Risk-based approach to Remote Electronic Monitoring for English inshore fisheries

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MRAG Ltd

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1.1.4 Keywords

Risk-based approach, Remote electronic monitoring, Inshore fisheries, Good Environmental Status.

1.1.5 Further information

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1.1.6 Acknowledgements

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Executive summary

This report was commissioned by Natural England for the Greener Farming and Fisheries programme and the Marine Evidence and Fisheries team in the Chief Scientist's Directorate. The aim was to develop a framework that will identify the most efficient and effective suite of Remote Electronic Monitoring (REM) technologies for the English inshore fisheries, operating within 12nm of the coastline in English waters. The framework adopts a risk-based approach, assessing the risks posed by different fishing métiers (gear types) to the wider marine environment (through Good Environmental Status (GES) descriptors) and subsequently evaluate how the various REM designs support data gathering to contribute to mitigating these risks. The framework includes an evaluation of the costs and benefits provided by different levels of monitoring, thereby providing Defra (and IFCAs / MMO thereafter) with the benefits that could be achieved by introducing incremental layers of REM to different métiers.

The UK Government has committed to achieving GES for English seas by 2024. In English waters, marine biodiversity (birds, fish, benthic habitats etc.) has been documented as being in a state of decline, as evidenced by the 2019 update to the UK Marine Strategy Part One (DEFRA, 2019). The UK Government explicitly linked the delivery of GES to the Ecosystem Objective as set out within the Fisheries Act 2020. The UK Marine Strategy Part One report identified that commercial fishing was the most significant factor preventing the achievement of GES.

This project was contracted to MRAG Ltd, with the intended goal of developing a framework that can be used by Defra to inform the development of a new fisheries data collection and monitoring regime as part of the UK's new catching policy, identifying the most efficient and cost-effective combination of REM technologies that can be applied across the fleet operating within 12nm, primarily, but also with the potential to extend to the entire English EEZ. Informing the development of a catching policy that incorporates REM systems utilising an evidenced risk-based approach that will: (i) help promote compliance; (ii) collect data for data-poor fisheries; (iii) protect sensitive species; and (iv) contribute to achieving GES.

This project was delivered in two parts; Objective 1: Risk analysis of fishing métiers to achieving GES; and Objective 2: Framework for a risk-based implementation of REM technology in English fisheries. Both with a primary focus on the inshore environment but with due consideration given to the whole EEZ. Within this project the inshore environment or inshore fishery s defined as: *the area of the coastal zone inside 12nm of shore*.

Objective 1 delivered a risk assessment framework investigating the impact of fishing effort on the marine environment across a selection of 15 fishing métiers; scoring these métiers was based on a qualitative literature review of their impacts against the 11 GES descriptors and six additional scoring criteria. Fishing impacts on the marine environment are relatively well documented and include direct impacts from fishing activities on target species, on non-target commercial fish species, other unmarketable fish, on protected, endangered, and threatened species and on habitats. Indirect impacts can arise from changes in trophic structure and function caused by discarding and from the differential removal of fish specific trophic levels. Information on fishing impacts were assessed for English fisheries, identifying the inherent risk of a fishing vessel's impact to the marine environment through determining the likelihood and consequence of an interaction occurring. The inherent risk was cross-checked against the adequacy of mitigation or management measures in place, thereby generating a residual risk score for each GES descriptor and additional risk factor across the métier. Residual risks were assigned a Red, Amber, or Green (RAG) status for the risk of each interaction, helping to identify high, medium, and low risk interactions. Residual risks were summed to provide an overall score per métier, and assigned a RAG status to identify the high, medium, and low risk métiers in an analysis fleet of 2185 vessels in the English fishery.

A systematic literature review was conducted based on established guidelines[1] and reported in line with the ROSES *pro forma* (Haddaway *et al.*, 2018). Literature searches were conducted in Google Scholar, allowing access to both peer-reviewed and grey literature. Searches used Boolean logic to combine terms relating to selected métiers and GES descriptors. 172 publications were deemed to be directly relevant to the risk analysis. Four high risk métiers were identified: Beam trawl, bottom otter trawl multi-rig otter trawl and, pair-bottom trawl. Seven medium risk métiers were identified: Boat dredge; gillnets, mid-water otter trawl, mid-water pair trawl, nephrops trawl, set gillnets and trammel nets. The remaining six métiers were all scored as low risk: Drift gillnets, hand and pole lines, hooks, and lines, longlines, pots and traps and set longlines.

In delivery of Objective 2, a global literature review of REM technologies and good practices was carried out to support the design of the modular framework and put together a series of recommendations for the implementation of a national REM programme. Global REM vendors, service providers and manufactures were engaged to determine what existing and developing technologies can be applied, and how much these would cost to purchase, install, maintain, and operate on an annual basis. Annual costs were reflected within the design of the modular framework.

English fisheries policymakers, managers, and regulators were also engaged to determine the data collection and monitoring requirements of REM and the

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[1] https://environmentalevidence.org/roses/

subsequent benefits for fisheries management. Each métier in the sample frame was evaluated in the context of the identified risk under Objective 1, the identified impacts of that gear type and the monitoring requirements set by the stakeholders. A literature review of fisheries monitoring by management objective was conducted to determine the most appropriate proportion of REM data that needs to be reviewed to satisfy the monitoring requirement and provide a statistically robust sample to extrapolate fleetwide impacts. This sample requirement was applied to fishing effort data to determine the volume of REM data (video and sensor) collected, and from this extrapolate the resource and financial costs for monitoring nationally. Furthermore, this was used as a tool to determine the resource and financial requirements necessary to implement (coordinate, report on and manage) a REM programme nationally.

Data volumes generated were calculated to exceed 2,000 TB annually across the analysis fleet of 2185 vessels. In terms of monitoring time, this generated more than 80,000 hours of work for REM analysts per year, at an anticipated annual staffing cost of ~£1,130,000. In our approach, we consider that REM should be used holistically alongside human observation, and therefore should complement existing monitoring regimes. As such, the proposed monitoring cost for an integrated monitoring package was developed to include REM data analysis, physical observation (as an achievable percentage of observer coverage per fishing métier) and programme management (including coordination and reporting). This came to a total cost to management organisations of ~£3,800,000 annually, or around ~£1,750 per vessel in the analysis fleet.

Objective 2 delivered a risk-based modular framework approach to implementing REM across the classified 15 métiers assessed under Objective 1. Development of the framework included the design of REM systems for each métier, the data collection and monitoring implications, an assessment of the impact each design will have against achieving the monitoring objectives and the financial cost. For context, monitoring rates for fisheries implementing REM vary widely, based on the overall management objectives. An audit model for monitoring fishing effort has been most applied where mature mandatory REM programmes are in place. The census approach, which monitors 100% of fishing effort, is generally applied to programmes where the focus is on monitoring marine mammal or seabird interactions with fishing. Financial costs were determined by the recommended REM system design for each fishing métier, and the inherent costs for installation, maintenance, licencing, service support, data transmission over the period of one year. Prices for REM system designs varied per métier, depending on the identified monitoring requirement and level of risk presented. REM systems ranged from £2,700 on the lowest risk and smallest vessels, to £11,300 for the high risk and largest vessels.

The modular framework is structured around prioritising REM for fishing vessels regionally which have the greatest potential for contributing toward achieving GES.

As such, the framework has been developed as a live, interactive, and adaptable tool to assist the development of a national REM programme. The cost calculator tool has been used to put together the inherent REM costs and the associated monitoring costs to provide an implementation cost per fishing métier (<>10m) for each IFCA region. IFCA regions with the most registered vessels typically experienced the highest costs. For instance, for Cornwall and Devon and Severn, the total implementation value per year is greater than £2,000,000. Whereas regions such as North-Eastern, North-Western and Northumberland cost around ~£590,000, ~£687,000, and ~£930,000 respectively.

