Marine Management Organisation

Evaluation of Marine Protected Area Management Measures Concerning Fishing (MMO1172)

MMO1172: Evaluation of Marine Protected Area Management Measures Concerning Fishing

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Executive Summary

A network of marine protected areas (MPAs) is one mean by which the UK seeks to protect the marine environment while also enabling sustainable use of its seas. As of June 2019 approximately 25% of UK waters were covered by over 350 MPAs to protect designated features within them.

MPAs encompass areas of fishing interest. In instances where fishing activity is not compatible with an MPA's conservation objectives, management measures may be implemented to limit adverse effects on those features.

The project sought examples of successful approaches and measures of managing fisheries in relation to MPAs from relevant countries around the world. An initial management needs assessment was undertaken through stakeholder structured interviews and a review of current literature to help target the searches and assessment of global best practice measures that could be recommended for implementation in English MPAs for fisheries management.

Case studies were sought from countries comparable in context to the UK e.g. geography, economic development etc. Case studies focused on managing the interaction between features (benthic reefs, highly mobile species (fish and marine mammals) and ephemeral / dynamic environments) and fishing activities (towed and statics gears). It was not possible to identify any case study demonstrating specific management of static fishing gear on ephemeral / dynamic species and habitats, but areas of good practice from other countries were found for other gear–feature interactions that could be applied in English waters to continue to improve the management of fisheries in MPAs.

Management measures recommended for further consideration include:

- use of technologies such as remote electronic monitoring, and high resolution vessel monitoring systems,
- changes to ways of working including industry engagement, marine spatial planning, seeking measures have benefits to fishermen or are not disproportionately restrictive
- improving information for e.g. location of sensitive habitats, recording of bycatch or limiting fishing footprint to historical
- use spatial and non-spatial measures in combination e.g. technical controls, observer programmes or reduction of ghost fishing.

It should be acknowledged that the current fisheries management regime in England is considering many of these approaches already. These recommendations should serve to strengthen areas of work that are already ongoing and to provide further impetus for development of measures in areas that are not currently being addressed.

1. Introduction

There is a global push to conserve the marine environment through marine protected areas (MPAs), driven through targets such as the UN Sustainable Development Goal 14 (UN 2019), within which target 14.5 sets out that “By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information”. However, the level of conservation or protection is not defined, which allows countries to implement protection measures to different degrees. Each country may take a different stance on the level of protection needed from activities that occur in the marine environment, of which the most prominent historically has been fishing.

In the UK there are over 350 MPAs which, as of June 2019, occupy approximately 25% of UK territorial waters (JNCC, 2019). The MPA network, (including marine conservation zones (MCZs), special areas of conservation (SACs), special protection areas (SPAs), Ramsar sites and nature conservation marine protected areas (NC MPAs) in Scotland) is one of the methods by which conservation and government bodies protect the marine environment, while also enabling its sustainable use.

Each UK MPA has conservation objectives associated with it, describing the desired state of designated features in relation to the extent, quality, supporting processes and associated diversity, community structure, and typical species (for habitats), and populations, habitat quality and provision of supporting processes and life stages, including prey availability (for species). Advice on the conservation status and management of MPAs is the responsibility of the relevant statutory nature conservation body. For English MPAs Natural England advise on sites within inshore waters (up to 12nm), and the Joint Nature Conservation Committee (JNCC) advise on UK offshore waters beyond 12nm. In English waters from 6-12nm, the Marine Management Organisation (MMO) is responsible for the implementation of management measures to ensure fishing is compatible with the conservation objectives of all MPAs, whilst minimising the socio-economic impact of such MPA management measures. Within 6nm this responsibility falls to the Inshore Fisheries and Conservation Associations (IFCAs) in English waters. In instances where fishing methods are identified as being not compatible with an MPA’s conservation objectives, these activities are reviewed and management measures may be implemented to limit adverse effects on sensitive designated features.

Recently, there has been an increase in the public awareness of conservation of the marine environment thanks in part to media coverage and non-governmental organisation campaigning. There is particular concern from those advocating for strongly regulated MPAs that although the number of MPAs globally is increasing, 94% of these MPAs still allow some form of fishing (Costello and Ballantine, 2015). In June 2019 the Department for Environment, Food and Rural Affairs (Defra) announced that it was reviewing the strongest protection measures for English seas through the possible implementation of highly protected marine areas (Defra, 2019).

1.1 Project Objectives

In order to help develop the effective management of fisheries in line with UK government’s responsibilities concerning MPAs, this project aims to identify solutions

that clarify and enhance compatibility between site-based conservation objectives and fishing activities and pressures. The project seeks to consider examples of successful approaches or measures of managing fisheries from around the world, particularly in comparable habitats and species including those that are ephemeral and highly mobile. It looked to identify areas of best practice that could help inform the development of MMO management measures; in particular, the MMO is interested in measures to ensure effective and proportionate protection of MPA designated features.

The overall objectives will be met by delivering the following requirements:

- review management measures or approaches applied globally that are relevant to UK MPA designated features;
- identify areas of best practice not currently used in England;
- evaluate whether identified approaches are proportionate and may improve effectiveness of management, relative to existing management measures;
- make recommendations for the inclusion of appropriate approaches into decision making.

1.2 Current English MPA management

There are currently over 350 MPAs in UK waters, including European marine sites (EMS) and MCZs. EMS were protected under the European Union Habitats Directive and Birds Directive (i.e. they are sites of international importance). There are currently over 200 EMSs within the Natura 2000 network, including:

- SACs – designated for Annex I habitats and certain species, such as seals
- SPAs – designated for Annex I bird species that are rare or vulnerable / threatened and associated internationally important breeding and over-wintering populations and assemblages.

MCZs protect species and habitats of national importance and are designated under the Marine and Coastal Access Act 2009 (i.e. they are domestic sites implemented through national legislation). There are currently 91 designated MCZs (Defra, JNCC and Natural England, 2019).

While the English MPAs, and their designated features, are afforded conservation status, they are not areas in which human activity is automatically excluded. Although the impact of any licensable activity or development in or near an MPA is assessed as part of the marine licensing process, fishing activity has historically not been included with this process. Management of fishing activity within an MPA can be described as a five stage process, as outlined below:

1. Site designation
2. Relevant regulator (Defra 12-200nm, MMO 6-12nm, IFCA 0-6nm) creates an MPA assessment (inshore sites)/joint recommendation (offshore sites)
3. Management measures recommended (public consultation)
4. Proposed measures introduced (byelaw/Council regulation)
5. Site monitored.

To understand the impact of fishing activity on an MPA, an initial assessment is completed to provide detail on designated features and fishing activity within the area, as well as the impact of this activity on the site features. The objectives of fisheries and MPAs can misalign with one another, as fisheries aim to selectively extract and/or target marine species within sustainable limits, whereas MPAs aim to spatially conserve and restore natural resources within an area. Conflicts may arise when fishing activity has the potential to adversely impact the conservation objectives of a site.

The MMO conducts site assessments for MPAs within English inshore waters (primarily in waters 6-12nm, also some in waters 0-6nm) to ensure current and potential future fishing activities do not have a negative impact on habitats and species within these inshore MPAs. A total of nine sites (seven EMSs and two MCZs) were assessed as part of the process between 2013 and 2016 (MMO, 2016a).

These assessments were carried out within the principles of Article 6(3) of the Habitats Directive (for EMSs) or Sections 125 and 126 of the Marine and Coastal Access Act 2009 (for MCZs). The assessments had two key phases:

- a screening phase, a likely significant effect type test (EMS) or MCZ screening (MCZ); and:
- an appropriate assessment (EMS) or significant risk assessment (MCZ).

If a fishing activity / designated feature interaction cannot be excluded at either of the two phases, then management measures will be required to be implemented.

These assessments determined whether fishing activities within the sites assessed were compatible with the conservation objectives of the site and aimed to provide a risk based and phased approach. This process allowed for the identification of those activity / feature interactions at a high priority, medium priority, low priority / priority risk and no interaction. These identified priority interactions supported active management of those interactions of highest priority.

Following the site assessment, if it is determined that commercial fishing activity may impact site features, steps are taken to identify possible measures to avoid or mitigate these impacts. These include potential management measures which are developed in consultation with both fishing and nature conservation sector representatives to allow for an identification of common interests. Potential management of the fishing activity within an MPA may be applied to a given area of the site and does not apply to an entire site. This allows for the protection and/or recovery of an impacted feature, while supporting the fishing industry and thus limiting socio-economic impacts.

Within English waters, there are management measures taken to reduce the impact of fishing activity within MPAs within the inshore environment (within 0-12nm of the coast). These measures may be introduced via byelaws or statutory instruments, or through the introduction of Several and Regulating Orders, which are permanent management measures introduced following public consultation and can be relevant to restricting fishing activity in MPAs.

A key stage in the management of fishing activity within MPAs located within English waters is ecological monitoring of the site. Due to the changing nature of the marine environment, sites habitats and designated features can undertake changes over time. Continued monitoring of MPAs is key to understanding the impacts of fishing activity on these designated sites and their features, or to study recovery when impacts cease. This continued acquisition of data allows for the identification of trends within both species and habitats in which there is currently limited evidence to determine whether impacts arise from fishing activity and provides information on those features which are harder to manage due to their complex life histories.

1.3 Overview of Identified MPA Management Issues within England

Management measures have been implemented where fishing activity has a clear negative interaction on designated ecosystem features of MPAs (i.e. red-rated on the Defra matrix[1]). In cases where a negative impact is certain and at an unacceptable level to the feature involved, the activity is typically excluded, and the management measure is focussed on monitoring compliance with the exclusion.

The next phase is to assess whether management measures are required where the potential for impact is less clear (amber and green rated interactions), and, if they are required, what are the most appropriate actions to be taken. The management measures implemented should be proportionate to the level of impact. Where the impact is less certain, the management measure often aims to constrain fishing effort to acceptable levels, or technical measures to reduce the impact.

There are numerous amber and green interactions. With 40 fishing activities and 43 ecosystem sub-features identified, there are a total of 1720 interactions, of which over half are amber or green rated. If information is limited, for example in the spatial extent of a feature or the potential for a fishing activity to cause a significant effect, the precautionary principle should be applied, and management measures should be implemented to ensure that a negative impact is not occurring.

Fishing has occurred for decades with relatively low levels of disturbance or interference from management authorities with regards to nature conservation. The introduction of MPAs has had to take into account fisheries interest and the management of the two is co-evolving. As a result, the management of fisheries, MPAs and their overlap is generally unique to every country. It is therefore important to get an understanding of how countries manage their nature conservation features in the context of fishing. Case studies from different countries can provide examples of management of fisheries / nature conservation interactions that may be applicable to similar interactions in other countries.

2. Phase 1 Methodology

This project was conducted in two phases with the outputs of Phase 1 directing the work of Phase 2.

[1] The matrix can be found at https://www.gov.uk/government/publications/fisheries-in-european-marine-sites-matrix.

In order to help target the assessment of global best practice measures that could be recommended for English MPA fisheries management, a management needs assessment was undertaken. The aim of this needs assessment was to gain an understanding of current and future MPA and fisheries control and enforcement challenges in the UK Exclusive Economic Zone (EEZ) which could guide future recommendations.

The assessment was conducted using a two step approach:

1. literature review including a review of ongoing relevant projects,
2. structured interviews with regulators, academics, and industry representatives.

2.1 Literature review

The literature review focussed on strategies, assessments and reviews of current English MPA management measures relevant to conservation objectives of English MPAs and fishery control enforcement systems. Key literature that were identified as part of the project inception and reviewed here included:

- NLAI, (in press). Innovative Technological Solutions for Sea Control and Enforcement: Phase 1 Needs Assessment. London: Defra.
- Reports produced by regulators such as the IFCAs.
- Guidance around evidence-based marine management and risk-based enforcement.
- Evidence and publications associated with the Environmental Audit Committee Inquiry on Marine Protected Areas Revisited.
- CAG Consultants (2018). Developing a participatory approach to the management of fishing activity in UK Marine Protected Areas: Workshop 1 – outputs. A report produced by CAG Consultants in conjunction with the National Federation of Fishermen's Organisations and Joint Nature Conservation Committee.
- ABPmer and Ichthys Marine (2015). Supporting Risk-Based Assessments of Fisheries in MPAs, Final Report. ABPmer Report No. R.2551. A report produced by ABPmer for National Federation of Fishermen's Organisations, December 2015.

The aim of the literature review was to identify the main issues in MPA management in a fisheries context. The findings of the literature review were combined with the findings of the interviews and presented together, in order to get a brief understanding of the current literature on the subject in addition to personal opinion.

2.2 Structured interviews

It was agreed that interviews with a selection of key stakeholders identified with the MMO was the most appropriate method of identifying views on the current needs of fisheries management in MPAs in England.

A list of recommended representatives was provided by the Project Steering Group and these were all contacted. These represented individuals from Defra, IFCA, Natural England, National Federation of Fishermen's Organisations (NFFO) and academia. Subsequent interviews were either conducted via Skype or telephone, and in a few instances where a suitable time could not be found within the time frame of the project, responses were given via email.

The range of questions/discussion points were designed to capture information in respect to the following themes:

- Individual respondent – role, time in job, affiliated organisation.
- Understanding of which UK designated habitats and species the respondent considers to be particularly vulnerable and at greatest risk due to fishing pressures and why.
- Understanding of which UK designated habitat/species the respondent believes is the most difficult to manage and why.
- Understanding of which sections of the UK fleet (vessel size, gear type, region) the respondent believes is the most challenging to manage and why.
- Understanding of what management measures the respondent considers to be working well.
- Understanding of which fisheries management measures the respondent considers to be missing.
- Does the respondent have any personal experience of overseas fisheries management measures that they feel would work in England?

Detailed scripts of the interviews were made, and key messages/statements tabulated in order for emergent themes to be identified and assessed with the literature review conclusions.

The summarised transcripts of the interviews are displayed in Annex 1.

3. Phase 2 Methodology

This Phase 2 utilised Phase 1 outputs. The methodology in Phase 2 comprised two stages.

3.1 Stage 1 – Identification of countries with similar fisheries and MPA management regimes

A list of comparable countries to England was identified. In order for a country to be considered comparable it needed to fulfil the following criteria:

- Overlaps the temperate zone, in order to have similar fisheries and habitats / species; and,
- Has an importance of fishing (in terms of total landings) that is similar or greater than the UK, as more developed and mature fisheries are likely to have more developed management measures.

The countries identified are as follows: New Zealand; Spain; Netherlands; Denmark; Norway; Faroe Islands; Iceland; Canada; United States of America (USA); Chile; Argentina; Japan; China; South Korea; and Australia.

A review of the management regime in England was also conducted for comparison.

Each comparable country was reviewed to gain an understanding of its fisheries management structure and current MPAs. The results were collated so that the key overarching messages could be deduced, and then evidenced through relevant case studies in part 2.

3.2 Stage 2 – Collation of global case studies of fisheries management in MPAs and applicability analysis

A literature review was undertaken to identify global examples of fishery / feature interactions to use as case studies. Case studies were sought primarily from the comparable countries identified in stage 1 of phase 2, with additional examples from other comparable countries (South Africa, Scotland, Estonia and Belgium[2]). For each interaction (benthic reefs, highly mobile species (fish and marine mammals) and ephemeral / dynamic environments) three case studies were used. It was not possible to identify any case study demonstrating specific management of static fishing gear on ephemeral / dynamic species and habitats.

Each case study was described in terms of the fishery, the issue, and solution. A method for rating the applicability of the case study was developed. The case study was characterised according to seven criteria. The justification as to why these criteria were selected is provided in **Error! Reference source not found.**.

An example of a criterion that was discussed but then excluded was '*evidence of good compliance*.' It was decided that this would be extremely hard to judge, as there may not be data available on compliance, and that the level of compliance in the case study may reflect specific, undocumented issues associated with a site that may not be directly reflected in sites in English waters.

