and sensitivities of CF/S. 2. Developing spatial 'risk-layers' that can be flexibly combined to evaluate and minimise the relative risks to conservation interests and fishers, across all UKCS pipelines, from all feasible decommissioning options. 3. Embedding the resulting assessment into decommissioning protocols. Impacts and beneficiaries The main beneficiaries of the project will be the UK Government, their advisors [5], fishers and the oil and gas industry who will benefit from an enhanced evidence-base that is shared across all sectors. The outputs of the project will facilitate cost-effective, rapid, consistent and transparent decision-making in relation to pipeline decommissioning. REFERENCES [1] Oil and Gas UK (2013), Decommissioning of pipelines in the North Sea region [2] Oil and Gas UK (2014), Decommissioning Insight 2014 [3] Department for Energy and Climate Change (2011), Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act [4] PipeFish - Optimising the decommissioning of oil and gas pipelines with respect to commercial fishing at the scale of the UK continental shelf. NE/N019369/1 [5] Marine Scotland and statutory nature conservation bodies such as Scottish Natural Heritage and Natural England
## Appendix C: Delegate List

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
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<tbody>
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<tr>
<td>Birgit Plietzsch</td>
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<td>Brian Bett</td>
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<tr>
<td>Carol Barbone</td>
<td>Fairfield Energy</td>
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<tr>
<td>Caroline Laurenson</td>
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<tr>
<td>Chandra Irawan</td>
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<td>Christopher Haworth</td>
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<tr>
<td>Daryl Burdon</td>
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<tr>
<td>David Bould</td>
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<td>David Campbell</td>
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<td>David Paterson</td>
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<td>Jaime Toney</td>
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<td>James Chapman</td>
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<td>Jeff Gibbons</td>
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<td>Jen Loxton</td>
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<td>Joe Ferris</td>
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<td>Karen Seath</td>
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<td>Kate Gormley</td>
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<td>Lizzie Hinchcliffe</td>
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<td>Louise Burt</td>
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<td>Marius Dewar</td>
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<td>Moya Crawford</td>
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<td>Peter Oliver</td>
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<td>Raymond Hall</td>
<td>Scottish Fishermen's Federation</td>
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<td>Rhys Cooper</td>
<td>British Geological Survey</td>
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<td>Richard Neilson</td>
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<td>Robyn Thomas</td>
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<td>Roger May</td>
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<td>Sally Rouse</td>
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<td>Sam Collin</td>
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<td>Sandra Barber</td>
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<td>Sarah Keynes</td>
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<td>Scott Bryant</td>
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<td>Stuart Martin</td>
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Appendix D: Discussion Session Notes

**Topic 1 – Automated vs In-situ**

- It’s not one vs the other, both are needed at present and we consider that will continue
- Challenge – whether to be the first to develop this type of new technology or is this really a race to “second place”. No one operator can foot the bill for development
- Greater incentive (for the operator) to invest in-situ as specific for their site.
- Opportunity – network of AUVs which operators could rent out or pay into scheme in return for access.
- Barriers – who pays for it – especially the initial outlay?
- What’s in it for me?
- Political issues – may reduce consultancy industry – may reduce jobs.
- What’s needed?
- Political consensus
- Needs to be regulator driven
- Test case to prove it works
- Regulator barriers need to be overcome e.g. specifications need to stop being field specific
- Challenge – Baselines
- We don’t have a consolidated baseline
- If we had used the same methodology for monitoring from the start then we would have one!
- Should we be looking at trajectories rather than comparing to a fixed baseline?
- Opportunity
- For automated monitoring we have an opportunity to develop methodologies now.
- Fixed = localised scale – mobile = “regional” scale – combine for cumulative effects
- Case – by case and sensor by question
- Possibility for common instrumentation/data and standardisation of environmental monitoring compared to the operator by operator approach currently used
- Attached instruments – operator value
- Societal value = what funds?
- Joined up survey/monitoring (across industries and regulators etc.
- Automated (mobile) – pros – cost effective, non-invasive, wider range, reduced people time at sea, large data volume. Cons – Battery life, reliability, not proven technology, calibration, recovery of data.
- In situ – pros – proven technology, more fine-scale detail, data recovery. Cons – cost, H&S, small coverage
- Utility depends on purpose
- Methods depend on environment and question being asked – this may vary for renewables and oil and gas
- Reliability over time of fixed structures
- Management challenges of in situ
- Cost is probably a driver for which method to choose
- Automated/mobile are cheaper and safer, but level of data is better with in-situ – consistency of data.
- However, in-situ built in systems may not measure everything – too many set-ups – how to decide what to measure
• How to manage quality?
• Standardise data and requirements – but these may change over time.
• Aims of the data collection change over the lifecycle - e.g. historical data with limited value
• What’s the purpose of the data collected?
• Causality – hard to link back to industry or environmental fluctuations – scale of operation
• Research stations – one geographical point – monitoring points – rather than “research” – would need to be over a large area to see any benefit – network – cost/management being main challenges
• More general monitoring required
• Developing methodologies for monitoring with AUVs
• How to develop systems with multiple functions.
• Opportunity for operators to collaborate, but a gamble for the operators – particularly around cost.
• Test cases for co-operation – such as AFEN for large scale monitoring
• Purpose and objectives of the monitoring would first need to be agreed. Policy/societal values need to be translated into common framework on which to hang a monitoring programme.
• Spatial scale of monitoring (e.g. device-scale vs. ecosystem scale) would define appropriateness of different technology
• Potential objectives could include: achieving a clean seabed, maximising alpha or beta diversity, maximising fisheries catches or maximising safety for other users – needs a clear objective
• Data handling challenges – spatio-temporal auto-correlation etc. – easy to gather, difficult to analyse. Risk of data rich, information poor scenario.