Across the analysis fleet of 2185 fishing vessels, the total annual implementation cost is around £11,500,000. Pot and Trap vessels are by far the most numerous in the UK, representing ~£3,000,000 of this total. These were generally considered low risk vessels, but due to their high proportion of the fleet, command the highest REM implementation cost. Bottom Otter Trawls were considered one of the highest risks métiers, and as such justified a more expensive REM design, as such, they generated a total annual cost of ~£2,600,000 despite being half as numerous, but still representing the second largest métier in the analysis fleet. An audit approach to collect 100% of data for all fisheries with a fixed audit/ review requirement for all fishing vessels is recommended with a high audit level or census approach taken for the highest risk métiers is recommended. For medium and lower risk vessels running a variable sampling regime across the fleet is recommended.

The project has identified that it is feasible to take a nation-wide approach to implementing REM, with a multitude of benefits available to stakeholders in addition to the recognised contributions toward fulfilling objectives of the GES and fisheries management. Immediate implementation and data gathering through REM should be a priority for the highest risk vessels. This will enable appropriate fisheries management measures and regulations to be put in place, offering the potential for significant progress in reducing fishing impact on the marine environment, and contributing to the UK Government’s commitment to achieving GES in English seas by 2024.

Implementing a national REM programme does come with several challenges, primarily surrounding resources, infrastructure, and capacity requirements to be able to process and act on the data collected. Significant investment in both infrastructure and human resources will be required to translate the data gathered into actionable information which can be used in a timely fashion to strengthen the scientific evidence base for fishing impacts, as well as bolster national fisheries enforcement efforts to combat illegal, unregulated, and unreported fishing (IUU). This would be a substantial undertaking and does not need to be completed alone. Implementation by Defra would benefit from experiences, resources, and knowledge available in the global community, developing a REM programme in tandem with the devolved nations and neighbouring EU countries would strengthen consistency in data gathering and fisheries management. Due attention must also be given to funding and cost recovery options. There are a variety of methods available for this such as government ownership and leasing/cost recovery from the fleet, or operator purchase with or without grant funding. Each of these have their merits and drawbacks but it was beyond the scope of this report to fully explore each these options.

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Natural England's role is to provide advice and evidence to help policy makers and fisheries managers make decisions which reduce environmental damage and instigate ecosystem recovery. In UK waters, commercial fisheries are currently responsible for causing the greatest pressures on the marine environment, with Good Environmental Status (GES) still having not been achieved. Different fishing gears impact the marine environment in different ways and to varying degrees pending both where and how frequently they are deployed. It remains logistically and financially difficult to effectively monitor fishing activity and measure catches to robustly understand the full impacts of fishing on the environment. The capability of Remote Electronic Monitoring (REM) to measure and mitigate some of these impacts has been accepted for some time, with project-level testing applying and refining the implementation of REM at relatively small scales. This work set about investigating which gears posed the biggest threats to the marine environment (including GES) and subsequently how various components of REM could help mitigate that risk through enhanced control and by supplementing the evidence base by bringing relevant data into fisheries management decisions.

Natural England believe the implementation of a REM programme would be a significant advancement in the UK's efforts to not only achieve GES but work towards the sought-after goal of World Class Fisheries. A pragmatic approach to the development of any such programme would be to prioritise those fisheries which pose the highest risk to the marine environment, and the achievement of GES. This report therefore considers the practicalities of operationalising REM utilising a modular design that allows policy makers and regulators to consider different policy approaches and understand the relative cost implications.

We thank MRAG for their exhaustive work on this topic and appreciate that the cost estimates may require subsequent fine-tuning if and when it came to actual phased deployment of REM.

1. Introduction

REM has been available as a fishery monitoring tool for nearly twenty years and has been used as a compliance tool for over fifteen years in Canada. However, it is only in the last few years that uptake and application has been gaining significant traction in world fisheries, due to increases in communication speeds, decreasing costs (which are critical for small scale fisheries) and the potential to monitor the high profile and wasteful practice of discarding. The technological advancements allowing for holistic and integrated data recording functionality, in addition to financial and operational scalability, the integration of machine learning and artificial intelligence software; has brought down costs of implementing REM programmes and enhanced its usability across fisheries. Numerous global success stories can be demonstrated from countries pioneering the application of this technology such as Australia, Canada, the USA, and New Zealand. These pioneers have proved that REM is an effective means for better policing and safeguarding countries natural resources along with providing an increased level of compliance and scientific data.

With increased granularity of data, higher resolution sensors, better communications links and increased data capacity on smaller devices and more secure encrypted storage onboard vessels, REM can be an effective tool for monitoring activities at sea. Application of REM systems in the UK's inshore fishing fleets can help to document fishing activities, providing information for fisheries managers and scientists. This is an important step towards achieving sustainability and safeguards the potential of future fisheries while enabling fisheries to meet the requirements of internationally driven and national commitments such as the Fisheries Act 2020, Habitats Regulations, future catching policies governing discards, and the UK Government's 25-year Environment Plan and Fisheries White Paper.

The UK Government's formal position is to pursue an ecosystem approach to fisheries management that aims for more sustainable management and seeks to minimise impacts on non-commercial species and the marine environment generally. Through REM, a record of fishing events and an estimate of the quantity of fish caught can be recorded and analysed by qualified reviewers in a cost-effective manner. Global examples taken from Australia, New Zealand, Federated States of Micronesia, and the Seychelles demonstrate the effectiveness of fleet-wide approaches to REM, allowing for targeted, vessel specific fisheries control measures. Drawing on a more local focus, the MMO, Ireland's SFPA, Marine Scotland, the Netherlands, France, and Denmark have been implementing projects and conducting sea trials of REM technologies on their respective fleets.

Currently, the UK is continuing to work towards achieving Good Environmental Status (GES) of UK seas by 2024. First introduced under the Marine Strategy Framework Directive (2008/56/EC; MSFD), GES is defined as the environmental status of marine waters where they provide ecologically diverse and dynamic oceans and seas which are clean, healthy, and productive. Assessed against a set of 11 descriptors listed in Annex 1 of the MSFD, each EU Member State must develop a marine strategy to achieve good status by 2020. In the UK, the MSFD was transposed into UK law by the Marine Strategy Regulations 2010 (the Strategy), providing a comprehensive UK-wide framework to assess, monitor and report progress towards GES targets using clearly defined indicators, as well as collaborate with other EU Member States in the northeast Atlantic, through the OSPAR Convention.

To date, the status of GES has either not been achieved or is uncertain for 11 of the 15 associated indicator assessments. Most notably commercial fishing has been flagged as one of the most significant pressures preventing the achievement of GES. Previous results in 2015, show 53% of marine fish (quota) stocks were fished within maximum sustainable yield (MSY) limits while at least 37% of national shellfish stocks were exploited beyond MSY or had no defined MSY reference point to conduct an assessment (61%) (Defra, 2019). The assessments of progress towards GES carried out in 2012 and 2018 determined that it was unlikely that GES would be achieved for benthic habitats by 2020. The main problem is caused by physical disruption of the seabed from fishing gear (Defra, 2019).

In a bid to deliver high-quality monitoring of the marine environment, the implementation of REM systems would not only contribute to the establishment of a fully documented fishery of the England’s inshore fishing fleet, but also contribute to achieving GES within the 12nm inshore zone. REM would need to be integrated effectively within the wider monitoring framework, e.g., REM outputs linked to landing data, sales records etc. to fully achieve this outcome.

Within this project we define the inshore environment or inshore fishery as: *the area of coastal zone inside of 12nm of shore*.

The aim of this project was to develop a modular framework that will identify the most efficient and effective suite of REM technologies which can be applied for the most common fishing métiers operating within the English 12nm territorial sea. The framework adopted a risk-based approach, assessing the risks posed by different fishing métiers to the wider marine environment (through GES descriptors) and subsequently evaluate how the various REM components could contribute to mitigating these risks in a proportionate and cost-effective way. The framework was designed around a three-tiered structure for REM technologies design and data collection (low cost, cost-effective, and maximised data collection), incorporating a cost-benefit analysis of the three approaches to each fishing métier; thereby providing Defra (and IFCAs / MMO thereafter) with the prospective benefits that could be achieved by introducing incremental layers of electronic monitoring technology to different parts of the fleet.