[2] Although these countries were not identified as priority countries in Part 1, they are deemed comparable for the purpose of identifying case studies.

Table 1: Criteria used to rate the applicability of case studies and justification for its selection

Criteria	Justification for its selection
Similar fishery / feature interaction occurs in English waters?	The more similar the fishery / feature interaction is to those occurring in English waters, the more directly applicable it is.
Measure applicable to other fisheries and features?	A measure may be introduced for a specific fishery / feature interaction however it could be broadly applicable to other interactions, which would be beneficial.
Potential for voluntary / industry-led implementation	Under the Regulators Code, regulators should always be looking for voluntary measure first. Voluntary measures have many benefits including reduced cost to government and those regulated, and no excess statutory measures. Voluntary measures with buy-in from fishermen may have better compliance. There is aspiration to introduce voluntary measures across government, though in reality statutory measures are often applied.
Implementation cost	Implementation cost is an important factor to take into account as low cost measures are favourable and high cost may be prohibitive to the measure being implemented. In the case studies cost was measured in terms of changes in fishermen practice (behaviours and / or gear changes), and cost to monitor compliance of the measure.
Potential to monitor compliance with existing tools	A measure must be able to be monitored to determine whether if it is successful. This criteria was assessed given the current compliance monitoring tools in English waters.
Compatibility of the measure with MPAs	The scope of the report is to identify management measures in MPAs, however there may be examples of management measures that do not occur in MPAs but are compatible with MPAs.
Any assumptions / caveats	This will capture any aspects of the case study not already included in the criteria which may limit the applicability of the case study to English waters.

For each criteria, the case study could be given a score of one, two or three, with three being the optimal score and one being the lowest score. The score was assigned based on expert judgement given the evidence in the case study. Each feature was weighted equally. The ratings were summed and a total score of

applicability was generated, out of a possible total of 21. Depending on the applicability score, the case study was rated as having:

- High potential to be applied (score of 21-17);
- Moderate potential to be applied (score of 16-12); or,
- Low potential to be applied (score of 11-7).

The applicability matrix against which the case studies were rated is provided in **Table 2**.

Similarities and lessons learnt were drawn from the case studies and the key recommendations are summarised in Section 6 Discussion and Recommendations.

Table 2: Applicability matrix developed for assessing the applicability of the case studies to English fisheries.

Rating	Similar fishery / feature interaction occurs in English waters?	Measure applicable to other fisheries and features?	Potential for voluntary / industry-led implementation?	Implementation cost	Potential to monitor compliance with existing tools?	Compatibility of the measure with MPAs?	Any assumptions / caveats
3	Yes	Widely applicable	Voluntary	Low	High	Yes	No – no reason it shouldn't be applicable
2	Yes, to a limited extent	Moderately specific	Co-development of management measure	Moderate	Moderate	To a limited extent	Some caveats which may affect the applicability
1	No but may be applicable to English fisheries / features	Fishery and feature specific	Statutory	High	Low	No	Yes – there is something that will likely affect applicability

4. Phase 1 Results

4.1 Fishing pressures on UK designated marine habitats

4.1.1 Brief overview of current level of fishing

The English fishing fleet is very diverse, with considerable variety in the size of vessels and the fish species caught (House of Commons, 2018). Most of the vessels (~80%) are 10m and under, a category commonly referred to as the inshore fleet, with the remainder being over 10m, known as the offshore fleet (MMO, 2017). The offshore fleet contribute the greatest proportion of landings, and the inshore fleet typically catch smaller quantities of high-value fish (MMO, 2017).

The inshore area (0-12nm) is almost exclusively fished by vessels under 15m in length (MMO, 2014). The inshore fleet use mobile gear (dredging, trawling) as well as static gear (netting, potting, and lining and commercial angling). The vast majority of trawling is for demersal species, rather than pelagic trawling. The most common inshore fishing activity by region is described in detail in a report to the MMO produced by Cefas (MB0117: Understanding the distribution and trends in inshore fishing activities and the link to coastal communities) (MMO, 2014). In general terms, mobile gears are most used along the north east, south east and south west coasts of England, with additional localised hotspots in the Wash, Solent, Cardigan Bay, and off Cumbria. Static gears are used most commonly around the north east and all along the south coast.

4.1.2 Overlap of fishing and MPAs

The objectives of fisheries and MPAs are sometimes at odds with each other. Fisheries aim to selectively extract target marine species whereas MPAs aim to spatially conserve and restore natural resources within an area. Conflicts may arise when fishing activity has the potential to adversely impact the conservation objectives of MPAs.

Certain designated habitats and species are more vulnerable to the effects of fishing than others due to the ecology of their features for which they are designated. Those interviewed agreed that in English waters, benthic habitats such as biogenic reefs and sea grass beds are particular sensitive as they protrude from the sediment and are subject to damage from demersal fishing gear. When species are long-lived and have low fecundity, it can also take a long time for recovery to occur post-impact. Sandbanks were also identified as being a sensitive habitat, but this is more likely due to the intensity of demersal fishing pressure on these features compared to other substrates. Interviewees identified that vulnerability increased for species/habitats that were long-lived, slow-growing, sessile, had low fecundity, and were rare. However, some felt that the habitats and species that were most obviously at risk where the easiest to protect due to the existing evidence. These interviewees felt that features were harder to manage when they were mobile, ephemeral, or had complex life histories due to the lack of adaptability when applying spatial restrictions.

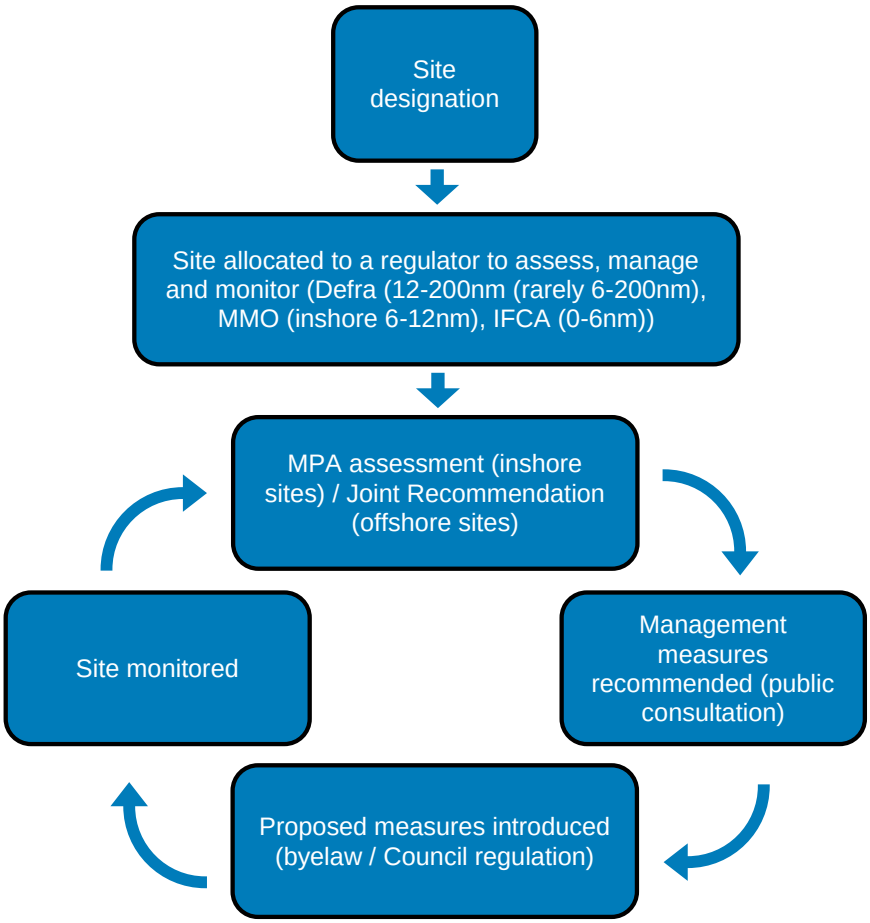
Pressures from fisheries on MPAs may be greater where there are challenges in delivering effective fisheries management. The interviewees diverged on where this occurred in UK waters. Some felt that historically offshore waters were harder to

manage due to the additional considerations of the EU Common Fisheries Policy (CFP) and the presence of non-UK vessels. However, others felt that the inshore fleet and / or those that use towed gear are the most difficult to manage. In particular, it was felt that difficulties with the inshore fleet were in part due to the absence of vessel tracking using vessel monitoring systems (VMS). Specific fisheries identified as being regionally difficult to manage included bait digging, crab-tiling, recreational angling, which are often intertidal or shore-based and are currently non-licensed, and potting and fishing for wrasse for the salmon industry. Fishing for *Nephrops* was also identified as problematic with challenges for undertaking stock assessment.

4.2 Current management practice for the UK fleet in MPAs

MMO licences all fishing vessels but fishing activity is regulated by IFCAs (of which there are 10 regional bodies) when within 6nm. The MMO regulates fishing beyond 6nm and licenses and regulates most other (non-fishing) activities e.g. developments, and throughout English waters. Fishing licences are specific to the vessel length and the category of fishing activity (MMO, 2014). Fishing licences do not include provisions specific for managing activity in MPAs. Management of fishing activity in MPAs is regulated through a separate process, as outlined in **Error! Reference source not found.**. Note that voluntary measures may also be included in Step 5 of the process.

Figure 1: Fisheries Management Process in Marine Protected Areas



For each MPA within 6nm, the relevant IFCA is typically in charge of assessing the risk of fishing gears on site interest features and implementing appropriate management of fisheries. In order to ensure a consistent approach among IFCAs, common frameworks to manage fisheries, specifically the evidence-based marine management cycle and common enforcement framework are used by all IFCAs. In offshore sites, Defra lead work to identify requisite fishing measures offshore, with the support of JNCC and the MMO.

All management practices, including that of fisheries in MPAs, should be based on best available evidence, taking into account the precautionary approach. Any measures proposed should have evidence to demonstrate that they will not have adverse effects on the conservation objectives of the site. Nonetheless, "*the absence of adequate scientific information should not be used as a reason for postponing or failing to take management measures"* (Defra, 2013). Current evidence bases used to inform fisheries management advice include relevant literature on gear-specific impacts, spatial monitoring methods, and stakeholder engagement to fill evidence gaps (Johnson et al., 2017).

In 2013, Defra announced a revised approach to ensure that all commercial fishing operations are managed in accordance with the EU Habitats Directive (Defra, 2013). A matrix was developed as a high-level assessment of the effects of gear types on the conservation objectives of designated features of European Marine Sites (SPAs and SACs). The fishing activities were given a colour classification based on their severity and given a corresponding management imperative. A red classification required immediate management plans to mitigate the risk, and an amber

classification required further assessment to determine if management plans were required. The matrix therefore allowed the prioritisation of management advice based on risk of activities to features.

4.3 Successful management measures

A range of successful fisheries management measures that are already being implemented in England were identified by the interviewees. Three interviewees stated that local byelaws work well as a management measure. An example of successful byelaws (as part of a suite of management measures) have been implemented in Kingsmere MCZ, as detailed below. Two interviewees described events where consent, specifically fishing permits and dredging licences, had not been given, as it was not possible to rule out the negative impacts of the activity, indicating that the best-practice management approach was being implemented. One example of an identified good management measure was that of the permitted scalloping blocks [areas] managed by the North Eastern IFCA.

Other country-wide examples of effective fisheries management include the collective management of quotas by producer organisations, and the shift of fishermen from mobile to static gear which is less destructive. For example, fishermen have been encouraged by public campaigns from celebrity chefs and non-governmental organisations to switch from scallop dredging to dive fisheries due to concerns over environmental impacts from the former (Beukers-Stewart and Beukers-Stewart, 2009). Although not directly related to MPAs, these identified success stories of management could be applied to fishing activities in MPAs.
It was highlighted that good management measures have been implemented in Kingsmere MCZ. The MCZ is divided into four zones within which different types of fishing gear can be used depending on overlap with the bream season (April 1st - June 30th) or not. Vessels fishing with towed gear in certain areas must use VMS, including an inshore monitoring system for those <12m. These management measures are enforced through local byelaws, as well as through a voluntary code of conduct specifically for anglers. All the relevant information and additional guidance is presented in one location online (SIFCA, 2019).

4.4 Gaps in the management toolbox

The pressures of fisheries on English MPAs are now relatively well understood. However, there are still residual pressures due to gaps in management, both in terms of MPAs and specific fisheries, as described below. Without effective management measures, MPAs can simply become “paper parks”, a concern of the House of Commons Environmental Audit Committee (EAC) (2017). However, the gaps identified below can be used to direct the search for management measures from abroad, which forms Phase 2 of this project.

4.4.1 MPA management

One of the gaps in MPA management identified by multiple interviewees was the omission of reference areas. A highly protected marine area is an area of an MPA

where no extraction, disturbance, or damage of resources can occur (House of Commons EAC, 2017). Highly protected marine areas are an important conservation tool as well as a scientific tool (House of Commons EAC, 2017). The EAC state that "Removing these impacts could restore [the area] to its 'reference condition'", which could be used as a benchmark for comparison against the impacted multi-use areas. Of the MPA network, only MCZs were proposed to include reference areas. However, no reference areas were designated from the original recommendation as they were deemed too small to be viable (Defra, 2018b), and no reference areas have been included since, in part due to strong opposition based on socioeconomic grounds (House of Commons EAC, 2017; Defra, 2018b). Reference areas have been proposed elsewhere, including in UK Overseas Territories (House of Commons EAC, 2017). In June 2019 Defra announced that it was reviewing the strongest protection measures for English seas through the possible implementation of highly protected marine areas (Defra, 2019).

Part of the current management toolbox requires the setting of a baseline against which favourable condition can be assessed. However this process has proved to be problematic, not only due to the lack of reference areas but also because there is uncertainty over whether this baseline does, or should, include fishing activity (ABPmer and Ichthys Marine, 2015). Any baseline condition identified will likely include some level of degradation due to historic human impact. Baselines (and conservation objectives) should be set subject to natural variation, and it is in the context of natural variation that impacts must be assessed (ABPmer and Ichthys Marine, 2015; Johnson et al., 2016). Furthermore, one interviewee expressed that all features of a designated site, including species associated, must be reflected in the baseline (and consequently the conservation objectives). The lack of an appropriate benchmark was identified during interviews as a contributing factor to the difficulty of managing designated habitats and species. Setting of a comprehensive baseline with the above details would aid the setting of thresholds of acceptable levels of impact (ABPmer and Ichthys Marine, 2015), another potential missing measure.

The House of Commons EAC (2017) report stated that communication of MPAs is "unsatisfactory" and that it would be beneficial to have a central source of MPA information. The information presented on this platform would need to be in terms suitable for non-specialists and the general public. A single platform could be used to improve understanding of all aspects of MPA management, such as ecological conditions, regulatory background, fishing impacts, benefits of sites etc. Lack of information was echoed by an interviewee, particularly on the topic of evidence of justification for an MPA and fisheries restrictions.

4.4.2 Conservation-based fisheries management

It was highlighted that the inshore fleet needs to be managed more sustainably. A major contributing factor to the difficulty in managing this part of the UK fleet is the lack of a standardised inshore VMS (I-VMS) for smaller vessels (<12m), as identified by four interviewees. An I-VMS is currently in development by the MMO in conjunction with the IFCAs (NLAI, in press). Such systems have been trialled in some MPAs (e.g. Lyme Bay and Torbay SAC), where they've successfully been used by fishers and regulators to protect habitats and also identify important fishing areas for spatial management (NLAI, in press). Other management measures not yet applied to the inshore fleet include automatic identification system (AIS; for vessels

<15m); statutory requirements to report landings (from vessels <10m); and remote electronic monitoring (REM; for vessels <10m) (NLAI, in press).