Topic 2 – Built to leave in or remove

• Look at how solutions that are fit for purpose today will also be relevant/suitable in the longer-term e.g. rock stabilisation materials
• Challenge – future development in deep sea and arctic will use more composite materials, many of which are not recyclable – decommissioning options for these material are then remove to land fill or leave in situ.
• Knowledge gap – environmental sensitivities in the new challenging environmental are not well understood. This should be taken into consideration in future developments
• Challenge – likely that subsea infrastructure in deep-ocean will not be recovered. How will this impact marine environment – what design criteria need to be considered
• Recommended that the inclusion of environmental monitoring systems be included in new installations, particularly subsea systems. E.g. BP DELOS project is good starting point. Is there potential to build in technology to pipeline to detect whether they have become exposed? This is done terrestrially.
• Challenges – each project thinking of short-term, not full life-cycle
  o  What is the length of a lifecycle?
  o  What are the real options at the end?
  o  Regulation but it is very basic during early stages of development
• Liability – e.g. waste regulations, what to do with materials, transfer of liabilities? Companies going bust.
• Opportunity – industry needs to be incentivised to do the right thing instead of “low liability” options
• Lack of standardised designs which makes strategic/efficient removal planning hard.
• Poor inventory of what’s in the water
• How to plan for the future? Technology changing, governments changing, baseline changing etc.
• Opportunities – if we introduce full lifecycle analysis now we can plan better, save in the future and understand and mitigate liability better
• Renewables – lessons learned from O&G mistakes. Keep a good and “live” inventory of subsea equipment etc.
• Investigating standardising designs to make decommissioning easier
• Look at regulations for waste management - room for improvement
• Safety net/insurance for fledgling renewables development – avoid abandoned “failed” test kit
• Engineering standards need updating for 2018 – current vs. conservative
• Modern materials – in sea, but also consider after it’s decommissioned
• In O&G equipment = bespoke – difficult to re-task
• Risk from wrecks should be used to quantify O&G leave risk – often exaggerated
• Engineering silos in planning – need cross sector thinking
• Engineering specifications only from first job
• Renewables and renewable – but how to repower, will placement be the same for future technology – floating, good; fixed, not so good.
• Decommissioning decisions needed - very smart
• Engineers and scientists and stakeholders need to understand each other’s needs
• Future – deep sea >200m/Arctic, North Sea – extend life?
• Lessons and parallels from deep sea mining
• Informed society – O&G fishing vs reefs vs Deep sea mining
• Offsetting vs huge cost of equivocal decommissioning – easy win – safe and offset
• Solutions fit for purpose now may not be suitable for the future
• How to deal with non-recyclable materials (e.g. composites)
• Monitoring stations built into platform would be good. As built – e.g. pipelines tracking to where they are.
• Engineering modern materials and standards to replace out of date materials e.g. composites – making new materials with lower environmental footprint
• Lessons learned from snagging on wrecks
• Repowering of renewables
• Materials important in this decision and will depend on decommissioning plan. If structures are being designed to leave and function as a reef after oil extraction, a rougher material may be more suitable for colonisation and enhancement of biodiversity and fisheries enhancement. If we are design structures to be removed, may want to design them to keep them as clean of biofouling as possible as this will aid removal/
• Cleanliness
• Cheaper bond from government and operator insurance if clearer plan for decommissioning – should be an incentive for designing/planning for decommissioning
• Future proofing technologies
• Ultra-sonic cleaning of biofouling
• Should consider onshore disposal of waste.
• Consider potential dual use of structures e.g. combining with aquaculture, which would require a power source
• Could pipelines be better designed for cut and lift operations. E.g. crimping end to reduce leakage
• Consideration of plastics in offshore infrastructure and alternatives if going to be left in situ. E.g. alternative designs for mattress that remove requirement for polyprop. rope e.g. interlock concrete.
• Future proofing designs is hard because uncertain technology and regulation changes over next 50 years.