Figure 1 is a map of the UK, indicating the study area for this report. It denotes all IFCA regions and the inshore (sub- 12nm) coastal zones.

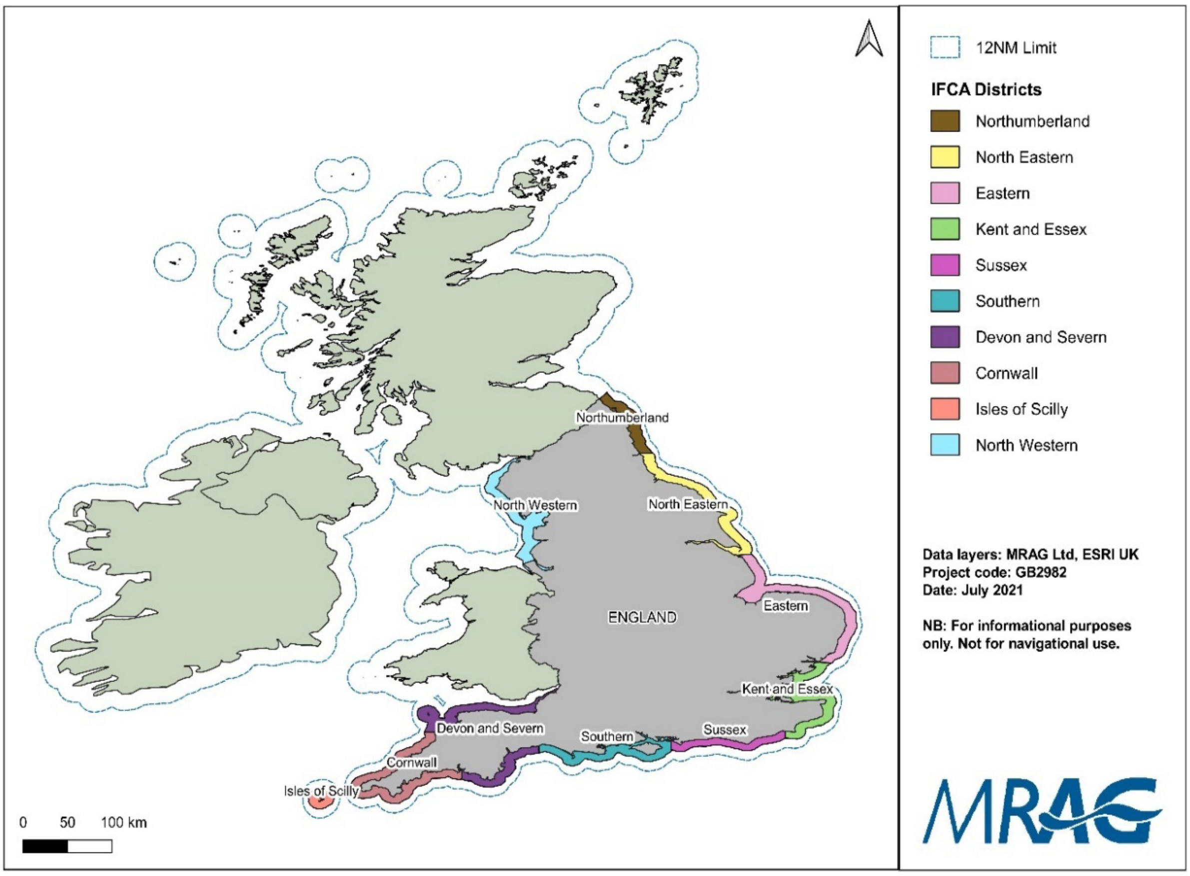

Figure 1 Study area highlighting the English 12nm limit, spanning ten IFCA regions

Under the terms of reference for this project, there are two key deliverables: Objective 1: Risk analysis of fishing métiers to achieving GES; and Objective 2: Framework for a risk-based implementation of REM technology in English fisheries. Given the complexity and scope of the deliverables covered under this project, a document map has been provided below to help guide the reader and highlight the core sections of the report.

1.1 Objective 1 - Risk analysis of fishing métiers to achieving GES

The aim of Objective 1 was to produce an evidence-based risk matrix classifying fishing métiers by the level of risk associated with each métier to the 11 descriptors of GES. This built on the work undertaken by Natural England to map fishing pressures against GES descriptors and fed into Objective 2; designing a modular framework to guide the roll out of REM on fishing vessels nationally.

Fishing métiers operationally have varying degrees of impact on the marine environment, habitats, and species. This is determined by the specific characteristics of the fishing operations, the species targeted and the management regime in place. The impacts on the marine environment are relatively well documented and include direct impacts from fishing activities on target species, on non-target commercial fish species, other unmarketable fish, on protected, endangered, and threatened species and on habitats. Changes in trophic structure & function can arise through a variety of fisheries impact pathways. The risk assessment process drew together the available literature on each fishing métier with a core focus on determining the fishing impact against the core GES descriptors; biological diversity (Descriptor 1), commercial fish and shellfish (Descriptor 3), food webs (Descriptor 4) and seafloor integrity (Descriptor 6). In addition to these core descriptors, the research was undertaken into the impacts against marine litter (Descriptor 10), and introduction of energy into the system (Descriptor 11); and six additional key risk factors which have a significant bearing on determining fishing impact on the marine ecosystem.

These include:

- Commercial fish bycatch;
- Protected species bycatch;
- Non-compliance with fishing regulations;
- Quota and area-based restrictions;
- Damage to essential fish habitats, and

- Displacement of fishing effort by external pressures (area closures due to marine spatial planning).

An analysis fleet of 2,185 vessels were classified under Objective 1. These were based on a sample of all UK and EU vessels registered to fish in English waters, split across 15 métiers containing a minimum of 40 registered vessels. Some exceptions to the 40-vessel cut off were included at special request from Natural England where vessels had been identified to be of a particularly high risk – or where their operational function, impacts and classification were equivalent to another métier.

Objective 1 has been structured as follows in this report:

Key Sections

Methods

- The six-step process to vessel identification and classification – producing the reference frame for vessels included in this study. Section - 2.1.1
- The risk assessment process methodology employed in this study. Section – 2.1.2

Results

- The risk matrix. Section - 2.2
- The evidence base and assessment breakdown for each fishing métier. Sections - 2.2.1 - 2.2.11

1.2 Objective 2 – Framework for a risk-based implementation of REM technology in English fisheries

The requirement of Objective 2 was to produce a framework for the implementation and modular rollout of REM technologies based on the identified risk established under Objective 1, with a specific focus on fishing vessels operating within 12nm of the English coast. In practice, all fishing vessels are capable of fishing within the inshore zone, and without position data available on the vessels <12m, it was not possible to make a distinction of positional fishing effort in the <>10m vessel categories. Therefore, the REM framework and design was built around all fishing vessels in the fleet classified under Objective 1.

REM components and companies were identified from the global community and literature. REM vendors were engaged to collate product specific information and from this a short-list of technologies synthesized to produce métier specific REM designs. National fisheries policy teams, managers and regulators were engaged to ensure the proposed designs were in keeping with the stakeholder requirements for REM in English fisheries.

The modular framework was built around the level of risk, the monitoring requirements determined through stakeholder engagement and the most appropriate REM design able to fulfil these requirements. Determination of the level of risk is a critical aspect of the modular design as it is this aspect that governs the proportionality of monitoring, and of cost, of the proposed design. The financial implications of running a REM programme were incorporated into this framework, covering purchasing costs; installation cost; programme implementation, monitoring and analysis costs; and management costs. Inclusion of the financial implications enables the reader to extract the potential benefits of incremental layers of monitoring within English fisheries, covering how these can contribute to alleviating the risks to GES identified in Objective 1. Some degree of interactivity was built into the modular framework design, transforming this from a guide into an interactive and usable tool for implementing REM based fisheries management. The interactivity of the framework allows the users to select between REM designs, to specify the proportion of data collected analysed under the monitoring requirement and specify the programme implementation costs. This is then displayed as a specific set of costs for each module in the framework.