One interviewee stated that there are insufficient tools to manage fishing effort of non-quota species i.e. ones without total allowable catch (TAC) limits. Non-quota stocks include shellfish, the most valuable of all stock in English waters. There is currently no limit on fishing effort or numbers caught for vessels under 15m (House of Commons, 2018). Minimum conservation reference size (which replaced minimum landing size in 2018) is the only management measure, aimed at sustaining breeding stocks. Although the UK shellfish stocks are currently deemed to be healthy, there is a concern that a sudden activation of latent effort (fishing capacity that is authorised for use but not currently being used) could undermine the status of stocks (NFFO, 2011). The implementation of catch limits has been discussed previously (NFFO, 2011) though it appears nothing has been implemented so far.

Fisheries management measures are thought to be too general by one interviewee. More targeted measures need to be implemented, specific to the exact interactions e.g. gear type, habitat type. It has been identified that impacts need to be assessed at the level of individual gear components (ABPmer and Ichthys Marine, 2015). Once individual effects are understood, gear modifications may be implemented. Seemingly in contrast, one interviewee suggested a blanket closure of offshore MPAs to demersal fisheries. These opinions demonstrate an overarching problem with MPAs, that is a lack of data, and, in the face of this, the extent to which the precautionary approach should be applied. It may also reflect the personal systems of the interviewees.

There may be several management gaps that arise from EU exit. The EU's CFP is the main control over fishing activity in England, and though it will be retained upon leaving (Defra, 2018) it may be revised in future years. Withdrawal will mean that policy can no longer be challenged through the European Court of Justice, therefore a new accountability mechanism may need to be put in place (House of Commons Environmental Audit Committee, 2017). Another gap may be funding. In addition to the identified gaps, there are many unknowns over what gaps will emerge as a result of the EU exit at the time of writing. Leaving the CFP may also provide opportunities for more flexible and adaptive management of offshore MPAs as the UK may be able to set unilateral measures to manage its own waters as an independent coastal state.

One identified shortcoming of the approach to current conservation-based fisheries management is the perceived lack of stakeholder engagement and involvement in management. Co-management, where more responsibility is given to the industry, is thought beneficial. In a recent report on the barriers to participatory management (CAG Consultants, 2018), it was recommended that a management toolkit should be developed to improve co-management. Interestingly, increased input by fishermen was not deemed universally helpful; one interviewee stated that MPAs do not work as well where fishermen have greater input, albeit in the context of designation. Again, this highlights the difference in opinion between individuals.

4.4.3 Enforcement of management measures

Management measures require compliance monitoring and strong enforcement mechanisms in order to be successful (House of Commons Environmental Audit Committee, 2017). However, the Environmental Audit Committee reported that current methods of compliance monitoring have recently declined (e.g. at-sea inspections) and follow-up enforcement requires more support. Control over the activities of other EU member states was mentioned in several interviews. The gaps in sea fisheries control and enforcement and potential technological solutions have been highlighted in a recent Defra-commissioned project (NLAI, in press). The reader is therefore referred to this report for more information on enforcement of fisheries management measures. It should also be noted that control and enforcement resources are changing to meet UK interests as an independent coastal state with staff, vessel and air resources for control and enforcement all increasing.

4.5 Summary

During Phase 1 it became apparent that there are many different answers to the questions posed to the interviewees. Some answers appear to be in conflict, though most likely highlight different priorities amongst individuals.

Nonetheless, a few emergent themes could be identified. The most vulnerable designated habitats and species are not always the hardest to manage in terms of fisheries activity, therefore it is the hard-to-manage habitats and species that should be focussed on in Phase 2. Generally, the hardest section of the fleet to manage are the inshore fleet, particularly due to the lack of spatial monitoring, and those using towed gear. Several management practices work well, though many more gaps in management were identified, indicating that there is room for improvement. The literature review revealed that some of these problems are currently being addressed in localised regions.

Several examples were given of successful management practices in local areas of English waters (e.g. permitted scallop blocks, I-VMS, zonal protection) that could be expanded and used to address perceived gaps in other areas. That such apparently successful measures have not been reapplied has been attributed to insufficient co-ordination between different administrations, an issue also highlighted by the House of Commons EAC (2017) and NLAI (in press). Indeed, the Association of IFCAs has stated that several areas of the current intelligence sharing system that could be improved by joint operations with the MMO (Association of IFCAs, 2018). Identification of measures from other parts of the country is therefore underway and should be continued.

To complement this, Phase 2 will identify successful relevant management practices from abroad that could be applicable to addressing management gaps in English waters.

4.6 Recommendations for Phase 2

The objective for Phase 2 was to review global management practices of at-risk species and habitats and challenging aspects of the fishing fleet for application to the management gaps identified in England. The key points from Phase 1, as highlighted by the interviewees and confirmed within the literature, have confirmed the approach and identified the habitats and species that remain at risk as well the difficult-to-manage parts of the UK fleet. It is not possible to address the plethora of responses under the scope of this Project. For the purpose of this project priority has been placed on habitats and species of 'medium' risk as these are often the hardest to determine appropriate management measures for and as such have the greatest potential to benefit from this study. This includes habitats/species that have a temporal occurrence in the site, such as ephemeral and mobile species. Medium risk combinations of fishing activity and designated features are hosted on Natural England's designated site system.

It should be noted that many of the issues of fisheries management in MPAs can lie within the process rather than the management measures themselves. To illustrate, management of offshore sites must go through the CFP which is a complex process. It is not under the scope of this project to address the constraints or shortcomings of the process of implementing fisheries management in MPAs.

5. Phase 2 Results

5.1 Stage 1 - Comparison of MPA and fisheries management regimes in comparable countries

5.1.1 Overview of MPA management regimes

Globally, MPAs may be designated under a multitude of national and international commitments and each country may have a different network of MPAs.

International commitments include:

- EU member states (e.g. Denmark, Netherlands, Spain) which are subject to the Habitats and Birds Directives;
- Contracting parties to the Convention for the Protection of the Marine Environment of the North-East Atlantic (Oslo and Paris (OSPAR) Convention), namely Denmark (and so the Faroe Islands), Iceland, Netherlands, Norway, Spain, UK;
- HELCOM (Baltic Marine Environment Protection Commission – Helsinki Commission) contracting parties (specifically Denmark and the EU);
- All 16 chosen countries as they are all signatories to the Ramsar convention (Ramsar, 2019a); and,
- Biosphere Reserves under the United Nations Educational, Scientific and Cultural Organisation (UNESCO) (all countries bar New Zealand, Norway and Iceland).

On a national level, there may then be several pieces of legislation which have provisions for the creation of MPAs, together resulting in MPAs of different types and protection levels being designated. The legislation may be specific to the creation of MPAs or general protected areas for biodiversity (i.e. also including terrestrial and/or freshwater environments). As a result, MPAs can be exclusively in the marine environment or be a protected area with a marine component. For example, MPAs in Chile can be designated under legislation for Natural Sanctuaries, National Monuments, Marine Parks, Marine Reserves and Multiple-use MPAs (Gelcich et al., 2015). In Canada there are just under 50 "legislative or regulatory tools for establishing protected areas with a marine component" (Fisheries and Ocean Canada, 2010). The corresponding legislation may not explicitly dictate the level of access within the MPA.

Furthermore, national legislation for the creation of MPAs may be divided between federal and state/province waters. Countries that have states often give those states the power to govern the nearshore waters out to a set distance from the coast, which can include the right to create MPAs. This has been implemented in countries including Australia (Grech et al., 2015), the USA (National Oceanic and Atmospheric Administration (NOAA), 2019), and Canada (Fisheries and Ocean Canada, 2019). For example, in Australia, the waters up to 3nm are under jurisdiction of the adjacent state or territory, and the waters from 3-200nm (edge of the exclusive economic zone (EEZ)) are 'Commonwealth waters' under the jurisdiction of the Commonwealth of Australia (Grech et al., 2015). Both State and Commonwealth government have regulations and legislation to implement MPAs. As a result, there are at least 15 types of MPA designations in Australian waters.

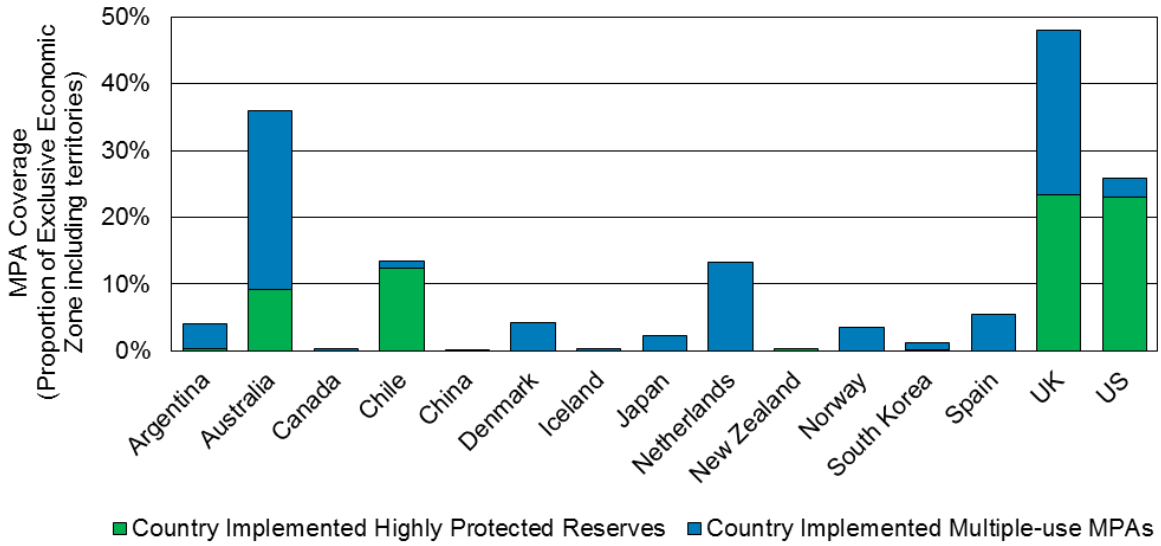
All of the countries reviewed have implemented MPAs that cover varying percentages of their EEZ (including the EEZ of territories). According to the MPA Atlas (2019)[3], the implemented area of MPAs as a percentage of total marine estate ranges from <1% (New Zealand, Iceland, Canada, China), 1-10% (Spain, Denmark, Norway, Argentina, Japan, South Korea), 10-20% (Netherlands, Chile), 20-30% (USA), and >30% (Australia)[4] (Figure 2:). It is worth noting that both New Zealand and Chile have a significant percentage (13.81% and 32.98%, respectively) of their waters that are currently in unimplemented MPAs[5]. Particularly in New Zealand these unimplemented MPAs will, when established, add to a long history of MPA science starting with the creation of New Zealand's first marine reserve at Leigh in 1975.

[3] The MPA Atlas represents the single most comprehensive online database for the global MPA network. However, there are notable discrepancies between the figures presented on the website and those on governmental portals or scientific papers, therefore the figures should be treated as indicative only and taken with caution.

[4] The Faroe Islands has three MPAs, all of which are Ramsar sites and cover a total of 62.87km^2 (Ramsar, 2019b), which is equivalent to 0.02% of the 274,000km sea area (Ministry of Fisheries and Natural Resources, 2017). However Ramsar sites are not classified as MPAs on the MPA Atlas but as "Other Marine Management Areas" hence the total MPA on the MPA Atlas is 0km^2.

[5] "Unimplemented MPAs" are understood to mean "newly proposed, committed, or designated areas within days of announcement…that are proposed of promised, areas that are legally designated but as of yet unimplemented on the water" (MPA Atlas, 2019).

Figure 2: Percentage of marine estate which lies within MPAs by nation (data includes country territories)



MPAs are designated to meet a variety of management objectives. The International Union for Conservation of Nature (IUCN) protected area management categories classify MPAs according to their management objectives (IUCN, 2019). With regards to fishing activity, MPAs can be classed as no-take, i.e. not allow any fishing activity, or multi-use, where a level of fishing is allowed. It should be noted that although the IUCN categories are internationally recognised best practice for designations, they are not used ubiquitously and there are cases of misallocation of categories.
The majority of countries assessed had a higher proportion of multi-use MPAs than highly protected marine reserves. Multi-use MPAs accounted for over 90% of the total MPA types in Spain, Netherlands, Denmark, Norway, Iceland, Canada, Argentina, Japan, and China. Countries with lower percentages of multi-use MPAs included (in decreasing order): South Korea (86% in multi-use MPAs), Australia (74%), UK (51%), the USA (11%), Chile (8%), and New Zealand, of which none of its MPAs are multi-use areas (based on the data on the MPA Atlas[3]).

A review of multi-use MPAs across countries shows that they allow a range of fishing activity levels, often depending on the sensitivity of the feature being protected. A clear overview of levels of protection, specific to the US, is provided by NOAA (2012). Levels of protection can be classified as:

- Uniform multiple use;
- Zoned multiple use;
- Zoned with no take areas;
- No access;
- No impact;
- No take; or
- Other (not yet determined).

This differs from the IUCN classification which is based on the management objectives, rather than the management measures.

A review has been undertaken to identify the different regulatory regimes under which MPAs are created and the different level of fishing within them. The results are presented in Table 3**Error! Reference source not found.** below[6]. It demonstrates that in all countries bar Australia there are more types of MPAs that allow a level of fishing than do not.

Table 3: Non-exhaustive review of the MPA types and level of fishing allowed in comparable countries to England

Country	MPA types that exclude all fishing	MPAs that allow a level of fishing
Argentina	Natural integrated reserves, natural reserves with a specific objective	Natural multiple use reserves, natural protected area, natural reserve, national park, hemispheric reserve
Australia	Marine reserves, aquatic reserves, sanctuary zone (seasonal), restricted access zone (seasonal), marine management area, marine nature reserve, no-take reserve, marine national park, marine sanctuary	Multiple-use MPAs include marine parks, aquatic reserves, special purpose area, marine conservation area, marine/marine and coastal parks
Canada	National wildlife area	Ecological reserve, provincial park, wildlife management area, migratory bird sanctuary, national park, national marine conservation area
Chile	Marine park	National monument, natural sanctuaries, marine reserves, multiple use MPAs
China	Marine natural reserve	Special marine protected area
Denmark	Inner Wadden Sea is a zero-use area	Protected areas under EU Directives, Baltic Sea protected areas
Faroe Islands	None	3 Ramsar sites
Iceland	Nature reserves	Conservation area, OSPAR MPA, natural monument
Japan	Protected waters, legally binding no-take zones, self-imposed no-take zones	Marine park areas, marine special areas, and special protected zones in wildlife protection areas

[6] This table is not meant to exhaustively cover all MPA types in each country but give an indication of the proportion of MPAs that allow fishing compared to those that do not.

Country	MPA types that exclude all fishing	MPAs that allow a level of fishing
Netherlands	Zone 1 in the Zoning Plan	Zones 2, 3 and 4 in the Zoning Plan, OSPAR and Natura MPAs
New Zealand	No take marine reserves, benthic protection areas,	Special management areas, Ahu Moana
Norway	Marine reserve	All other MPAs
South Korea	None	Coastal and marine national parks, areas for protecting fisheries resources, areas for protecting tidal wetlands, conservation area for marine ecosystem, special island
Spain	Marine reserves	Protected areas under EU Directives, marine reserves of fishing interest
US	Marine reserves, ecological reserves, (sometimes explicitly called fully protected), wilderness area	Sanctuaries, national and state parks, cultural and resource MPAs, national wildlife refuges, state MPAs, national marine sanctuaries, national parks

In many of the MPAs it may be the case that there are no restrictions on fishing, so long as fishing is not perceived to have a detrimental impact on the feature that the MPA is designated for. The literature review returned examples of trawling bans in MPAs for New Zealand, Spain, Netherlands, Denmark, Norway, Faroe Islands, Canada, USA, and Chile. Not dissimilarly, South Korea have banned trawling through their waters due to habitat concerns, and in Iceland trawling is restricted to specific areas of the coast only. More rarely all bottom-contact gear may be excluded, akin to vertical zoning (MPA News, 2017), as has been implemented in New Zealand and Canada. Some MPAs only allow recreational fishing, such as the special management areas of New Zealand.