Topic 3 – Eco-Engineering

• Are there benefits to ecosystems in the North Sea through eco-engineering?
• What are they trying to achieve? Is the spatio/temporal scale of potential benefits relevant given the spatial of North Sea
• Should emphasis be engineering to avoid interactions/impacts to other users of the sea?
• Doubt whether there are eco-engineering outcomes that are better than what we are doing now – particularly given the current regulatory requirements. As structures are, they are providing habitat for marine species so do we need to try and enhance.
• Ideas:
  • In regards to pipelines – engineering methods so that they stay buried and not become exposed and become a risk to other users. This would be substrate limited though, and potential limited in hard clays.
  • Improve design of subsea structures and stabilisation material so that they last for duration of field life and designed for ease of removal when through – therefore reducing environmental impact. The switch from steel cables to polyprop. rope on mattress is an example of improved design for longevity.
  • Design platforms to enhance future/current use as marine habitat (e.g. reef) if legislation changes
  • Most of the eco-engineering solutions need to be accompanied by policy considerations/reviews and the economics of the proposed solution.
• Regulatory background
• Whole life cycle ecological approach
• Creating multi-use structures
  • Habitat (but is it valuable)
  • Fisheries enhancement via exclusion
  • “Unnatural habitats”
• Less relevant for deep-water O&G infrastructure
• Less relevant for floating platforms
• How much can we actually enhance or control?
• Installation site not selected as best location for habitat – but for the resource
• If sensitive species already there, preserving pre-existing habitat suitability should take priority
• Liability – if designed to function as a particular type of habitat do operators/designers have liability if it fails to meet ecological objectives
• Unexpected consequences of installation difficult to plan for
• Connectivity? Maintaining suitable habitat requires connectivity and this must be accounted for in design/placement of structures, but current individual/case by case approach can be a barrier to designing this.
• Balance of doing something vs nothing
• Recovery rates
• Adapting structures and procedures (pile drive?) and alternatives (floating) for positive impact of environment and species - 2 angles – life time of installation or forever – what about compensation
• Impact of removing home – ecosystem change
• Design to withstand marine growth – jackets, wind towers but factor in decommissioning
• Reef or sophisticated lobster pot? Need to identify target specie that eco engineering is seeking to enhance.
• Why
• More of favoured species in combination with ecosystems
• Question – reef materials? Concrete, steel, orientation
• Objective needs to be defined – compromised – CAPEX vs. OPEX – and this varies by location/habitat
• Problems
• Lack of information on effects
• Fishing shouldn’t dictate decisions
• Case studies needed
• Not just a marine issue – steel mines etc.
• Commercial benefit needed
• Easy wins – it depends
• Commercially viable and good for the environment
• More capex, less OPEX for biofouling cleaning
• Leave in has less impact on the environment from decom,
• OSPAR 98/3 outdated? Need solid science
• 55m-35m removal for navigational clearance
• Increase lifespan
• Legislation on not moving concrete mattresses outdated
• Smart fishing vs snagging –long term decisions on decommissioning now may not consider how fishing is likely to change e.g. move to autonomous fishing
• Better mapping of stuff on the seabed
• Offset and spend better things e.g. river discharges, removing plastics from enviro
• Depends on geographical location and designation – changing environmental conditions
• Do we need to design to remove, or leave in-situ? Depends on the habitat – more mobile areas you may want it to come out and return to existing condition – but you could leave it in if it’s less mobile habitat – e.g. Northern North Sea.
• What about invasive – how would this be managed?
• Case-by-case – keep whatever if the richer habitats
• How would you eco-engineer to ensure safety?
• Impacting lifecycle of structure – reuse of structure is potentially limited
• Commitment to manage the new ecosystem – who would own the liability? Operator or government?
• Environmental variability may change the purpose of what you wanted to eco-engineer for – e.g., fish enhancement may not happen, but something else may happen in its place.
• Opportunistic enhancement of biodiversity towards the end of life to allow for rigs to reef – leave what you have in place – or relocation
• Strong scientific evidence for alternative – otherwise it’s the status quo.
• Need to rigs to reef in other areas is to promote new industries, but just for ecosystem enhancement
• Retrofitting rather than designing up front. Adding components (off the shelf perhaps) to be added at decommissioning for whatever purpose – rather than designing 30 years in advance
• Suitability for location – coincidence if the ecosystem develops in the first place on the structure – your resource may not be suitable for an ecosystem – how do you know where the right location is?
• Is there an actual benefit – added cost? Would need to investigate the cost benefits etc.
• Engineering structures to avoid interaction with other users
• Network analysis not individual structures
• How might other industries change? E.g. fishing? Snagging and safety issues etc might not be an issue in the future due to changing technologies – hard to predict – making long-term decisions that might change in the future challenging.
• Hard to get passed current regulatory restrictions
• Would be a complete shift in the whole approach and a shift in attitudes needed – multiple use might be difficult to understand – change consenting and policy – move to an ecological life cycle approach – may not be easy to change political opinion.
• How is eco-engineering any different from what already happens – targeting for a specific use is difficult to manage