Objective 2 has been structured as follows in this report:

Key Sections

Methods

- The REM vendor engagement. Section - 3.1.3

- Fisheries policy and managers stakeholder survey. Section – 3.1.4
- Assessing REM technologies for their applicability to English fisheries. Section – 3.1.5
- Assembly of the modular framework. Section - 3.1.6

Results

- Stakeholder responses – informing the monitoring requirements of the REM design. Section - 3.2.5
- Recommended REM technologies for English fishing vessels. Section - 4

Description of the Modular Framework

- Split Matrix – covering the assessment, monitoring requirements and recommended REM designs for each of the fishing métiers. Section – 5
- Determining the monitoring and data analysis requirement for each fishing métier. Section – 6.1
- Modular framework excerpt covering the first 50 groups of vessels to implement REM, split by vessel type, length (<>10m) and IFCA region registration and ordered by an overall score calculated from the identified risk, the monitoring requirement, and the recommended REM design. Section – 6.2

Cost framework - REM equipment and programme costs

- Equipment and purchasing costs. Section – 6.3.1
- Annually reoccurring costs. Section – 6.3.2
- Programme set up costs. Section - 6.3.3
- Programme implementation costs. Section - 6.3.4

National REM Programme Management Recommendations and Summary

- National Implementation and Monitoring requirements – Section - 7.1 and 7.2
- Infrastructure requirements, audits, and certification – Sections – 7.3 and 7.4
- Stakeholder benefits – Section – 7.5
- Project Summary – Section - 0

2. Objective 1: Risk analysis of fishing metiers to achieving GES

The below sections document the Methodology and Results of delivering Objective 1: Risk analysis of fishing metiers to achieving GES.

2.1 Methodology

The following sections provide a detailed description of the methods undertaken to identify and classify fishing métiers operating within 12nm (including foreign vessels) and assess the risks associated with each métier to the 11 GES descriptors and selected additional risk factors.

2.1.1 Identification and classification of fishing métiers

Fishing métiers operating within the English 12nm limit were identified and classified to level four (Table 1) as defined by Appendix IV of Commission Decision 2010/93/EU. This included UK domestic vessels (both under and over 10m) and EU vessels licensed to fish in UK waters. Norwegian and Faroese vessels were not included due to the current exclusion from fishing in UK waters.

Métiers were classified to Level Four to ensure continuity with other fisheries management initiatives e.g., marine protected area assessments and to effectively fit the requirements of the analysis required under Objective 2 of this work.

Table 1 Level 4 classification of fishing métiers

Level 1	Level 2	Level 3	Level 4
Activity	**Gear classes**	**Gear groups**	**Gear type**
Fishing	Trawling	Bottom Trawl	Bottom Otter Trawl (OTB)

The process for the identification and classification of fishing métiers was conducted in six steps.

2.1.1.1 Step 1: Data acquisition - fleet identification

Open-source vessel data (Table 2) was accessed and downloaded from the MMO and European Commission (EC) websites to identify the domestic and foreign fleets operating within the English 12nm limit. These data are updated year on year ensuring the continuity of this work. Further, the UK Government are familiar with these data giving strong rationale for their use.

Table 2 Data sources to be utilised for Task 1.1 under Objective 1

Data source	Description	Source
EU Vessel List for UK Waters	List of EU vessels with a licence, issued by the UK Single Issuing Authority (UKSIA), to fish in UK waters.	MMO[2]
EU Fleet Register	Database where all the fishing vessels flying the flag of an EU country must be registered.	EC[3]
Over 10m and Under 10m Vessel List	List of over 10m and under 10m fishing vessels registered in the UK.	Marine Management Organisation[4]

2.1.1.2 Step 2: Data extraction - gear type mapping

The primary gear type employed by each vessel within the domestic and foreign fleets was identified and extracted.

To identify the primary gear type of EU vessels, the '*EU Vessel List for UK Waters*' and '*EU Fleet Register*' data sets were joined based on the field value 'CFR number'. To identify the primary gear type of UK vessels (>10m and <10m), the '*Over 10m vessel list*' and '*Under 10m vessel list*' and '*EU Fleet Register*' datasets were joined based on the field value 'Registry of Shipping and Seamen number'.

Within the accessed fleet registers, both a 'primary gear' and a 'secondary gear' code were listed. However, no indication was provided concerning the frequency of use of these (or other) gears. Therefore, in all cases the 'primary gear' code was therefore assumed to be the gear employed by the vessel.

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[2] https://www.gov.uk/guidance/united-kingdom-single-issuing-authority-uksia

[3] https://webgate.ec.europa.eu/fleet-europa/index_en

[4] https://www.gov.uk/government/collections/uk-vessel-lists

2.1.1.3 Step 3: Data cleaning

Applicable field values were isolated by deleting unwanted or duplicated field values in the joined data sets. The following field values remained in each of the fleet registers:

- Flag State e.g., BEL or Home Port e.g., North Shields;
- CFR Number e.g., BEL000021964 or Registry of Shipping and Seamen number e.g., C18592;
- Vessel Name e.g., Calypso;
- IMO Number e.g., 7936777 or Licence number e.g., 23670; and
- Main fishing gear e.g., TBB.

2.1.1.4 Step 4: Vessel identification

A summary table was produced to identify the number of domestic and foreign vessels per métier fishing within the UK 12nm limit at a level four classification (gear type).

2.1.1.5 Step 5: Métier identification and vessel validation

Domestic and foreign fishing vessels were aggregated together to identify the métiers operating within the English 12nm limit. This identified approximately 40 individual métiers (Appendix 1).

2.1.1.6 Step 6: Métier classification

Métiers with a total number of vessels (foreign and domestic) greater than 40 were selected for analysis (Table 3). This represents over 93% of vessels within the domestic and foreign fleets operating within the English 12nm limit. Pair bottom trawl (PTB) and Mid-water pair trawl (PTM) were also selected for analysis, despite having fewer than 40 vessels, due to the perceived increased risk by operating with two vessels.

Table 3 Number of foreign (EU) and domestic (UK >10m and <10m) vessels per métier, at level four classification, operating within the English 12nm limit

Level 1	Level 2	Level 3	Level 4	Number of vessels			
Activity	**Gear classes**	**Gear groups**	**Gear type**	**EU**	**UK >10m**	**UK <10m**	**Total**
Fishing	Dredges	Dredges	Boat dredge (DRB)	189	141	82	412
	Traps	Traps	Pots and traps (FPO)	115	279	2298	2692
	Nets	Nets	Gillnets (GN)	-	14	406	420
			Drift net (GND)	13	3	58	74
			Set gillnet (GNS)	113	15	120	248
			Trammel net (GTR)	75	2	49	126
	Hooks and Lines	Rods and Lines	Hand and pole lines (LHP)	29	4	335	368
			Hooks and lines (LX)	-	1	113	114
		Longlines	Longlines (LL)	1	6	56	63
			Set longlines (LLS)	101	11	10	122
	Trawls	Bottom trawls	Bottom otter trawl (OTB)	511	357	397	1265
			Multi-rig otter trawl (OTT)	47	65	4	116
			Beam trawl (TBB)	237	88	63	388
			Nephrops trawl (TBN)	-	25	21	46
			Pair bottom trawl (PTB)	-	27	-	27
		Pelagic trawls	Midwater otter trawl (OTM)	110	30	6	146
			Mid-water pair trawl (PTM)	23	5	1	29

Selected métiers were classified by the origin of vessels in order to identify the vessel distribution amongst métiers within the English 12nm region (Appendix 2). EU vessels were classified based upon their flag State (e.g., BEL). UK vessels were classified by devolved nation based upon their home port. English registered vessels were further classified into IFCA regions, based on their home port. Where a flag State or home port was not given or listed as 'Unknown', vessels were classified as Unknown. This classification supports the granularity of costings that can be achieved under Objective 2.