The percentage of country waters in implemented highly protected marine reserves (assumed to be no-take zones) is generally lower and less variable than all MPA types (Figure 2:). Most countries assessed (n=13) have less than 1% of their waters in implemented highly protected marine reserves, of which some have practically none (<0.01%) at all, specifically Denmark, the Faroe Islands, Norway, Iceland, Japan, and China. Of these, Faroe Island and South Korea do not have a mechanism to implement no-take reserves (Table 3). The countries with higher percentages of implemented highly protected marine reserves are the US, Chile and Australia.

No-take reserves are typically statutory due to the cost to the fishermen and the importance of ensuring that no fishing takes place. One exception is in Japan, where more than 30% of individual no-take MPAs were self-established by the local fishing community (Yagi et al., 2010).

No-take reserves are predominantly implemented for biodiversity conservation and have been argued to be the only tool that protects biodiversity effectively from direct impacts (Costello and Ballantine, 2015). When biodiversity has been severely impacted by destructive fishing practices and / or over-fishing, no-take reserves can help to alleviate pressure and support recovery (Kearney et al., 2015). No-take reserves can also be implemented for fisheries benefit, to protect critical spawning or nursery habitats, or critical portions of the stock. Such reserves also have the potential to benefit local fisheries, with evidence that they can support growth and spillover of harvestable individuals of some species into adjacent, fished areas, as well as spawning and the subsequent recruitment of juveniles more widely (e.g. Sweeting and Polunin, 2005), though these effects are not guaranteed and there are still gaps in understanding on the success of this measure (Sale et al., 2005). Additionally, no-take reserves can be implemented as reference areas for comparison to areas where activities continue.

All countries have a higher proportion of designated MPAs that allow some form of fishing than exclude it completely in no-take reserves. This is not unexpected, as 94% of MPAs globally allow some form of fishing (Costello and Ballantine, 2015). Many countries stress the prevalence of multiple-use MPAs. For example, a summary document of the USA MPA network states that “nearly all (86%) USA MPAs are multiple use” and that “less than 8% of the area in MPAs in the US is no-take” (NOAA, 2012)[7]. The prevalence of multi-use MPAs that allow fishing has been suggested as a “compromise to get some elements of biodiversity protected” (Costello and Ballantine, 2015), as broad-scale implementation of no-take reserves has often been met with resistance from marine users. However, multi-use MPAs allow for management measures that are proportionate and targeted to the impact. As stated by Kearny et al. (2012), “waters do not have to be closed to all forms of fishing to be effectively protected against adverse effects of fishing”.

5.1.2 Overview of Comparable Fisheries Management Regimes

The fishery profiles of the countries reviewed in this project are broadly similar to that of England. Most countries have several different species contributing notable (>5%) proportions of the total landings catch, with no one species dominating catches. The Organisation for Economic Co-operation and Development indicates that Japan, United States and Korea (as well as the UK) harvest many different species, whereas Argentina and Canada had the lowest diversity of landings, due to the prevalence of a few (often shellfish) species (Organisation for Economic Co-operation and Development, 2018).

Often countries will have a mix of demersal fish, pelagic fish and shellfish as their most important commercial species, typically two or more categories. A range of fishing gear, methods and vessels is used in each country to target the varied important commercial species. In all countries the fleet is divided by vessel size (either length or weight). Most of the countries assessed have a greater proportion of small vessels (defined differently between countries), that typically have a lower contribution to a country’s total catch in comparison to larger vessels.

[7] This percentage is notably lower than the area of HPMR presented on the MPA Atlas website. It does not appear to take into account the Papahanaumokuakea Monument (Hawaii), which was created in 2006, restricted to all commercial fishing in 2010, and significantly expanded in 2017 to cover a total of 582,578 square miles (MPA Atlas, 2019).

Almost all countries have divided their waters into inshore and offshore areas, though the boundary varies between 3 and 12nm from the coast (with the exceptions being South Korea (division based on vessel size only) and China (unknown)). Management of the fleet sections and the inshore/offshore waters is split. The inshore waters are typically under the jurisdiction of the adjacent region (e.g. state) for management, whereas offshore waters are federally managed.

Globally, fisheries management regimes are essentially founded on the same principles. Options to regulate fishing may include input controls (restriction of fishing effort), output controls (restriction of catches), and technical control (restriction of fishing gear and areas) (Food and Agricultural Organisation of the United Nations, 2019), as well as fishermen's voluntary regulations, to manage the exploitation of stock. These may be implemented through management plan or licence conditions. All countries assessed implement management plans for their fisheries, though the extent of the use varies inter- and intra-country.

Input (effort) and output (catch) controls are broadly implemented to regulate extraction of target species. These controls may also have indirect benefits to nature conservation, for example where reducing impacts on or catches of a target species also coincidentally reduces impacts on or catches of non-target species, communities and habitats. Technical measures, those that regulate “how, where and when fishermen may fish” (European Commission, 2019) through gear, landings, and spatial restrictions[8], are more widely used to achieve nature conservation objectives, and as such are implemented alongside MPA designation. Gear restrictions or modifications may be implemented to reduce seabed impact or bycatch of non-target species that include sensitive nature conservation features. The spatial aspect of area restrictions create zones of greater protection from the impacts of fishing which is synonymous with MPAs.

5.2 Stage 2 - Case Studies of Fisheries Management to Protect Ecosystems

As identified during Phase 1, and consistent with the Defra matrix, there are three major designated habitats and species of concern when considering the overlap between fisheries activities and MPAs:

- Benthic reefs;
- Highly mobile species (fish and marine mammals);
- Ephemeral / dynamic environments.

These features were identified as vulnerable and / or difficult to manage during Phase 1. The towed gear sector was identified as posing the greatest risk to habitats and was challenging to manage because of the mobile nature of the activity, while habitat impacts associated with static gear use are less well-documented, and the science is not yet conclusive (Stephenson et al., 2017). For all gears, particularly in inshore areas, a key management challenge is that there is limited understanding of

[8] Note that the definitions of input control and technical measures overlap in the literature. However, this definition of technical measure is being used for the purpose of this report.

where fishing activity has occurred over time because vessels <12m in length have not been subject to routine spatial monitoring. Accordingly, the impacts of both static and mobile gears on the three major designated habitats and species of concern should be investigated. This section of the report aims to identify international examples where the aforementioned habitats and species of concern interact with mobile and static fishing gear and management measures have been introduced to manage the interaction.

5.2.1 Benthic reefs

Towed gear

Case Study 1 (CS1): Mapping sessile habitat / stock to target fishing effort and reduce bottom contact in sensitive areas (Eastern Canada Offshore Scallop Fishery (Blyth-Skyrme et al., 2015))

Overview of fishery

- The Eastern Canada Offshore Scallop Fishery targets sea scallops (*Placopecten magellanicus*) using New Bedford scallop rakes / dredge on the St Pierre Bank, Eastern Scotian Shelf, Browns and German Banks, and Georges Bank.

Overview of issue

- Many benthic invertebrate species are associated with the scalloping grounds, including crustaceans, bivalves, echinoderms, gastropods and polychaetes.
- The area is known to contain erect sessile fauna such as sea pens, sponges, tunicates and corals.
- The area is important for young fish such as gadoids and contains herring spawning grounds.
- Scallop dredgers are known to be one of the most impacting gear types to these benthic habitats.

Overview of solution

- The distribution of coral has been mapped, which shows that they are almost exclusively found off the shelf edge, in waters deeper than those targeted by the fishery due to ecological niche separation.
- A range of ecologically and biologically sensitive areas were identified through scientific opinion and local ecological knowledge. As a result several MPAs have been established. MPAs with sensitive bottom fauna have restricted bottom fishing activity. For example, the Coral Conservation Area in the Northeast Channel is 90% closed to bottom fishing, with limited bottom fishing (open to longline fishermen who carry Fisheries Observers only) in the remaining 10% (Department of Fisheries and Oceans (DFO), 2006).
- In order to minimise the potential impacts of scallop dredging, detailed habitat maps were created (using data collected in partnership between the Canadian Government and fishing companies (Kostylev et al., 2001)), so that the preferred habitat type for scallops can be accurately targeted and overall bottom contact reduced.
- Regular surveys of the scallop grounds are now conducted with industry to identify locations with the highest abundance of commercially harvestable scallops, and a TAC is employed to limit the harvest to sustainable levels. This approach has led to cost savings in the fleet and a significant reduction in the amount of habitat impacted.

Table 4: Applicability scoring: Case Study 1 - Mapping sessile habitat / stock to target fishing effort and reduce bottom contact in sensitive areas

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes	3	Scallop dredging, as well as the conservation features in the case study, are present in English waters.
Measure applicable to other fisheries and features?	Moderately specific	2	The approach is moderately specific as mapping of habitat and stock is suited to more sessile species / habitats and target species.
Potential for voluntary / industry-led implementation	Co-development of management measure	2	The data collection for mapping was conducted in partnership between the fishermen and regulators. The measure of targeting fishing effort to areas of high scallop concentrations received support from fishermen as it has direct benefits to them.
Implementation cost	High	1	There is assumed to be a moderate cost in mapping benthic habitat data and doing regular stock surveys. The measure of targeting fishing effort led to cost savings for the active fleet in the case study. However, the benefits for habitats occurred because the effort was constrained by the introduction of a scallop TAC. Introducing a TAC for scallops in English waters would incur science and policy development costs, and there may be significant implementation costs associated with fleet restructuring.
Potential to monitor compliance with existing tools	Moderate	2	The proposed measure could be monitored using VMS or another positional monitoring system. However, VMS is currently only required for vessels >12m and so does not cover all fleet vessels. Furthermore, VMS has a low ping rate (once every 2 hours) which would make it difficult to monitor compliance with small spatial closures. Most closed areas were large in the case study, though the smallest was 15km^2.

Criteria	Comment	Score	Rationale
Compatibility of the measure with MPAs	Yes	3	Closed areas are compatible with MPAs. Targeting fishing effort to areas of high scallop density could take into account MPA designation.
Any assumptions / caveats	Some caveats which may affect the applicability	2	The case study found that the ecosystem could quickly recover from the effects of scallop dredging, however this would need to be validated for the ecosystem in English waters. Also noted is that introducing a TAC for scallops in English waters would be a significant change in approach and a challenge to implement.
Total	**15 (Moderate)**		

Case Study 2 (CS2): Mapping of benthic environment and subsequent industry-led closure of areas to trawling (New Zealand bottom trawling and dredging (Helson et al., 2010))

Overview of fishery

- The deep-water trawl fishery of New Zealand is comprised mostly by 10 deep-water species (70% by volume of total catch). The majority of the quota for deep-water fisheries is held by the Deepwater Group Ltd..

Overview of issue

- The seabed contains vulnerable marine ecosystem (VME) habitats; biota that is rare, fragile, functionally significant, slow growing and has long regeneration times, and as such are sensitive to the impacts of trawling.

Overview of solution

- Establishment of Benthic Protection Areas, which cover a large total oceanic area (1.1 million square km) and are closed to bottom trawling and dredging. This closure was proposed and developed by the commercial fishing industry. The Benthic Protection Areas cover a broadly representative sample of benthic habitats, in essentially pristine (unfished) conditions, to avoid any future adverse effects of fishing.
- Deepwater Group Ltd made use of the Marine Environment Classification, which was developed by a Government research body with public funding. Note the classification is based on predominantly physical attributes of the seabed; it is not a habitat map.
- The data on the trawl footprint comes from the information collected by the Ministry of Fisheries.
- The identification of Benthic Protection Areas was conducted by Deepwater Group Ltd. In acknowledgement of this contribution, future research into the effects of trawling will be at a reduced cost to the quota owners (under an otherwise “polluter-pays” principal).
- There are strict measures on pelagic trawling within the Benthic Protection Areas to ensure the gear does not come into contact with the seabed. These include observers and an electronic net monitoring system, with fines for entering the seabed buffer zones.

Table 5: Applicability scoring: Case Study 2 - Mapping of benthic environment and subsequent industry-led closure of areas to trawling

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes, to a limited extent	2	Sensitive benthic habitats occur in English waters although most fishing occurs in relatively coastal areas in water <200m.
Measure applicable to other fisheries and features?	Widely applicable	3	Mapping can be applied to most fisheries and sessile features.
Potential for voluntary / industry-led implementation	Co-development of management measure	2	The measure itself was industry led though the data had come from regulators.
Implementation cost	Moderate	2	The fishing industry bore the costs of proposing the area. However, they were compensated in that future research would not be as costly to them.
Potential to monitor compliance with existing tools	Low	3	There is the potential to monitor deep-water spatial closures with current VMS as the fishery is targeted by larger vessels (>12m) that are obligated to have VMS. The spatial closures are also large, therefore the 2 hour ping rate in English waters is unlikely to be an issue.
Compatibility of the measure with MPAs	Yes	3	Spatial closures are complementary to MPAs.
Any assumptions / caveats	Some caveats which may affect the applicability	2	The case study states that the user rights system in New Zealand (essentially, a licensing and individual transferable quota system) has been pivotal in making the measure work, however individual quotas are not applied to all species in

Criteria	Comment	Score	Rationale
			English waters. Also, large areas of New Zealand's EEZ are unfished, which is not the case in English waters.
Total	**17 (High)**		

Case Study 3 (CS3): AGARBA Spain Barents Sea Cod Fishery (Lassen et al., 2019)

Overview of fishery

- The AGARBA (Spanish association of cod fishing ship owners) Spain Barents Sea Cod Fishery targets the Northeast Arctic Cod (*Gadus morhua*) in the Barents Sea (in the Norwegian EEZ) using bottom otter trawling using a minimum mesh size of 145mm.

Overview of issue

- Many endangered, threatened and protected (ETP) species occur in the fishery area. ETP species include invertebrates, seabirds, elasmobranchs and fish, marine mammals.
- There has been one record of fatal interaction with a cetacean species (*Orcinus orca*).
- Vulnerable marine ecosystems (VMEs) are also present, as well as megabenthos communities.
- Trawling effort overlaps areas of sensitive benthic habitats and species (between 150-400m) and so can cause damage.

Overview of solution

- Ongoing mapping of seabed habitats, as well as mapping of fishing operations.
- Recording of interactions with sensitive habitats and species, including training on minimising interactions, identification, handling, and recording. Recording of interactions are reported and mapped.
- Move-on rule of 2 nautical miles if excess VME (30kg coral or 400kg sponge) implemented in areas of high bycatch of sponges. Fishers voluntarily implemented the move-on rule at quantities of sponges far below the threshold (40-90kg) as they are costly to remove from nets, therefore fishermen are disincentivised to fish in areas of sponge.
- Vessel mapping updated with OSPAR cartography to enable vessels to avoid areas of VME, proximity alert system.
- Voluntary agreement to not expand trawling activity into areas that have not been subject to regular fishing.
- Areas are closed to fishing, including OSPAR MPAs, nationally-protected areas, restrictions on trawling in depths >1000m, and within 12nm of coastline around archipelagos.

Table 6: Applicability scoring: Case Study 3 - Mapping of benthic environment and fishing; recording of interactions to update maps on fishing vessels and alert system; move on rule; voluntary restriction of trawling to historical footprint

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes	3	The fishery for cod and VME features occur in English waters.
Measure applicable to other fisheries and features?	Widely applicable	3	The management measures are apply to all demersal fisheries. Mapping is more applicable to sessile habitats.
Potential for voluntary / industry-led implementation	Co-development of management measure	2	Data for mapping was inputted by both fishermen and regulators, hence a co-development. In the case study there were reports of voluntary moving-on at lower levels of bycatch than strictly required. The restriction to historic footprint was also voluntary.
Implementation cost	Moderate	2	Ongoing cost of enforcement is thought to be moderate. There would, though, be an initial cost associated with implementing VMS on vessels not currently equipped with VMS. There may also be a cost to increasing the VMS ping rate for those already covered, where this was deemed necessary to achieve management objectives. There would be a cost in undertaking research to create maps and then uploading them to the current VMS. Implementation of a move-on rule would require research to establish feasible thresholds for gear-habitat interactions.
Potential to monitor compliance with existing tools	Low	1	Monitoring compliance could occur through VMS, supported by independent monitoring tools (CCTV and/or observers). However, CCTV coverage is not yet available, and observer coverage in English waters is low and may not be sufficient to

Criteria	Comment	Score	Rationale
			ensure compliance with the proposed measure (move-on rule) for all applicable vessels. VMS is currently only required for vessels >12m and so does not cover the majority of the fleet. Furthermore, VMS has a low ping rate (once every 2 hours) which would make it difficult to monitor compliance with small spatial closures. A system of reporting interactions would need development.
Compatibility of the measure with MPAs	Yes	3	The spatial measures are compatible with MPAs.
Any assumptions / caveats	Some caveats which may affect the applicability	2	In the case study only two vessels partake in the fishery, however if this measure was widely applied then the number of vessels could be far greater and so incur higher costs (for observer coverage, VMS etc.). Though the quantity of VME bycatch may not be as high in English waters, bycatch limits can be set at an appropriate level and for any sensitive species / habitats. There is likely to be resistance in the fishing community to closing off areas of fishing ground based on limited data. In the absence of independent monitoring, the success of any move-on rule is likely to be limited.
Total	**16 (Moderate)**		

Static gear

Case Study 4 (CS4): Shetland Shellfish Management Organisation (SSMO)
Shetland inshore brown & velvet crab and scallop fishery (Acoura Marine Ltd., 2018)

Overview of fishery

- The SSMO Shetland inshore fishery targets brown crab (*Cancer pagarus*), velvet crab (*Necora puber*) and scallops (*Pecten maximus*). The two crab species are targeted using creels/ pots, and the scallops are targeted using scallop dredges.

Overview of issue

- There are a series of sensitive habitats around the coast of Shetland which may overlap with shellfisheries.
- In particular the area is known to contain horse mussel beds and maerl beds.
- Sensitive species are protected under designated areas, specifically SACs and Nature Conservation MPAs. Two SACs are overlapped by important shellfisheries.
- Scallop dredgers are known to be one of the most impacting gear types to benthic habitats, though the level of impact can vary depending on habitat type and environmental conditions.
- Creel habitat interactions have limited, localised impacts but there is still uncertainty on the level of impact on the specific benthic species in the area.

Overview of solution

- As part of the Shetland Islands' Marine Spatial Plan (North Atlantic Fisheries College Marine Centre, 2015) the habitat seabed types, biotopes and sensitive habitats have been mapped. This allows a clear understanding of the location and distribution of mapped sensitive species.
- Mapping was also undertaken of the distribution of shellfish potting, using fishermen's knowledge and fishing effort data collected by the North Atlantic Fisheries College Marine Centre.
- Closure of horse mussel beds and maerl beds to scallop dredging. Area closures are monitored by VMS data.

Table 7: Applicability scoring: Case Study 4 - Mapping habitat and fishing effort to understand level of interaction and create closed areas; monitoring compliance using VMS

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes	3	Potting and scallop dredging occurs in English waters, as does the sensitive habitat.
Measure applicable to other fisheries and features?	Widely applicable	3	Mapping can apply to all fishing effort, though with regards to habitat it is most easily undertaken for sessile species / static habitats. Creating closed areas to protect sensitive features is broadly applicable however.
Potential for voluntary / industry-led implementation	Co-development of management measure	2	The mapping in the case study was co-developed, as the maps of fishing effort came from fishermen input. Collection of habitat data and subsequent area closures was top-down.
Implementation cost	Moderate	2	There is a moderate level of cost from the mapping and also increasing VMS coverage to make it suitable to monitor compliance (see below).
Potential to monitor compliance with existing tools	Low	1	Monitoring compliance with the spatiotemporal closures could be undertaken by VMS. However, VMS is currently only required for vessels >12m and so does not cover the majority of the fleet. Furthermore, VMS has a low ping rate (once every 2 hours) which would make it difficult to monitor compliance with small spatial closures.
Compatibility of the measure with MPAs	Yes	3	Closed areas are directly compatible with MPAs. Mapping can be used to inform MPAs and overlap with other marine users.

Criteria	Comment	Score	Rationale
Any assumptions / caveats	Some caveats which may affect the applicability	2	There is a caveat in that no formal Appropriate Assessment has been undertaken of the fishery. It is also assumed that creel pots have no impact, based on studied interactions with pink sea fans (although sea fans do not occur in Shetland waters).
Total	**16 (Moderate)**		

Case Study 5 (CS5): Caribbean Spiny Lobster Trap Fishery (Uhrin et al., 2005)

Overview of fishery

- The fishery comprises traps set for spiny lobster (*Panulirus argus*). The fishery occurs within the Florida Keys National Marine Sanctuary, USA.

Overview of issue

- The traps are often deployed on the seagrass beds. Several hundred thousand traps may be deployed during one fishing season, therefore there is potential for a significant impact to the seagrass resources.

Overview of solution

- A study (funded by NOAA) was conducted to evaluate the soak times beyond which there would be significant impacts to the seagrass and estimates of the recovery rates.
- Pots were shown to damage seagrass when left resting on top for extended periods of time. It was concluded that traps must be recovered within a 6-week period, as beyond this significant injury to beds was predicted. Optimal soak period would not exceed 4 weeks.
- As the standard fishing practice in this area was to have a soak time of <5 weeks, there was no need to alter the current practices. However, it could be theorised that if soak times were significantly longer than 6 weeks, a maximum limit could have been set as part of the permits and/or on a voluntary basis. It is therefore this hypothetical management measure which is assessed below.

Table 8: Applicability scoring: Case Study 5 - Research to determine appropriate management measures; theoretical maximum soak time for pots

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	No but may be applicable to English fisheries / features	1	Both the fishery (potting) and features (seagrass) occur in English waters, though there are no specific examples of the two interacting.
Measure applicable to other fisheries and features?	Fishery and feature specific	1	The measure itself (soak time restriction) is specific to static gear. In this case study it was implemented to reduce impacts on seagrass, though duration of gear in water could have impacts to other nature conservation features.
Potential for voluntary / industry-led implementation	Co-development of management measure	2	Though the measure may be proposed from the top-down, it has the potential to be implemented voluntarily if not perceived to be detrimental to fishermen.
Implementation cost	Low	3	There is limited cost to fishermen. The only cost envisaged could be from an increase in number of fishing trips in order to retrieve / deploy gear, however this is expected to be minimal. There is some cost associated with the research, which in the case study was funded by the regulators.
Potential to monitor compliance with existing tools	Low	1	A system to report soak times would need to be created.
Compatibility of the measure with MPAs	Yes	3	The measure is a change in fishing behaviour. Though there is not a specific spatial aspect it could be applied fishery-wide or more localised through a byelaw.

Any assumptions / caveats	Some caveats which may affect the applicability	2	The measure has been developed specifically for seagrass. The impacts of potting on seagrass include shading and being pushed under the sediment, which are unique response not shared by other sensitive benthic habitats that are more rigid. Another caveat is that research was needed first in order to determine the appropriate soak time limits. In the case study it was found that current practice on maximum soak time was within acceptable limits. Furthermore, it is understood that there is no current fishery in England with such extended soaks. However, this example demonstrates how capping soak duration can be applied to static gear, following investigation into effect of soak time on MPA feature.
Total	**13 (Moderate)**		

Case Study 6 (CS6): Canada sablefish fishery (Furness et al., 2010)

Overview of fishery

- The sablefish (*Anoploploma fimbria*) fishery occurs in the Canadian Pacific EEZ using Korean traps and long lines.

Overview of issue

- There is concern over impacts of the fishery on fragile habitats, specifically sponge and coral, as dragging gear across seabed could cause physical damage.
- Distribution of sponge and coral habitats is not well known.
- Knowledge of impacts of bottom-set gear is also not well known.
- Seamount habitats (present in fishery) are considered particularly sensitive.

Overview of solution

- Some seamounts designated as Essential Fish Habitat and closed to fishing with all bottom contact gear.
- On Bowie Seamount MPA, longline fishing is not permitted but trap fishing is allowed (trap fishing was the only commercial fishing activity before the MPA was designated and after consultation was allowed to continue upon designation).
- Trap fishing in the MPA is subject to several restrictions:
    - It can only occur in a limited spatial area, and below the extent of the photic zone (>457m);
    - It is limited entry, determined in a lottery process;
    - The fishery is conducted between May 1 and August 31, allowing four vessels to fish every year (one per month). There were also trip length limits; and,
    - From 2014, at-sea observer coverage, additional data requirements, and implementation of a coral/sponge encounter protocol were implemented.
- Research on the MPA has been conducted by the DFO, the MPA Management Board, as well as by Wild Canadian Sablefish Ltd. (industry). Industry research was conducted in response to the management board concerns and focussed on potential fishing effects, using sensors deployed on the traps to quantify bottom contact.
- The combined data showed that traps came into contact with corals and sponges. As a result, trap fishing was eventually excluded from the MPA.

Table 9: Applicability scoring: Case Study 6 - Spatio-temporal and entry restrictions; additional research requirements on impacts

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes, to a limited extent	2	The sensitive features (corals and sponges) occur in English waters though the specific fishery does not.
Measure applicable to other fisheries and features?	Widely applicable	3	Spatio-temporal restrictions and requirements for research are widely applicable
Potential for voluntary / industry-led implementation	Co-development of management measure	2	In this case study there appears to be many aspects of co-management, particularly with regards to conducting research.
Implementation cost	High	1	The level of research undertaken as part of this case study would likely come at a high cost. In the case study the onus of this cost was placed on the industry, as they were obliged to show that the fishing activity had an acceptable level of impact to be allowed to continue. The very limited entry and large exclusion zone would come at high cost to the fishermen.
Potential to monitor compliance with existing tools	High	3	Due to the few number of vessels allowed to partake in the fishery, and the large size of the vessels due to the distance offshore, this measure would be monitorable with current VMS.
Compatibility of the measure with MPAs	Yes	3	The measure originated in conjunction with an MPA.
Any assumptions / caveats	Yes – there is something that will likely affect applicability	1	A major caveat to the direct applicability of this case study is the significant entry restrictions which were part of the suite of

Criteria	Comment	Score	Rationale
			measures to reduce impacts on the seamount. This is unlikely to be acceptable to fishermen in English waters.
Total	**15 (Moderate)**		

5.2.2 Highly mobile species

Towed gear

Case Study 7 (CS7): Bering Sea-Aleutian Islands Alaska Flatfish Fishery (Bowen et al., 2015)

Overview of fishery

- The fishery occurs in the USA federal EEZ and State waters of the Bering Sea-Aleutian Islands. It targets yellowfin sole (*Pleuronectes asper*), flathead sole (*Hippoglossoides elassodon*), arrowtooth flounder (*Atheresthes stomais*), Alaska plaice (*Pleuronectes quadrituberculatus*), Northern rock sole (*Lepidopsetta polyxystra*), and kamchatka flounder (*Atheresthes evermanni*) using trawl gear.

Overview of issue

- Marine mammals are present in the area and are sometimes taken incidentally.
- Seabirds also occur in the Bering Sea-Aleutian Islands area and can also be caught incidentally in the fisheries.
- Areas of sensitive habitat could be impacted by trawl fishery.

Overview of solution

- There is an extensive observer programme across all fisheries in the area. Observers collect data on interactions with protected resources alongside other fisheries monitoring. Fishers are required to notify National Marine Fisheries Service in advance of their fishing trip so that the National Marine Fisheries Service can determine if an observer is needed.
- Fisheries are characterised by the amount of marine mammal bycatch they have as a percentage of the allowable catch (the potential biological removal) of that species.
- 3nm no-entry zone around critical habitats (rookeries) for sea lions; certain rookeries also have 10-20nm zone where trawling is prohibited.
- Large areas of sensitive habitats are closed to different levels of fishing (e.g. all bottom contact gear; all mobile bottom contact gear; no contact with bottom permitted).

Table 10: Applicability scoring: Case Study 7 - Extensive observer programme; spatial closures, specifically no entry zone within 3nm and variable no fishing zones (10-20nm) around pinniped rookeries

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	No but may be applicable to English fisheries / features	1	Flatfish trawl fisheries, seabirds and marine mammals all occur in English waters, although there is limited evidence of significant interactions in UK waters.
Measure applicable to other fisheries and features?	Widely applicable	3	The approach of excluding fishing effort from sensitive/ higher risk areas is widely applicable, though in this case study it is specific to land-based haul out sites.
Potential for voluntary / industry-led implementation	Statutory	1	Implementation of an extensive observer programme, and closed areas is likely to be a top-down method.
Implementation cost	High	1	Implementation of an extensive observer programme would come at a cost. Though, in the case study the costs of the observer programme were redistributed to be more equitable.
Potential to monitor compliance with existing tools	Low	1	Current level of observer coverage in English waters is considerably lower than in the case study. Monitoring compliance with the spatiotemporal closures could be undertaken by VMS. However, VMS is currently only required for vessels >12m and so does not cover the majority of the fleet. Furthermore, VMS has a low ping rate (once every 2 hours) which would make it difficult to monitor compliance with small spatial closures.
Compatibility of the measure with MPAs	Yes	3	The spatial closures are compatible with MPAs. Increased observer coverage may be implemented for a specific fishery in a specific area.

Criteria	Comment	Score	Rationale
Any assumptions / caveats	Yes – there is something that will likely affect applicability	1	The case study assumes that there is detailed knowledge on the level of biological removal of the species and acceptable limits. Several resources are available in the case study (observers, notification system, aerial surveys) that aren't necessarily available in English waters. In this scoring there is an assumption made that the measure can be implemented voluntarily and at low cost (to an extent), as demonstrated in Cornwall, with the risk that statutory measures may be brought in if voluntary measures are not successful. Implementation via statutory measures would decrease the overall rating of this management measures.
Total	**11 (Low)**		

Case Study 8 (CS8): Pilbara trawl fishery (Stephenson et al., 2008)

Overview of fishery

- The Pilbara trawl fishery uses trawl nets to target a variety of scalefish (demersal fish) species off the coast of Western Australia.

Overview of issue

- There is considerable bycatch in the trawl fishery. Bycaught species include dolphins, turtles, large sharks and large rays. Bycatch in the trawl typically results in fatality of the individual.

Overview of solution

- There was a trial of both pinger and bycatch reduction devices in the Pilbara trawl fishery. Pingers were found to be ineffective at deterring dolphins from the nets, and so were discarded as a mitigation device.
- The proposed bycatch reduction device (a selection grid) was trialled onboard, alongside significant observer coverage and video capture of the animal-grid interactions. The trial showed the bycatch reduction device to be effective and it is now a mandatory requirement of the fishery.
- There has also been a trial of an electronic observer program (on-board cameras) in this fishery, which has confirmed that bycatch of certain species is not higher than reported.

Table 11: Applicability scoring: Case Study 8 - Bycatch reduction device to reduce bycatch of dolphins and other marine megafauna

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	No but may be applicable to English fisheries / features	1	Trawling and marine mammals occur in English waters, although there is limited evidence of significant interactions with dolphins and other marine megafauna in English waters.
Measure applicable to other fisheries and features?	Moderately specific	2	The management measure is aimed specifically at reducing bycatch of marine megafauna in mobile gear and as such is specific to this problem.
Potential for voluntary / industry-led implementation	Statutory	1	Due to the costs associated with substantial gear modification it can be assumed that the initiative would be top-down.
Implementation cost	Moderate	2	Though the case study does not detail the cost of the trial nor the body responsible for the cost, it can be assumed that the costs were at least moderate. The trial was also covered by increased observer effort, the cost of which was covered by a mixture of government and industry funding.
Potential to monitor compliance with existing tools	Moderate	2	Monitoring gear compliance is currently ongoing in English waters. However there is limited on-vessel visual monitoring compliance (e.g. observers, electronic monitoring) in English waters compared to the case study.
Compatibility of the measure with MPAs	To a limited extent	2	If applied, this measure would likely be for specific fisheries in specific areas only. It could be compatible with MPAs, by working within or alongside them.