2.1.2 Risk analysis against Good Environmental Status (GES) descriptors

A risk analysis framework was developed for the assessment of selected fishing métiers against the 11 GES descriptors and selected additional risk factors (Table 4).

As identified by Natural England in previous work investigating approaches to linking fisheries pressures to GES descriptors**,** key GES descriptors of relevance to fishing and associated impacts on the marine environment selected for assessment included:

- GES 1) Biodiversity is maintained;
- GES 3) The populations of commercially exploited fish and shellfish are healthy;
- GES 4) Elements of marine food webs ensure long-term abundance and reproduction;
- GES 6) Sea floor integrity ensures functioning of the ecosystem;
- GES 10) Marine litter does not cause harm in respect to lost gear and impact of ghost fishing; and
- GES 11) Introduction of energy (including underwater noise) does not adversely affect the ecosystem.

The remaining descriptors were not considered applicable to the impacts of fishing and were excluded. In addition to GES descriptors, additional risk factors were built into the risk assessment framework, descriptions of which are given in Table 4.

Table 4 Risk assessment framework

GES Descriptor / Additional Risk Factor	Description
GES 1) Biodiversity is maintained	This risk factor assessed the risk posed by fishing métiers to biodiversity through a review of peer-reviewed literature using key indicators such as mortality rates per species from incidental bycatch; population abundances; population demographic characteristics and distributional range.
GES 3) The population of commercial species is healthy	This risk factor assessed the risk posed by fishing métiers to the population of key target commercial species exploited by that métier through a review of peer-reviewed literature; review of stock assessment data and advice and key indicators such as fishing mortality rate; stock spawning biomass and the age and size distribution of individuals in the populations.
GES 4) Elements of food webs ensure long-term abundance and reproduction	This risk factor assessed the risk posed by fishing métiers to food-web interactions that ensure the long-term abundance and reproduction of target and associated species through a review of peer-reviewed literature.
GES 6) The seas floor integrity ensures functioning of the ecosystem	This risk factor assessed the risk posed by fishing métiers to the physical condition and extent of benthic habitats that are key to ensuring ecosystem functioning through a review of peer-reviewed literature using key indicators such as spatial extent and distribution of physical loss and disturbance.
GES 10) Marine litter does not cause harm in respect to lost gear and impact of ghost fishing	This risk factor assessed the risk posed by fishing métiers in contribution to marine litter as ALDFG and the consequential harm that could cause on species and habitats through ghost fishing. This was assessed through a review of peer-reviewed literature.
GES 11) Introduction of energy (including underwater noise) does not adversely affect the ecosystem	This risk factor assessed the risk of underwater noise introduced by different fishing métiers through a review of peer-reviewed literature. Underwater noise could have an impact on marine fauna, specifically transient marine mammals.
Commercial fish bycatch	Within the context of this work, commercial fish bycatch refers to discards including choke species, non-quota species and undersized individuals (below the minimum landing size). Discarding of undersized species is primarily discussed under Non-compliance against minimum landing size and quota species (e.g., misreporting). This risk factor assessed the percentage of target species retained in catches from peer-reviewed literature and stock assessment reports to inform the associated likelihood and risk of catching non-target species. This would inform the risk of potential misreporting, in order to carry on fishing, which could have knock-on effects on the stock or related parts of the environment through fishing for that target species.
Protected (ETP) species bycatch	This risk factor assessed the risk of each métier for the bycatch of ETP species using presence and absence data of protected species. The use of gear that is prone to incidental catch of protected species may increase the risk of non-compliance against the Wildlife and Countryside Act 1981 and Annex IVa of

GES Descriptor / Additional Risk Factor	Description
	the Council Directive (92/43/EEC) and impact the population of the affected species.
Non-compliance against minimum landing size and quota species (e.g., misreporting)	This risk factor assessed the risk of non-compliance against TAC and quota regulations using reports of previous instances of IUU / misreporting within grey literature. Non-compliance against these regulations could impact the stock for which the regulations are set.
Non-compliance against area restrictions e.g., gear type / marine protected areas	This risk factor assessed the risk of non-compliance against area restrictions e.g., gear restrictions and marine protected areas using reports of previous instances of IUU / misreporting within grey literature. Non-compliance against these restrictions could impact the stock for which the restrictions are set and or the designated habitats.
Essential fish habitat	This risk factor assessed the risk of physical damages to nursery and spawning grounds. Use of certain gear types may increase the risk of damage to nursery and spawning grounds, which in turn may impact the population of the species affected.
Displacement of fishing activity due to presence of offshore wind farm	This risk factor assessed the risk of displacement of fishing activity due to the presence of a wind farm and associated structures. The increasing impetus to implement wind farms could lead to the displacement of fishers that primarily use certain gear type, which in turn can lead to an inadvertent focus of fishing effort – the concentration could be at the expense of GES.

2.1.2.1 Risk analysis

A consequence – likelihood approach was adopted in order to conduct the risk analysis against GES descriptors and additional risk factors.

Inherent Risk = Consequence (C) x Likelihood (L)

(i) Likelihood is the probability of occurrence of an impact that affects the environment.
(ii) Consequence is the environmental impact if an event occurs.

This approach was used in tandem with the criteria and indicators described in the GES framework detailed in Part I of Commission Decision (EU) 2017/848[5].

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[5] Part I of Commission Decision (EU) 2017/848

2.1.2.1.1 Assessment of ‘likelihood’ and ‘consequence’.

Each risk interaction was assigned one of five qualitative ratings for both likelihood and consequence, as shown in Table 5 and Table 6. Likelihood ratings were based on the probability of the risk interaction occurring within a one-year period (e.g., based on the number of vessels within the operating region). Consequence ratings were based on the expected impacts on the integrity of management arrangements and the achievement of regional fisheries goals if the risk occurred.

Table 5 Likelihood ratings

Likelihood	
Risk Rating	**Description**
Almost certain	A very high probability exists that the impact will occur during the specified period i.e., the activity will be expected to occur in most circumstances.
Likely	A high probability exists that the activity will occur during the period i.e., the activity or event will probably occur in most circumstances.
Moderate	A moderate probability exists that the activity will occur during the specified period i.e., the event should occur at some time.
Unlikely	A low probability exists that the activity will occur during the specified period i.e., the event could occur at some time.
Rare	A very low probability exists that the activity will occur during the specified period i.e., the event may occur under exceptional circumstances.

Table 6 Consequence ratings

Consequence	
Risk Rating	**Description**
Serious	The consequence of the risk occurring would significantly undermine the integrity of the management arrangements and threaten the achievement of one or both regional goals.
Major	The consequence would probably undermine the integrity of the management arrangements and may threaten the achievement of one or both regional goals.
Moderate	The consequence may present some impact to the integrity of the management arrangements and there may be some minor threat to the achievement of one or both regional goals.
Minor	The consequence may present minor impacts to the integrity of the management arrangements however the achievement of regional goals would not be threatened.
Insignificant	The consequence would present minimal to no impact to the integrity of the management arrangements and there would be no threat to one or both regional goals.

2.1.2.1.2 Rating of inherent risk

Likelihood and consequence ratings were combined in a C x L matrix to generate a rating of inherent risk (see **Table 7**). For example, risk interactions that occur rarely and are insignificant were rated as 'low risk'; by contrast, risk interactions that are almost certain and serious were rated as a 'high risk'.

Table 7 Inherent risk matrix

	Consequence					
		Insignificant	Minor	Moderate	Major	Serious
Likelihood	Rare	Low	Low	Low	Medium	Medium
	Unlikely	Low	Low	Medium	Medium	Medium
	Moderate	Low	Medium	Medium	Medium	High
	Likely	Medium	Medium	Medium	High	High
	Almost Certain	Medium	Medium	High	High	High

2.1.2.1.3 Assessment of the adequacy of existing mitigation / management measures

For each risk interaction identified, the key mitigation or management measures currently in place to mitigate the risk, where identified, were given a qualitative rating of adequacy (Table 8) in terms of likelihood and consequence. In the event that no mitigation is available or would not have an observed effect on changing the inherent risk, N/A (non-applicable) was assigned to the mitigation score.