Criteria	Comment	Score	Rationale
Any assumptions / caveats	Some caveats which may affect the applicability	2	The applicability of this measure depends if the solution (and associated cost) is proportional to the predicted level of impact to the protected feature. Also, bottlenose dolphins were the main target species and it is not certain how applicable the specific bycatch reduction devices could be to other cetaceans (e.g. harbour porpoise). Other types may be more applicable, or indeed pingers.
Total	**14 (Moderate)**		

Case Study 9 (CS9): South African Hake Fishery (Andrews et al., 2015)

Overview of fishery

- The South African hake fishery targets cape hake (*Merluccius paradoxus*) in deep and shallow waters, using a demersal otter trawl.

Overview of issue

- Seabirds, including ETP species, are present within the fishery. Interactions with the fishing gear could be fatal to seabirds. Interactions were most prevalent when gear was being deployed or recovered, or when offal was being discharged to the water.
- Trawling negatively interacts with the seabed. There are a variety of seabed habitat types include VME indicator species.

Overview of solution

- Bird-scaring lines or Tori lines were introduced as a requirement of the licence
- Offal discharge is now restricted until the Tori lines are deployed.
- Commitment to restrict effort to historic trawl footprint and not expand further (than the extent in 2007). The commitment was initially self-imposed, but later formalised through permit conditions. Compliance is monitored using VMS.
- Seabed mapped into habitats, vulnerability of each habitat assessed, and overlaid with trawl effort to highlight areas habitat types of concern. Suite of mitigation measures proposed. One includes experimental spatial closures, to compare recovery from trawling impacts, which is being complied with on a non-statutory basis.

Table 12: Applicability scoring: Case Study 9 - Gear and practice modification to reduce interaction with seabirds; seabed habitat mapping and experimental spatial closures; restriction to historic footprint

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes, to a limited extent	2	The fishing gear, demersal otter trawls, are utilised in English waters, though not to directly target hake. Seabirds are also present in English waters.
Measure applicable to other fisheries and features?	Moderately specific	2	The gear modification adopted in the case study (Tori lines) is specific to reducing interactions with seabirds. The amount of seabird bycatch in English waters is not well known. Seabed habitat mapping can be applied to any fishery, as can restriction to historic footprint, although defining the historic footprint (which year, which vessels, etc to consider for the baseline situation) would not be easy for English fisheries.
Potential for voluntary / industry-led implementation	Co-development of management measure	2	In the case study the measures were co-developed; the experimental closures were non-statutory, and the Tori lines were a joint measure from fishers and conservation bodies. Restriction to historic footprint was at first self-imposed, and later formalised.
Implementation cost	Moderate	2	There is an assumed moderate cost of gear modification incurred upon fishermen. Seabed mapping is also at a cost from statutory bodies. There should be limited immediate cost to industry associated with restricting activity to an historic footprint, although research costs would be associated with defining the historic footprint.
Potential to monitor compliance with existing tools	Low	1	Monitoring compliance with the spatiotemporal closures could be undertaken by VMS. However, VMS is currently only required for vessels >12m and so does not cover the majority of the fleet. Furthermore, VMS has a low ping rate (once every

Criteria	Comment	Score	Rationale
			2 hours) which would make it difficult to monitor compliance with small spatial closures. There is limited observer effort in English waters, leading to low opportunity to monitor compliance with proposed gear and practice modification.
Compatibility of the measure with MPAs	Yes	3	Mapping and closures are both compatible with MPAs. Gear and practice modification does not have a spatial element, though it could occur fishery-wide.
Any assumptions / caveats	No – no reason it shouldn't be applicable	3	Perceived risks to future opportunities if species distribution was to change may be balanced through protecting access to the historic footprint, indefinitely.
Total	**15 (Moderate)**		

Static gear

Case Study 10 (CS10): Lake Peipus Perch and Pike-perch Fishery, Estonia (Blyth-Skyrme et al., 2017)

Overview of fishery

- The Lake Peipus fishery targets perch (*Perca fluviatilis*) and pike-perch (*Sander lucioperca*) using gillnets, trapnets and Danish seines.

Overview of issue

- The area is home to several ETP species including bird species and lacustrine mammals and amphibians, as well as designated fish species.
- The area contains fish spawning and nursery grounds. Certain fishing methods techniques (Danish seines) were identified as catching high levels of juveniles of valuable (target) fish species.

Overview of solution

- Collation of information on habitats and spawning locations.
- Closed areas and closed seasons have been enforced to protect fish at times and locations where they are particularly vulnerable. For example, no fishing is permitted within 500m of any river mouth to protect fish aggregating prior to spawning.
- The large mesh gillnet fishery is not permitted within 1km of the shoreline, as this is away from key bird foraging areas.
- All commercial vessels are required to have a working VMS with a high reporting rate. Note that the majority of fishing vessels (90%) were <12m in length, with some as small as 5m.
- Restrictions on effort of Danish seine (limited to autumn, only on a limited number of days), as well as increase in mesh size.

Table 13: Applicability scoring: Case Study 10 - Mandatory VMS; spatiotemporal restrictions

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes, to a limited extent	2	Though the species aren't targeted commercially, the fishing method (gillnets) are used widely in the UK. Nursery areas and ETP species are also present in English waters.
Measure applicable to other fisheries and features?	Widely applicable	3	The measures, spatiotemporal restrictions and mandatory VMS, are not specific and could be applied to any fishery.
Potential for voluntary / industry-led implementation	Co-development of management measure	2	Mandatory VMS would be a top-down approach; it is unlikely to be adopted voluntarily due to the cost involved. The same is likely true of spatiotemporal restrictions. However, if the closures are small and not perceived to cause cost to the fishermen there is the potential for voluntary collaboration, particularly if it comes with some assurance of protecting access to other locations, or may protect juveniles of valuable target species.
Implementation cost	Moderate	2	In the case study every vessel in the Lake was equipped with VMS, regardless of size. There would be an additional cost associated with equipping the entire English fleet with VMS. It should be noted however that there is cost already invested with the rollout of I-VMS.
Potential to monitor compliance with existing tools	Moderate	2	Monitoring compliance with the spatiotemporal closures could be undertaken by VMS. However, unlike the case study, complete coverage of the fleet with VMS is not the case in England. The VMS ping rate would also need to be high enough to monitor compliance with small closures.
Compatibility of the measure with MPAs	Yes	3	Spatiotemporal restriction are compatible with MPAs.

Criteria	Comment	Score	Rationale
Any assumptions / caveats	No – no reason it shouldn't be applicable	3	
Total	**17 (High)**		

Case Study 11 (CS11): Canada snow crab and lobster fishery (DFO, 2019b-d)

Overview of fishery

- The snow crab and lobster fisheries occur in the southern Gulf of St. Lawrence and uses baited traps set on the seabed (DFO, 2019b).

Overview of issue

- ETP marine mammal species, particularly North Atlantic right whale, are at risk from entanglement with static gear (DFO, 2019c).

Overview of solution

- Variety of tools to detect the whale e.g. aerial surveys, acoustic monitoring (DFO, 2019c).
- Season-long area closure for snow crab and lobster fishery whilst whales are in the area. Spatial extent of the season-long area closure is adjusted every year, based on data from the previous year (DFO, 2019d).
- Temporary closures of dynamic areas if one or more whales are observed in the area. Closure lasts for 15 days.
- Temporary closures following sighting in shallow waters, either within 10-20m isobath, or, in waters <10m, around the sighting.
- Fishery-specific gear marking, requirements to minimise the amount of floating rope in the water and reporting of any lost gear (and gear subsequently recovered).

Table 14: Applicability scoring: Case Study 11 - Spatiotemporal closures; gear modification

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes to fishery	2	Potting and marine species at risk of entanglement occur in English waters, although the specific species of cetacean does not.
Measure applicable to other fisheries and features?	Moderately specific	2	The measures implemented, in terms of spatio-temporal closures and gear marking, could be applied to any static gear fishery. The management method is particularly targeted to reducing bycatch.
Potential for voluntary / industry-led implementation	Statutory	1	Spatio-temporal closures are typically a statutory approach because it utilises government data, and is extensive so not as likely to be complied with voluntarily. Requirements for gear marking and modification is also likely to be top-down.
Implementation cost	Moderate	2	There would be a moderate cost to the fishermen in terms of exclusion from the area. There is a cost associated with gear marking however this is already a requirement in English waters (MMO, 2016b). There is a cost involved with reducing amount of floating ropes through innovative gear modification though in the case study there was funding for this.
Potential to monitor compliance with existing tools	Moderate	2	Gear marking is already a requirement in English waters (for certain fisheries (MMO, 2016b)). There are existing tools already in place to monitor this requirement. Monitoring compliance with the spatiotemporal closures could be undertaken by VMS. However, VMS is currently only required for vessels >12m and so does not cover the majority of the fleet. Furthermore, VMS has a low ping rate (once every

Criteria	Comment	Score	Rationale
			2 hours) which would make it difficult to monitor compliance with small spatial closures.
Compatibility of the measure with MPAs	Yes	3	Pre-determined spatiotemporal closures are directly compatible with MPAs, whereas dynamic closures could work alongside MPAs.
Any assumptions / caveats	Some caveats which may affect the applicability	2	One aspect of the case study was that it required information on the location of whales (from aerial and acoustic monitoring) in order to inform dynamic closures. Large cetacean entanglement has traditionally not been perceived as a problem, however there is clearly the potential for interaction (e.g., MacLennan, 2018).
Total	**14 (Moderate)**		

Case Study 12 (CS12): Danish gillnetting fishery (Kindt-Larsen et al., 2012)

Overview of fishery

- The Danish gillnetting fishery targets cod and plaice (*Pleuronectes platessa*) using trammel nets and bottom set gillnets.

Overview of issue

- Marine mammal bycatch and quantification is a problem in terms of management of protected species. Typically this has been assessed using observers, however this has high associated cost.
- Similarly there is a strong incentive to discard unwanted catch under the CFP.

Overview of solution

- Installation of closed-circuit television cameras for remote electronic monitoring (REM) on six vessels as part of a trial. Post-processing of video data for bycatch occurrence. This enabled a more accurate estimation of bycatch than fisheries observers alone, at a lower cost with very high coverage.

Table 15: Applicability scoring: Case Study 12 - REM systems for bycatch monitoring

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes	3	The fishery and feature both occur in English waters.
Measure applicable to other fisheries and features?	Widely applicable	3	The tool of REM to monitor vessel activities can be applied to any fishery or feature of concern. Though it is not specific to the fishery / feature it is broadly specific to the issue of bycatch.
Potential for voluntary / industry-led implementation	Co-development of management measure	2	The example in the case study is a government initiative, and as such has come from a statutory basis. However, it is possible that the system could be adopted on a more voluntary basis by fishermen as it has significant cost benefits over observers.
Implementation cost	Moderate	2	The trial had a high upfront cost. In the case study the cost associated with installing the systems on the 6 vessels was ~60,000 euros, with cost of sensor and video analysis an additional 18,900 euros. This being said, this cost is considerably lower than using observers to obtain an equivalent amount of coverage.
Potential to monitor compliance with existing tools	n/a	-	This is a tool for monitoring compliance therefore this category is not applicable.
Compatibility of the measure with MPAs	To a limited extent	2	Though REM is good at visually monitoring activities it has limited capabilities in providing positional data, and so is not suited to monitoring compliance with spatial management measures.

Criteria	Comment	Score	Rationale
Any assumptions / caveats	Some caveats which may affect the applicability	2	There are several caveats with the feasibility of the measure. This trial was only introduced on a small number of vessels, though it's application to the greater fleet appears to be feasible. Fishermen are also sceptical to being monitored.
Total	**14 (Moderate)[9]**		

[9] The approach listed here is a compliance tool therefore it is not applicable to assess the 'potential to monitor compliance with existing tools.' The applicability score is 14 out of a possible total of 18, equivalent to 16 out of 21, which gives an applicability rating of Moderate.

5.2.3 Ephemeral/dynamic species and habitats

Towed gear

Case Study 13 (CS13): North Sea Brown Shrimp Fishery (Acoura Marine Ltd., 2017)

Overview of fishery

- The North Sea Brown Shrimp Fishery targets the North Sea Continental Brown Shrimp (*Crangon crangon*) using a lightweight beam trawl, with bobbin / roller groundrope. The species is fished down to the 20m contour. The fishery is targeted by the Dutch, German and Danish fleets.

Overview of issue

- The habitats present in the North Sea are diverse. There are vulnerable marine ecosystems (VMEs) including *Sabellaria* spp. reefs, seagrass (*Zostera* spp.) meadows, blue mussel (*Mytilus edulis*) beds, and Lanice (*Lanice conchilega*) fields. The first three of these species are protected under a network of SACs in the area. VMEs may be impacted by fishing activity.

Overview of solution

- An independent Appropriate Assessment was conducted for the Dutch Wadden Sea and showed that shrimp fishing had no significant effect on the integrity of the Natura 2000 sites. Gear design is important, and light (shrimp) beam trawls generally have considerably less impact than heavy (flatfish) beam trawls. The community is subject to high natural disturbance.
- Each country has implemented a zoning plan in their inshore waters, which regulates fishing along with other human activities. In the Dutch and German Wadden Sea shrimp fishing is allowed with the exception of no-take zones. In Danish waters fishing is only allowed between the islands and in the offshore area.
- An example of zoning is in Dutch waters. Here, the coast is split into a series of zones which allow different levels of fishing. Zones may have fishing excluded; exclude only bottom-contact fisheries; fishing allowed according to best practice; and fishing unregulated. Depending on the area, shrimp fishing may be; excluded all year; only allowed once mussel banks disappear; closed only in August.
- In Denmark closed areas are monitored using VMS and signals have been increased from 2 to 1 hour intervals.
- A new black-box that incorporates VMS and monitors the vessels fishing winches was introduced for Dutch vessels in 2017, with the aim to improve knowledge of where vessels were fishing.

Table 16: Applicability scoring: Case Study 13 - Coastal zoning, in conjunction with increased monitoring coverage

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes	3	The fishery occurs in English waters, such as in the Wash and the Thames. The sensitive habitats are also present.
Measure applicable to other fisheries and features?	Widely applicable	3	The management measure, coastal zoning plans, is applicable to all fisheries and indeed all activities in the marine environment.
Potential for voluntary / industry-led implementation	Co-development of management measure	2	The creation of a zoning plan, as well as increased monitoring coverage, would likely be a top-down approach, albeit with significant industry engagement.
Implementation cost	Moderate	2	The cost associated with implementing zoning plans and increasing monitoring coverage, through increased VMS ping rates or new black boxes, would come at a moderate cost.
Potential to monitor compliance with existing tools	Low	1	Monitoring compliance with this measure could be undertaken by VMS. However, VMS is currently only required for vessels >12m and so does not cover the majority of the inshore fleet. Furthermore, VMS has a low ping rate (once every 2 hours) which would make it difficult to monitor compliance with small spatial closures. The black box system could be implemented as a new technique to monitor compliance at a fine spatiotemporal scale required.
Compatibility of the measure with MPAs	Yes	3	MPAs can be one form of spatial designation under a zoning plan.
Any assumptions / caveats	No – no reason it shouldn't be applicable	3	Though this is not a caveat, it is interesting to note the countries have worked collaboratively and implemented a

Criteria	Comment	Score	Rationale
			tri-lateral agreement to manage areas used by fleets of several different nationalities.
Total	**16 (Moderate)**		

Case Study 14 (CS14): Danish mussel fishery (Nielsen and Petersen, 2017)

Overview of fishery

- An extensive mussel (*Mytilus edulis*) fishery occurs in Denmark. Wild stock blue mussels are exploited by dredging (Dolmer and Frandsen, 2002).

Overview of issue

- The blue mussel fishery is conducted in several Natura 2000 areas. Trawling has the potential to impact the features and conservation objectives of the sites. For example, the fishery is conducted within the Løgstør Bredning, Vejlerne og Bulbjerg SAC which has sandbanks as a feature (European Environment Agency, 2019).

Overview of solution

- VMEs (eelgrass and reefs) within the Natura 2000 sites are designated as no-take zones.
- As part of the permits for the fishery it is required that vessels are fitted with geographic positioning and sensor equipment is used (black-box system).
- An environmental impact assessment is conducted by the National Institute for Aquatic Resources, Danish Technical University each year for fishery activity occurring in Natura 2000 sites. As part of the Danish Mussel Policy it has been determined that the acceptable level of disturbance from blue mussel fishing within a Natura 2000 site is 15%. Therefore blue mussel fishery (cumulatively with all other fishing that uses bottom contact gear) cannot occur in more than 15% of the area.
- Area over which the fishery is conducted is collected using the geographic positioning data from the black box system. This data in turn feeds into the future assessment.

Table 17: Applicability scoring: Case Study 14 - Fishing restricted to 15% of Natura sites; monitored using mandatory geographic positioning from black box system

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes	3	The fishery occurs in the UK (such as Morecambe Bay, the Wash, the Thames, and the Exe), as does the Nature 2000 sites for sandbanks
Measure applicable to other fisheries and features?	Widely applicable	3	The approach of protecting a certain percentage of a Natura 2000 site can be applied to any feature.
Potential for voluntary / industry-led implementation	Statutory	1	Limiting area usage to 15% of a site, and subsequent monitoring, is a top-down approach that is unlikely to be undertaken voluntarily.
Implementation cost	Moderate	2	Level of cost associated with a geographic positioning / black box system as well as with the assessment process may be moderate (though more to the regulators rather than to the fishermen, depending on which party is responsible for equipment costs).
Potential to monitor compliance with existing tools	Low	1	Monitoring compliance with this measure could be undertaken by VMS. However, VMS is currently only required for vessels >12m and so does not cover the majority of the inshore fleet. Furthermore, VMS has a low ping rate which would make it difficult to monitor compliance with small spatial closures. The black box system could be implemented as a new technique to monitor compliance at a fine spatiotemporal scale.
Compatibility of the measure with MPAs	Yes	3	The measures is based upon MPA designation and contained within the spatial limits of the MPA.

Criteria	Comment	Score	Rationale
Any assumptions / caveats	Some caveats which may affect the applicability	2	One caveat is that Habitats Regulations Assessments would have to be undertaken for fisheries occurring in UK SACs. Though 15% has been set as the acceptable limit for disturbance within the Wadden sea Natura site it is area-specific as it is calculated based on regeneration time of specific ecosystem components (blue mussel stock, eelgrass, macroalgae and benthic fauna).
Total	**15 (Moderate)**		

Case study 15 (CS15): Fisheries in Belgium (Flanders Marine Institute, 2016)

Overview of fishery

- Belgium coastal waters are small and there are a range of anthropogenic activities that compete for space. This includes fishing activity and nature conservation designations. Fishing activity by the Belgian fleet includes beam, otter and shrimp trawler, alternative trawl gear (with lower impact), passive fishing methods and pelagic fisheries.
- Belgian coastal waters are utilised by the Belgian, Dutch, British, French, German and Danish fleet.

Overview of issue

- There are sensitive habitats and species within Belgian coastal waters. The seabed is characterised by a complex system of sandbanks, including biogenic and geogenic reefs.
- In particular, there is the Flemish Sandbanks SAC, which contains protected sandbanks. Within this SAC there are aggregations of white furrow shell (*Abra alba*), gravel beds, and sand mason (*Lanice conchilega*) reefs. These have the potential to be impacted by fishing activity.

Overview of solution

- Belgian coastal waters have been divided and allocated to different human activities under the Marine Spatial Plan (MSP).
- There are four zones within the Flemish Sandbanks SAC that have been designated as the most valuable and vulnerable zones. Each zone has a different level of acceptable fishing activity:
    - Zone 1: Bottom-contact gear can continue so long as beams are fitted with wheels (“roller shoes”) and shrimp fishing uses a sieving net. Only existing fishing activity with bottom-contact gear can occur; new vessels must use non-seabed disturbing fishing techniques. This will create a gradual fade out.
    - Zone 2: Only non-seabed-impacting fishing gear is allowed. Testing of alternative seabed-impacting fishing gear (i.e. lower impact on the seabed than classic beam trawlers) is allowed. There is a 3-year transition period for existing seabed-contacting gear.
    - Zone 3: immediate switch to non-seabed-impacting gear. Only this type is allowed.
    - Zone 4: Only non-seabed-impacting or alternative seabed gear is allowed.
- The different zones have been created to allow comparison of the effects of the measures. It should be noted that no ‘no take zones’ are proposed, as this is against the principle of multiple-use.
- In addition, there is the general measure that within 4.5nm of the coast, no vessels >20m or >70 gross tonnage are allowed.
- Compliance with the measures is monitored using VMS (for vessels >12m).

Figure 3: Overview Map of the Belgium's Marine Spatial Plan (Flanders Marine Institute 2016)

Table 18: Applicability scoring: Case Study 15 - Marine spatial plan including zoned areas of variable bottom-impacting gear to assess impacts

Criteria	Comment	Score	Rationale
Similar fishery / feature interaction occurs in English waters?	Yes	3	The fishery and features occur in English waters.
Measure applicable to other fisheries and features?	Widely applicable	3	Marine spatial planning can be applied to any fishery, though it is more applicable to benthic, sessile features.
Potential for voluntary / industry-led implementation	Statutory	1	Creating a MSP at that level is a top-down approach albeit with significant stakeholder interaction. Gear modification is also likely to be a top-down requirement if it is less cost-effective, as it is unlikely to be taken up voluntarily.
Implementation cost	Moderate	2	Creating a MSP is likely to have moderate cost to the Government, then modification of gear to be allowed/exclusion may also be of moderate cost to the fishermen. Note that vessel VMS have shown that exclusion is only over a small area so cost is not significant. There is the option for fishermen to change their spatial usage of areas, to not enter areas that require modified gears and so not incur the cost.
Potential to monitor compliance with existing tools	Moderate	2	Monitoring compliance with this measure could be undertaken by VMS. However, VMS is currently only required for vessels >12m and so does not cover the majority of the inshore fleet. Furthermore, VMS has a low ping rate which would make it difficult to monitor compliance with small spatial closures. This being said, the same VMS limitations are present in the case study, and the measure has been implemented nonetheless.

Criteria	Comment	Score	Rationale
Compatibility of the measure with MPAs	Yes	3	Measure is compatible with MPAs, as per this example, it occurs within an MPA.
Any assumptions / caveats	Some caveats which may affect the applicability	2	The size of Belgium's coastal waters is far smaller than England and therefore the MSP would be more complex. However, Belgium has similar issues to England in terms of crowding in a small space and competition between industries.
Total	**16 (Moderate)**		

5.2.4 Summary of case studies by interaction

Benthic trawling is widely viewed as damaging to benthic reef habitats and there is a large evidence base to show that recovery can take anything from weeks to centuries, depending on the habitat type and impact severity (e.g. Hiddink et al., 2017; Jennings and Kaiser, 1998; Rijnsdorp et al., 2018; Sciberras et al., 2018). However, fishing cannot always be completely excluded from an MPA; often the impacts need to be managed to an acceptable level.

The three case studies on mobile gear / benthic reefs mapped the vulnerable benthic habitats (or physical seabed, as a proxy) and the fishing effort to determine the amount of interaction, and subsequently implemented spatial closures to mitigate the impact of trawling on benthic habitats. In CS1 and CS3, the most sensitive areas identified were closed to benthic trawling, an approach that has been implemented in English waters. Also, in CS9 (which has elements applicable to this interaction), experimental closures were implemented in order to determine the level of impact. CS2 also adopted spatial closures, although benthic trawling was excluded from unfished 'pristine' zones rather than utilised zones. The areas designated in CS2 also had strict regulations on pelagic trawling to ensure no impact on the seabed. Some novel measures were implemented alongside spatial closures. In CS1, the key fishing grounds were also mapped so that fishermen targeted the best grounds, which reduced the overall footprint of trawling and so impact on the benthos. In CS3, a 'move-on' rule was implemented from areas of high benthic VME bycatch. In CS9, the footprint of trawling was limited to its historical extent.

It is typically assumed that static gear has less impact on benthic reefs than mobile gear, therefore there has been less research on the impacts and management measures are not often prioritised. From the case studies, a general process of managing this interaction can be deduced:

1) Assess the level of impact. In the literature there are several publications showing little impact (e.g. Stephenson et al., 2017), though some also show some level of impact (e.g Ibrahim et al., 2018). In the case of CS4, it was assumed that impact was low based on another species.
2) If no impact is found / assumed, then the level of interaction is mapped. Once mapping has been undertaken and interactions between static gear and habitats are identified, there may be no need for closed areas or restrictions if impacts are at an acceptable level (CS4). Mapping establishes a baseline of interaction and so can be used to monitor any changes.
3) If an impact is found, then additional input controls are implemented in order to reduce impact. For example, in CS5, it is likely that soak times would have been restricted if standard practice of soak duration was too long and impacting the benthos. In CS6, the gears with the greatest impact were excluded, with only low impact gears allowed. For the allowed fishing method, there is limited entry and fishing days.
4) If the impact is still unacceptable after input controls, then fishing activity may be excluded, as was the end result in CS6.

The main impact upon mobile, non-target species from fishing is bycatch. This is the case for both static and mobile fishing methods, and so there are similar management approaches for both gear types. Three of the case studies on mobile species implemented a high level of monitoring effort, from observers (CS7) or an electronic monitoring programme (trialled in CS8 and CS12). Two case studies implemented spatial exclusion zones around sensitive areas; in CS7 this was around pinniped haul outs, and in CS10 this was for sensitive fish nursery habitat and bird feeding area. Four case studies included modifications to fishing practices, in terms of gear modification (CS8, CS9 and CS11), fishermen behaviour (CS9), or limitation of effort by the most impactful gears (CS10). In CS11, where ghost fishing is a significant part of the bycatch problem, gear marking and reporting of lost gear are also required.

The impact of interactions between ephemeral / dynamic species and habitats and fishing gear is not well known. No international examples were found of management measures for static gear in ephemeral / dynamic habitats, presumably because this interaction is not deemed to be problematic. Management of the impacts of mobile benthic gear on these habitats and species is summarised, following the case studies. The first stage is to undertake an impact assessment, such as an appropriate assessment (for sites designated under the Habitats Directive), which was undertaken in CS13 and CS14. Undertaking this assessment requires knowledge of the distribution of the feature and fishing effort; in CS14, fine-scale fishing effort was gathered from VMS. In two of the case studies this feature was managed under a zoning plan. The zoning plan contained zones of different permitted levels of fishing activity, depending on the sensitivity of the habitat in that area. These zones also allowed for comparison of the impact under different fishing regimes, which in turn can be used to inform the assessment (as per CS15).

An overall feature of all the studies was enhanced monitoring of activity, be that through increased VMS coverage, other electronic monitoring, or observer coverage.

6. Discussion and Recommendations

The case studies have been selected as they contain management measures that are considered applicable to fisheries and nature conservation features in English waters. Despite each case study having its own benefits and limitations, the scores are fairly consistent, with most given a rating of ‘Moderate’. There was one example of a ‘Low’ and one example of a ‘High’ rating. No case studies have been screened out based on applicability, therefore all are discussed below, and the key recommendations drawn out.

6.1 Comparison of management measures

6.1.1 Spatial measures

In the case studies several different methods of spatial restriction of fishing effort were implemented. One method is to exclude damaging fishing activity from areas that are sensitive and being impacted. Exclusion of fishing can be applicable to all gear, i.e. a no-take zone, or specific to the most impactful gears. The spatial extent of the zone can be around the known extent of a sensitive feature, or can be based

on environmental parameters, such as depth or distance from the coast, to encompass a range of features in that area. The exclusion measure can be in place year round or have a temporal aspect e.g. be seasonal or dynamic. In English waters there are many feature-specific areas where certain damaging fishing methods are excluded. Exclusion of certain fishing methods based on distance from the coast are typically regional (e.g. implemented by Sussex IFCA (2019)) and there is one example of a ban on pair trawling within the southwest area of the UK EEZ. This measure of excluding impactful fishing from sensitive areas is therefore already broadly implemented in English waters.

One way to designate areas to protect is to exclude fishermen from areas that are rarely or have never been fished. This was adopted in CS3, CS5 and CS9, where the fishing footprint was limited to existing or core areas. In CS9 this measure was introduced by the fishing industry. The method in CS2, of designating areas protected from future fishing, is a special case that is only applicable to countries that have large parts of the EEZ where fishing has never occurred, which means that it has limited applicability to English waters.

The approach of limiting fishing footprint to existing areas is gaining scientific support. ICES (2017) reported that areas of high trawling intensity already have modified communities. Increasing effort in these areas will have little effect on the assemblage, whereas limiting effort on peripheral grounds will have greater ecological benefits to sensitive species. Similarly, Dinmore et al. (2003) found that seasonal closures lead to displacement of activity to previously unfished areas, which had slightly greater cumulative impacts on the benthos than permanent closures or no closures. It is questionable whether the English fishing industry would agree to this in a changing climate, with changing species distribution. However, if managers could guarantee them access to existing grounds, rather than restricting access to current grounds and moving them around to avoid closures, it may be more applicable. Implementing this measure requires in-depth knowledge of historical (or current) fishing extent, which could be achieved using VMS and fishermen input.

Key recommendation: Further investigate the applicability of limiting fishing footprint to historical / current extent.

Although not strictly a spatial closure, in CS3 the fishermen were provided with OSPAR cartography and proximity alerts on the vessel mapping system as part of a suite of measures to reduce bycatch. The fishermen are naturally disincentivised from fishing in areas of high bycatch as it is costly to remove the VME features from their nets. Therefore, it can be said that the mapping has enabled voluntary avoidance of VMEs and so minimisation of impacts on these habitats, without requiring a statutory exclusion measure. The success of this measure in English waters would rely on fishermen being disincentivised from fishing in areas of sensitive habitats. The method by which they are disincentivised requires further investigation.

Key recommendation: Provide information on location of sensitive habitats to fishermen. Disincentivise fishermen from fishing in these areas.

Marine spatial planning (MSP) was undertaken in CS3, CS13 and CS15. MSP is a form of spatial management. Spatial management can be beneficial to understand the impacts of not only fishing but also other activities on nature conservation features. It requires knowledge of the spatial use by different users, and using the information, zones are assigned to different activities. Spatial management can include a range of multi-use zones with different levels of fishing, including no-take zones if deemed necessary. Such zoning can allow for comparison of the effects of fishing when data on the impacts are limited, which is particularly beneficial for improving understanding of interactions between static gear and benthic reefs or all fishing gear and ephemeral / dynamic habitats and species. This additional information can inform the impact assessment process. Spatial management can occur at the scale of individual MPAs, i.e. zoning, or at a broader, even national scale, i.e. MSP. It is considered that zoning of MPAs is more readily achievable in English waters, as MSP for fisheries would have to be implemented through the CFP.

Key recommendation: Spatial management should be applied, particularly to areas with multiple users, and with varying levels of fishing, to determine impacts.

The management measures that have a spatial component are directly compatible with MPAs. Nevertheless, management measures that do not have this aspect can still be compatible with MPAs. For example, additional restrictions (input controls, such as limited entry or soak time) or compliance monitoring could be implemented specifically to cover MPAs or other sensitive areas. This could be imposed through byelaws in inshore waters, or more generally through permit conditions.

Key recommendation: Measures without inherent spatial components (e.g. technical controls) can be specified to a specific fishery / area, and so are compatible with MPAs.