Table 8 Mitigation ratings

Mitigation	
Rating	**Description**
Very Strong	The mitigation or measure in place would minimise the likelihood of an impact occurring or the magnitude of that impact.
Strong	The mitigation or measure in place would significantly reduce the likelihood of an impact occurring or the magnitude of that impact.
Moderate	The mitigation or measure in place would reduce the likelihood of an impact occurring or the magnitude of that impact.
Weak	The mitigation or measure in place would see minimal to no reduction in the likelihood of an impact occurring or the magnitude of that impact.
N/A	The mitigation or measure in place would see no reduction in the likelihood of an impact occurring or the magnitude of that impact. Equally, there may be no mitigation available to have an effect on reducing the likelihood of an impact occurring or the magnitude of that impact.

2.1.2.1.4 Rating of residual risk

Inherent risk and adequacy of mitigation ratings were combined in a residual risk matrix to generate a residual risk rating for each risk interaction (Table 9). Residual risk scores were assigned using a RAG status with where high = 3, medium = 2 and low = 1. In the event that no mitigation is available or would not have an observed effect on changing the inherent risk, N/A (non-applicable) is assigned to the mitigation score and therefore the residual risk score is the same as the inherent risk score.

Table 9 Residual risk ratings

	Inherent risk			
Mitigation		Low	Medium	High
	Very Strong	Low	Low	Low
	Strong	Low	Low	Medium
	Moderate	Low	Medium	High
	Weak	Low	Medium	High
	N/A	Low	Medium	High

2.1.2.1.5 Overall risk

Residual risk scores for each descriptor and addition risk factor were summed together to give an overall risk score (Table 10).

2.1.2.1.6 Literature review

In order to build an evidence base upon which to conduct GES risk analysis, a systematic literature review was conducted based on established guidelines[6] and reported in line with the ROSES *pro forma* (Haddaway *et al.*, 2018). Literature searches were conducted in Google Scholar, allowing access to both peer-reviewed and grey literature. All searches were carried out on the 27th July 2021.

Searches used Boolean logic to combine terms relating to selected métiers and GES descriptors. A full list of search terms is given in Annex 3. Literature searches were restricted to the time period 2000 to 2021. The first 10 results from each search were extracted and saved using reference management software Zotero.

Search databases were combined, and duplicate references (n = 129) removed, leaving 283 unique references. Unique references were screened first by title,

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[6] https://environmentalevidence.org/roses/

removing 51 references not relevant to the scope of work. The remaining 232 candidate references were screened by abstract and/or executive summary, excluding a further 60 references not relevant to the scope of work. The criteria for inclusion were:

- The subject of the publication was on the impact of fishing métiers (gear type) on marine environment and species;
- The geographic scope was UK-based or relevant to UK fisheries in terms of vessels, target species and or gear types; and;
- The publication addressed risk interaction related to GES Descriptors and or additional risk factors.

The remaining 172 publications were deemed to be of direct relevance to the risk analysis and were examined in full to extract the relevant information and to highlight additional sources of information for inclusion. The literature selection process is depicted in Figure 2.

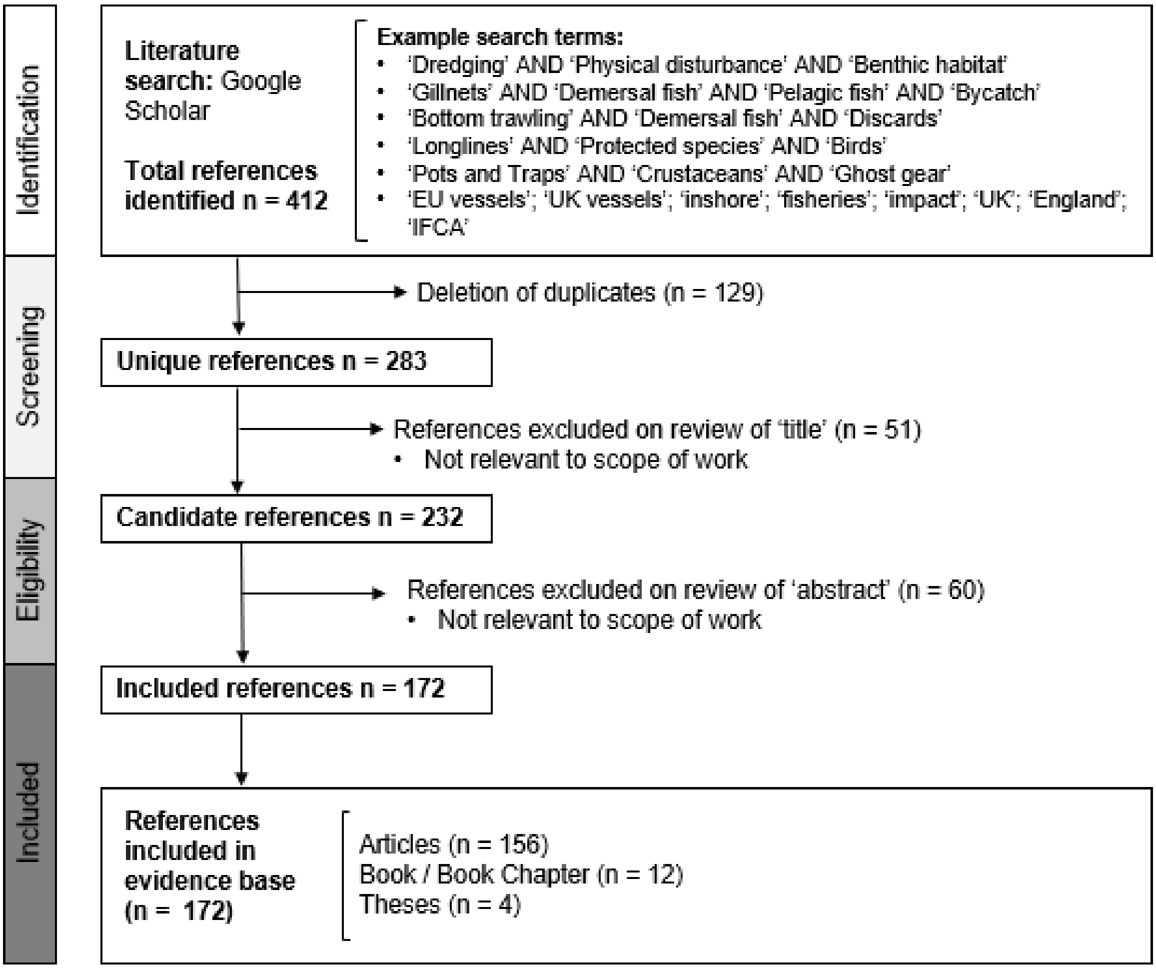

Figure 2 **Literature search process**

2.2 Results

The results for literature review and risk analysis carried out under Objective 1 have been given in the section below.

Overall scores for the risk analysis have been given for each fishing métier are displayed in Table 10. The evidence to support the scores given have been presented for each métier in sections 2.2.1-2.2.11.

Four high risk métiers were identified:

- Beam trawl (TBB);
- Bottom otter trawl (OTB);
- Multi-rig otter trawl (OTT); and
- Pair-bottom trawl (PTB).

Seven medium risk métiers were identified:

- Boat dredge (DRB);
- Gillnets (not elsewhere included, hereafter referred to as “nei”) (GN);
- Mid-water otter trawl (OTM);
- Mid-water pair trawl (PTM);
- Nephrops trawl (TBN);
- Set gillnets (GNS); and
- Trammel nets (GTR).