6.1.2 Measures to reduce bycatch

In the case studies there were several approaches to reduce bycatch of non-target and, especially, ETP species. Several case studies implemented gear modification to reduce bycatch (CS8, CS9, CS11, CS13, CS15). Some case studies also restricted effort with the most damaging gear (CS10, CS13, CS15). Where ghost fishing is an issue, measures have been implemented to increase accountability (gear marking) and report lost gear (CS11). Several case studies also improved the awareness and recording of bycatch through increased visual monitoring (observers, REM) or a strict bycatch identification training and reporting regime.

There is limited data on bycatch of ETP species in English waters. Major bycatch issues are thought to occur between: harbour porpoise and seals and bottom-set trawling and gillnets; common dolphin and mid-water trawling; baleen whales and lobsters pots; birds and longlines and gillnets (BirdLife, 2019; Calderan and Leaper, 2019; Konigson et al*.,* 2015; National History Museum, 2019). Further information is needed on the greatest bycatch pressures, as the approach to reduce bycatch will be specific to the fishery and feature interaction and several different options may be available. It is outside of the scope of this report to detail all potential mitigation measures for all bycatch interactions.

Key recommendation: Improve recording of bycatch and increase visual monitoring coverage. This will help identify key fishery / species interactions that need to be managed through specific approaches.

In addition, all species have the potential to be impacted by ghost fishing gear. There are already requirements in place for fish gear marking and reporting of lost gear in English waters (MMO, 2016b). Methods to reduce the amount of ghost fishing are in their infancy but are growing at a substantial rate. The issue of ghost fishing has received international attention. Research and programmes to reduce ghost fishing have been undertaken by international organisations (such as the UN (UN News, 2016)), the Global Ghost Gear Initiative (2019), and Global Bycatch Exchange (2019). There have also been studies around the UK such as the Deepnet project (Hariede, et al., 2005). The successes of these efforts should be applied to English waters where feasible.

Key recommendation: Apply the successful measure from international programmes to reduce bycatch and ghost fishing to English waters.

6.2 Compliance monitoring

The current VMS in English waters limits the applicability of several of the spatial closures measures. Many of the case studies (9 of 15) could have a higher level of applicability if VMS coverage was improved. The current VMS restrictions (ping rate of 2 hours, only on vessels >12m) at best is only suitable for monitoring compliance with large offshore closures; it is not suitable for monitoring small spatial closures or restrictions in areas of <12m vessel activity, which is often the case inshore.

Several case studies had higher levels of VMS coverage. In CS13, ping rate was increased from 2 hours to 1 hour. In CS10, all the vessels in the fishery were

equipped with VMS, irrespective of size, with the majority of vessels <12m. In CS13 and CS14, a black box system with geographic positioning was introduced, that monitored fine-scale movements, and also incorporate fishing activity data. More fine-scale VMS data could also contribute to the assessment process on level of interaction. For example, in CS14, it would not be possible to calculate the percentage of the Natura 2000 site exposed to fishing without the more detailed VMS. The potential to apply VMS (and other technological solutions) to the fleet <12m has been discussed in NLAI (in press).

Key recommendation: VMS coverage should be improved to enable compliance monitoring. There should be increased requirements for VMS on vessels <12m. Ping rate should be increased, particularly in inshore areas.[10]

Observers are another tool that was used in five case studies where bycatch is/may be an issue (specifically CS1, CS2, CS6, CS7, and CS9). In some cases, observer coverage was consistently high throughout the fishery. CS7, located in the US, had a restructured observer system where the regulators must have prior notification of fishing trips so they can assign an observer if needed, based on the likelihood of interaction with non-target species or juveniles. The cost of the observer programme has also been redistributed more equitably; a broad-based fee was established, irrespective of the level of observer coverage on a specific fishery (as the observers were deployed by the National Marine Fisheries Service when and where they were deemed necessary). Observer coverage is low in English waters; in the EU, target sample rates are 1-2% of fishing trips per fishery (Mangi et al., 2013).

It would be logical to assign observer effort to vessels which have the highest potential to interact with ETP species and sensitive habitats, such as in CS7. However, level of interaction in English waters is poorly understood. In CS5 the regulators were not aware of the bycatch problem until observers were put on board. With the current level of coverage within the observer programme it is not possible to rule out that bycatch of ETP species occurs at non-negligible levels, while any move-on rule protocol for sensitive and catchable habitats (e.g., pink sea fans, some species of sea pen) would require higher levels unless undertaken entirely voluntarily. Observers can also provide enhanced information in support of other management measures, such as reporting of sightings and interactions with ETP species, and lost (and recovered) gear. However, it is acknowledged that observers are costly in terms of human resource, therefore increased coverage may only be feasible on a short-term and/or occasional basis (to establish impact levels or check compliance with new measures) and if other visual monitoring options are not more feasible.

Key recommendation: Observer rate should be increased in specific areas / fisheries that have potentially high bycatch rates to establish level of impact.

An alternative to the observer programme is remote electronic monitoring (REM), which was trialled in CS8 and CS12 to monitor bycatch. Although this technology

[10] It was suggested by one of the authors that a phase approach to ping rate, such as 15 minutes inside 6 nautical miles, 30 minutes in 6-12 nautical miles, and 1 hour beyond 12 nautical miles could be appropriate. The authors are of the understanding that the ping rate can be increased with the current VMS.

has only been trialled in the case studies, it has the potential to be widely applicable. Though REM is still a recent development in the EU, it has been operationally implemented in eight fisheries worldwide (Mangi et al., 2013). REM can improve accuracy in reporting bycatch over non-dedicated observers and also has lower costs than the equivalent observer coverage. One caveat to this management measure is that fishermen hold some level scepticism to being monitored and what the data will be used for (Mangi et al., 2013). Nonetheless, trials are ongoing in England (Mangi et al., 2013) and there has also been a recent renewal of calls to implement mandatory CCTV in English waters (Independent, 2019).

Key recommendation: REM has potential and should be trialled in English fisheries where bycatch is a known / potential issue.

6.3 Importance of co-management and co-development of measures

Elements of co-management were present in many of the case studies. In the case studies, the fishing industry was involved in data collection (CS1, CS3, CS4, and CS6), proposing management measures such as closed areas (CS2 and CS9), restriction to historic footprint (CS3 and CS9), restrictions of fishing gears (CS6), and voluntary compliance with measures introduced (CS9). Engagement of fishermen can be an iterative process, for example in CS3 where fishermen were trained in identification and handling of vulnerable marine ecosystems (VMEs), interactions with VMEs were reported and subsequently added to the distribution displayed on the onboard vessel mapping. There are examples from the case studies where, although the measure may have been implemented through statutory means, the specific management measure could be implemented on a more voluntary basis. For example, a management measure similar to the spatial closure in CS7 has been implemented in Cornwall in the form of a netting prohibition (Cornwall IFCA, 2019). Engagement with the fishing industry has many benefits including increased compliance.

Key recommendation: The fishing industry can and should be engaged throughout the development and implementation of management measures.

Many of management measures in the case studies required significant input from the regulators that would come at a cost. The regulators are typically responsible for collecting data on habitats, fishing effort, mapping, MSP, and impact assessments. As it is the responsibility of the regulators that the fishery is managed sustainably, the inputs needed to inform management measures are also their responsibility. The level of regulator-funded research in some case studies is likely to be prohibitive, such as the aerial surveys for marine mammals in the US, as described in CS7 and CS11. There are however, several instances of the cost associated with measures being contributed to by the fishing industry.

Key recommendation: Involvement of the fishing industry in developing and implementing management measures can reduce cost to regulators, through data collection, measure proposal, and voluntary compliance.

The likelihood of co-management increases when the benefit outweighs the cost to fishermen. For example, in CS1 there was a benefit to fishermen as the highest density scalloping grounds were mapped, which allowed them to target them and get better catch. Another example is CS3 where the move-on rule was beneficial, and adhered to at even lower quantities than required, because bycatch was costly to remove. CS12 also showed that the cost of REM was lower overall than observers. On the other hand, measures that are highly restrictive without due justification are unlikely to be followed voluntarily and may have a low compliance rate. For example, CS6 had extremely limited entry measures that would be hard to implement in English waters without resistance.

Key recommendation: Measures that have benefits to fishermen should be sought. Measures should not be disproportionately restrictive.

6.4 Summary

In summary, this report has found that there are several areas of good practice from other countries that could be applied in English waters to continue to improve the management of fisheries in MPAs. Key recommendations were:

1. Further investigate the applicability of limiting fishing footprint to historical / current extent.
2. Provide information on location of sensitive habitats to fishermen. Disincentivise fishermen from fishing in these areas.
3. MSP should be applied, particularly to areas with multiple users, and with varying levels of fishing, to determine impacts.
4. Measures without inherent spatial components (e.g. technical controls) can be specified to a specific fishery / area, and so are compatible with MPAs.
5. Improve recording of bycatch and increase visual monitoring coverage. This will help identify key fishery / species interactions that need to be managed through specific approaches.
6. Apply the successful measure from international programmes to reduce ghost fishing to English waters.
7. VMS coverage should be improved to enable compliance monitoring. There should be increased requirements for VMS on vessels <12m. Ping rate should be increased, particularly in inshore areas.
8. Observer rate should be increased in specific areas / fisheries that have potentially high bycatch rates to establish level of impact.
9. REM has potential and should be trialled in English fisheries where bycatch is a known / potential issue.
10. The fishing industry can and should be engaged throughout the development and implementation of management measures.
11. Involvement of the fishing industry in developing and implementing management measures can reduce cost to regulators, through data collection, measure proposal, and voluntary compliance.
12. Measures that have benefits to fishermen should be sought. Measures should not be disproportionately restrictive.

It should be acknowledged that the current fisheries management regime in England is considering many of these approaches already. These recommendations should

serve to strengthen areas of work that are already ongoing and to provide further impetus for development of measures in areas that are not currently being addressed.

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8. Annex 1: Phase 1 Results of structured interviews

Each question that was asked to the interviewees has been listed below, and responses are listed (where they were provided). The number of respondents that gave the answer is given in italicised parentheses after the answer. There was no restriction on the number of answers a respondent could give to a single question.

8.1 Background to the interviewees

Of the 11 interviewees who responded, 4 were in academia, 2 were from non-governmental organisations and 2 from regulatory bodies (specifically IFCAs). There was also one representative from each of the fields of consultancy, fisheries and government. Interviewees came from a range of knowledge backgrounds including fisheries, conservation, management, policy, licensing, and social science. The majority of the interviewees drew from experience in the UK, although some had experience in other countries including Australia, Russia, and Estonia.

8.2 Vulnerable designated habitats and species

Question 1 *"In your opinion, which UK designated habitats and species are considered to be particularly vulnerable and at greatest risk due to fishing pressures? Do you have any evidence to justify your comments?"*

The interviewees listed the following features in response:

- Biogenic reefs (*n=3*);
- Seagrass (*n=3*);
- Long-lived species/habitats (*n=3*);
- Sedimentary habitats (including sandbanks) (*n=3*);
- Rare species/habitats (*n=2*);
- Rocky habitats (*n=1*); and,
- Degraded habitats (*n=1*).

8.3 Difficult to manage designated habitats and species

Question 2 "*In your opinion, which UK designated habitat/species do you find the most difficult to manage and why? Do you have any evidence to justify your comments?"*

The responses given by the interviewees have been summarised in Table A19.

Table A19: Responses given by the interviewees to Question 2 of the interview

Most difficult to manage habitat/species	Justification
Resilient habitats to fisheries (*n=1*)	• No appropriate benchmarks (*n=1*)
Offshore sites (>12nm) (*n=2*)	• No control over other member states (*n=2*) • Poor real-time monitoring and enforcement (*n=1*) • Inadequate management measures (*n=1*) • Attitudes of fishermen (*n=1*)
Sedimentary habitats (*n=4*)	• Science is less conclusive on the impacts (*n=3*) • Less appetite to protect (*n=1*) • Inadequate management measures (*n=1*)
Mosaic habitats (*n=1*)	• Science is less conclusive on the impacts (*n=1*)
Highly mobile species (*n=3*)	• Inadequate management measures (fisheries and other activities) (*n=3*) • Science is less conclusive on the impacts (*n=1*)
Species with complex life stages (*n=1*)	• Inadequate management measures (*n=1*)
Species with low fecundity (*n=1*)	• Inadequate management measures (*n=1*)

8.4 Most challenging section of UK fishing fleet to manage

Question 3 "*In your opinion, which sections of the UK fleet (vessel size, gear type, region) are most challenging to manage and why?*"

The responses given by the interviewees have been summarised in Table A20.

Table A20: Responses given by the interviewees to Question 3 of the interview

Most challenging part of UK fisheries fleet to manage	Justification
Towed gear sector (*n=4*)	• Absence of VMS (<12m) (n=3) • Lack of/inadequate enforcement (n=2) • Low resolution of VMS (>12m) (n=1)
Inshore fleet (*n=4*)	• Absence of VMS (<12m) (n=3) • Attitudes of fishermen (n=1) • Lack of/inadequate enforcement (n=1)
Bait digging, crab-tiling (*n=1*)	• Lack of/inadequate enforcement (n=1)
Recreational angling (in context of Highly Protected Marine Areas) (*n=1*)	• Lack of/inadequate enforcement (n=1)
Potting and fishing for wrasse (*n=1*)	• Lack of/inadequate enforcement (n=1)
Nephrops fishing (*n=1*)	• n/a
People who are not interested in being managed (*n=1*)	• Attitudes of fishermen (n=1)
No one part a bigger challenge than another (*n=1*)	• Regional difficulties (n=1)

8.5 Successful fisheries management measures

Question 4: "*In your opinion, what management measures do you consider to be working well?"*

The responses given by the interviewees were as follows:

- Local byelaws (*n=4*);
- Spatial segregation agreement (*n=3*);
- Licenses not being given for destructive activities (*n=2*);
- Licensed scallop blocks (*n=1*);
- Collective management of quotas (*n=1*); and,
- Shift people to static gear (*n=1*).

8.6 Missing fisheries management measures

Question 5 *"In your opinion, which fisheries management measures do you consider to be missing?"*

The responses given by the interviewees were as follows:

- More targeted measures based on specific components (*n=1*);
- Gear modification (*n=1*);
- Sustainable management of inshore fleet (*n=2*);
- Enforcement planning (*n=1*);
- Joint management with other activities (*n=1*);
- Additional measures to reduce target fisheries on non-quota species (*n=1*);
- Reference sites (*n=2*);
- Zonal protection of MPAs (*n=2*);
- Evidence of justification for management measures (*n=3*); and,
- Offshore MPA closures to demersal fisheries (*n=1*).

8.7 Missing fisheries management measures

Question 6 *"Do you have any personal experience of overseas fisheries management measures that you feel would work in England?"*

The responses given by the interviewees are summarised in Table A21. These results have been used to inform Phase 2 of this project.

Table A21: Responses given by the interviewees to Question 6 of the interview

Country	Management Measure
USA (*n=4*)	• Closure of certain areas to certain fishing activities (*n=2*) • Gear modification (*n=1*) • Management plans (*n=1*)
Isle of Man (*n=2*)	• Closure of areas to fishing, in particular scallop dredging (*n=2*)
Chile (*n=2*)	• Property rights (*n=1*) • Closure of areas to scallop dredging (*n=1*)
Australia (*n=2*)	• Zonal approach (*n=1*) • Management plans (*n=1*)
New Zealand (*n=1*)	• Closure of areas to scallop dredging (*n=1*)
Canada (*n=1*)	• Management of offshore scallop fleet (*n=1*)
Ascension Islands (*n=1*)	• No fishing in MPAs (*n=1*)
Holland (*n=1*)	• Joint approach between marine industries (*n=1*)
Norway (*n=1*)	• Economic approach (*n=1*)
Estonia (*n=1*)	• Individual transferable quotas (*n=1*)
Portugal (*n=1*)	• Closure of inshore areas to towed gear (*n=1*)
Scotland (*n=1*)	• Closure of inshore areas to towed gear (*n=1*)