The remaining six métiers were all scored as low risk:

- Drift gillnets (GND);
- Hand and pole lines (LHP);
- Hooks and lines (LX);
- Longlines (LL);
- Pots and traps; and
- Set longlines (LLS).

All descriptors and additional risk factors assessed in the matrix were analysed and scored independently. Consideration was not given to the weighting of the impacts these risk factors may present to the environment. It would be reasonable to suggest that fishing impacts against Descriptors 1-6 are more detrimental to the marine environment than Descriptors 10 and 11. Additional research may be carried out to determine the correct weighting which may be applied to these descriptors and risk factors, to assess the impacts of fishing pressures across the fishery. This research hasn’t been carried out as part of this study.

Table 10 Overall risk matrix

	D1 - Biodiversity is maintained	D3 - The population of commercial fish species is	D4 - Elements of food webs ensure long-term	D6 - The sea floor integrity ensures functioning of	D10 - Marine litter does not cause harm	D11 - Introduction of energy (incl. underwater	AFR1 – Commercial fish bycatch	ARF2 – Protected species bycatch (ETP)	ARF3 – Non-compliance MLS / quota	ARF4 – Non-compliance area restrictions	ARF5 – Essential fish habitat	ARF6 – Displacement	Total
Beam trawl (TBB)	High	Medium	Medium	High	Medium	High	High	Medium	High	High	Medium	Medium	**High (30)**
Boat dredge (DRB)	High	High	Medium	High	Low	High	Medium	Low	Medium	High	Medium	Medium	**Medium (27)**
Bottom otter trawl (OTB)	High	High	Medium	Medium	Medium	High	High	Low	High	High	High	Medium	**High (30)**
Drift gillnets (GND)	Medium	Low	Low	Low	Medium	Low	Medium	Medium	Low	Low	Low	Medium	**Low (17)**
Gillnets (GN)	High	Medium	Low	Low	High	Low	High	High	Medium	Medium	Low	Medium	**Medium (24)**
Hand and pole lines (LHP)	Low	Low	Low	Low	Medium	Low	Low	Low	Low	Low	Low	Low	**Low (13)**
Hooks and lines (LX)	Low	Low	Low	Low	Medium	Low	Low	Low	Low	Low	Low	Low	**Low (13)**
Longlines (LL)	Low	Low	Low	Low	Medium	Low	Low	Low	Low	Low	Low	Low	**Low (13)**
Midwater otter trawl (OTM)	Medium	High	Medium	Low	Medium	Low	Low	Medium	Low	High	Low	Medium	**Medium (21)**
Mid-water pair trawl (PTM)	Medium	High	Medium	Low	Medium	Low	Low	Medium	Low	High	Low	Medium	**Medium (21)**
Multi-rig otter trawl (OTT)	High	High	Medium	Medium	Medium	High	High	Low	High	High	High	Medium	**High (30)**
Nephrops trawl (TBN)	Medium	Medium	Low	Medium	Medium	Medium	Medium	Low	Medium	Low	Medium	Medium	**Medium (20)**
Pair bottom trawl (PTB)	High	Medium	Medium	High	Medium	High	High	Medium	High	High	Medium	Medium	**High (30)**
Pots and traps (FPO)	Medium	Low	Medium	Low	Low	Low	Low	Low	Low	Low	Low	Low	**Low (14)**
Set gillnets (GNS)	High	Medium	Low	Low	High	Low	High	High	Medium	Medium	Low	Medium	**Medium (24)**
Set longlines (LLS)	Low	Low	Low	Low	Medium	Low	Low	Low	Low	Low	Low	Low	**Low (13)**
Trammel nets (GTR)	High	Low	Medium	Medium	High	Low	High	Medium	Low	Low	Low	Medium	**Medium (22)**

All descriptors and additional risk factors assessed in the matrix were analysed and scored independently, without considering the weighting of the impacts these risk factors may present to the environment. Some risk factors will have been scored higher than anticipated as a precautionary measure taken where information availability on that risk for that métier has been found to be poor.

N.B Overall risk score is calculated by combining the risk scores for each descriptor: high (red) = 3; medium (orange) = 2; low (green) = 1 to generate a total risk score. The minimum and maximum score achievable was divided in equal third scores to generate the final scoring: 12-19 = Low; 20-28 = Medium; 29-36 = High.

2.2.1 Boat dredge (DRB)

Boat dredges (DRB) (Table 11) are mobile demersal fishing gear consisting of rigid cage-like structure(s) with chain mail collecting bag(s) that are towed, or dragged, along the seabed to target various species of shellfish (Figure 3). In the UK, the main dredge fishery is for king scallops (*Pecten maximus*) and to a lesser extent queen scallop (*Aequipecten opercularis*), mussels (e.g., *Mytilus edulis*), oyster (e.g., *Ostrea edulis*), and razor clams (e.g., *Ensis ensis*). Each dredge is designed specifically for the fishery and target species. Target species are extracted from the seabed usually via a toothed bar located at the front of a triangular frame. Several dredges are usually towed from each side of the vessel using a heavy spreading bar. It is the length of this bar and power of the vessel that determines the number of dredges towed.

Table 11 Classification of boat dredges (DRB)

Métier	
Level 1	Fishing
Level 2	Dredges
Level 3	Dredges
Level 4	Boat dredges (DRB)

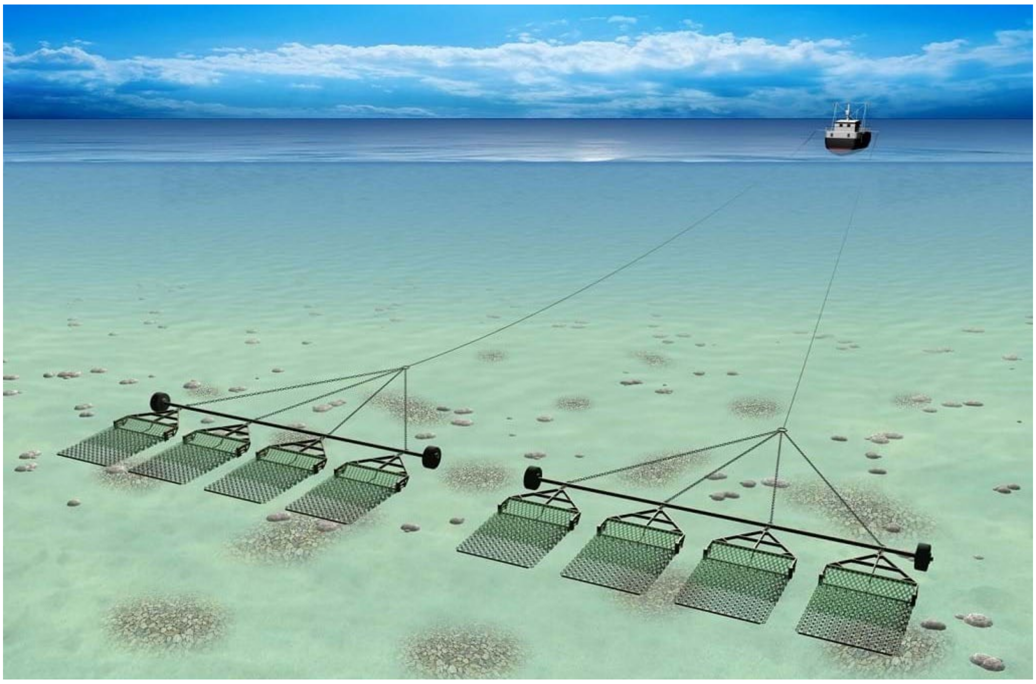

Figure 3 Boat Dredge (DRB) (©Seafish. Reproduced with permission: www.seafish.org[7])

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[7] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/drb-scallop-dredge/

2.2.1.1 Distribution of vessels

In total, there are 412 DRB vessels licensed to fish within UK waters (357Appendix 2), of which almost 50% are EU vessels, 102 French and 90 Irish flagged.

There are 193 DRB vessels registered to ports scattered throughout the UK, however, they tend to be quite irregular in their fishing patterns which are driven by the spatial distribution of good fishing grounds at the given time. UK registered boat dredgers are more commonly over 10m than under 10m in length. Devon and Severn (25), Kent and Essex (14) and Southern (25) IFCA regions are where the largest numbers of boat dredges are registered.

In comparison to other selected métiers, there are a large number of DRB vessels fishing in UK waters. It could be suggested that this is due to a combination of favourable stock levels, tight quotas on main alternative species (e.g., finfish) and the high market value of target species such as the king scallop (*Pecten maximus*) (Howarth and Stewart 2014).

2.2.1.2 Risk ratings

Numerous studies and reviews have examined and reported the effects of dredging activity on target species and the wider environment in the UK, with may focusing specifically on scallop populations (Hall-Spencer and Moore 2000; Beukers-Stewart *et al.*, 2009; Craven *et al.*, 2013; Howarth and Stewart 2014). The particular concern arising from many of these studies is that dredges are considered to be among the most damaging of all fishing gears to benthic communities and associated habitats.

2.2.1.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Moderate	High

The inshore region of English waters offers the greatest diversity of habitat, both topographically and biologically. Given the spatial overlap with dredgers targeting scallops, this presents major effects on marine biodiversity (Beukers-Stewart *et al.*, 2009). Dredging activity directly impacts biodiversity in two main ways (i) the removal of target and non-target species and (ii) physical damage and disturbance to the sea floor.

The removal of target species reduces the available harvestable biomass of scallop populations, which in turn can reduce reproductive capacity (Vause *et al.*, 2007; Kaiser *et al.*, 2007) negatively impacting scallop recruitment through truncating age structures towards younger ages and smaller sizes (Howarth and Stewart, 2014). For example, in the most recent assessment of king scallop stock status for selected waters around the English coast, 35% of the catch surveyed from the eastern English Channel was below minimum landing size (Lawler and Nawri, 2021), threatening the ability of stocks to breed at sustainable levels in the future (Beukers-Stewart *et al.* 2005; Roberts *et al.* 2005).

In order to mitigate the removal of undersized scallops, legal minimum landing sizes and gear mesh sizes have been employed in the management of scallop dredge fisheries in the UK. However, reported fishing mortality rates, varying from 2% to more than 20% (Beukers-Stewart *et al.*, 2009), meaning that few individuals reach the size of those in undisturbed populations (Beukers-Stewart *et al.,* 2005). High levels of mortality may also occur in non-target species that incur injury through contact with the scallop dredge but are not caught. Through the use of SCUBA surveys, Jenkins *et al.* (2001) reported that over 75% of non-target mobile species encountered by scallop dredges remained on the seafloor. Similar levels of injury and or mortality amongst these species were recorded in comparison to the bycatch landing on the deck.

Due to their penetrative nature, one of the most marked effects of scallop dredges on the seabed is physical disturbance, damage and removal of benthic substrate and the associated species of epibiota (Hall-Spencer and Moore, 2000; Kaiser *et al.,* 2002; Beukers-Stewart *et al.*, 2009). The homogenization of sediments and loss of these species through fishing disturbance can therefore cause a series of major knock-on effects that are reported to decrease benthic community abundance on average by 8%, with recovery times back to control conditions predicted to be at least three years for scallop dredging (Sciberras *et al.,* 2018). The removal of benthic organisms, such as hydroids, bryozoans, sponges, and maerl, can also have consequences on scallop recruitment due to the decline in essential habitat for settlement and nursery grounds (Howarth and Stewart, 2016).

Protecting benthic ecosystems can be achieved through three primary management measures: effort restrictions, spatial management, and gear modifications. For UK scallop fisheries, seasonal closures in the Irish Sea (from June to October) and in the eastern English Channel (from August to October)[8] is an effective effort control to protect scallops during their spawning season (Howarth and Stewart, 2016). Additionally, there is also evidence that it allows limited recovery time for fast growing benthic species, such as hydroids, which provides settlement substrate for newly arrived scallop spat and larvae of other species (Bradshaw *et al.,* 2003). Spatial management is ideally suited to promote scallop stocks as spatial closures can protect the entire life history of scallops due to their sedentary nature, as well as conserve local biodiversity and associated ecosystem services. Off the Isle of Man, a network of protected areas has been designated to revitalise the fishery for the king

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[8] ICES area VIId king scallop fishery closure

scallop, *P. maximus* (Isle of Man Government, 2014), as well as Lyme Bay, a marine protected area off Dorset which has statutory protection from scallop dredging. Modifying gear is less common in the UK scallop fishery, trials of a 'hydrodredge' showed initial promise but revealed reduced efficiency in catch rates, albeit decreased bycatch rates and damage to the seabed (Shephard *et al.,* 2009). It is therefore unlikely to be adopted by the industry. Recent developments of a 'N-Virodredge'[9], which runs on skids and uses spring tines instead of teeth to catch scallops, also has potential to reduce environmental damage and increase fuel and catch efficiency. A report by Catherall and Kaiser (2014) stated around 40 UK vessels currently use N-Virodreges, as well as a number of French fishermen.

2.2.1.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Weak	High

King scallop fisheries around English coasts represent the most valuable single marine species in the region, making up 20,872 tonnes of UK annual landings in 2019 (Guille *et al.*, 2021). The status of scallop stocks is directly impacted by international overexploitation, and injury or mortality to the target species.

Fisheries administrations manage dredging activity by setting licence limits, minimum landing sizes, restrictions on number of dredges, gear specifications, area, and effort controls, and in some cases, such as in the Devon and Severn IFCA's District, there are seasonal closures and time restrictions via the Mobile Fishing Permit Byelaw. Scallop fisheries are currently not subject to EU or national total allowable catches, and before 2017 stocks did not undergo routine monitoring or formal assessment.

Recent assessments identified six stock assessment units in English waters[10], of which one is overfished with estimated harvest rates significantly above the MSY reference value, three are data limited inhibited by low sampling rates and the remaining two are sustainably exploited from a population perspective with low proportions of the survey catch by weight below minimum landing size (Lawler and Nawri 2021).

The MMO and associated UK Fisheries Administrations have closed the king scallop fishery in UK waters from the 15 August until 4 October 2021 to all over-10m vessels. The closure also applies to all UK vessels, including those under 10, in EU waters of ICES Area VIId. Alongside this closure, the sea area south of parallel

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[9] http://n-virodredge.com/index.php

[10] Four in the English Channel, one in the Celtic and one in the North Sea

49°42’ N in ICES area VIId known as the Bay of Seine will be closed to scallop fishing by UK vessels from 15 August until 18 October 2021. These closures have been implemented following scientific advice and are designed to protect spawning and sustain stocks, that have been close to unsustainable levels. The efficacy of these specific measures is unknown.

2.2.1.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Moderate	Medium	Moderate	Medium

Although most studies examining the effects dredging have concentrated on benthic invertebrates and habitats, alterations to marine food webs through changes in the abundance and size distribution of demersal fish populations could also have important consequences for benthic ecosystems.

Exploitation and mortality of benthic fish through bycatch are likely to have important consequences on the functioning of marine ecosystems (Craven *et al.*, 2012). For example, discards and damaged organisms from dredging may provide an increase in food supply in the short term for scavenging and predatory species (e.g., dogfish, crabs and starfish). This aggregation of species may further present additional pressures on exploited species (Bradshaw *et al.*, 2001; Kaiser and Hiddink 2007; Beukers-Stewart *et al.*, 2009).

2.2.1.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Serious	Likely	High	Moderate	High

Along with direct biological effects, dredging may also change the physical nature of the seabed. These physical effects may indirectly flow back to cause further negative effects on benthic communities that alter ecosystem functioning (Beukers-Stewart *et al.*, 2009).

Inshore benthic areas subject to high levels of dredging activity are likely to undergo serious changes in structural complexity reducing the spatial extent of suitable habitat type for adult scallops. For example, dredging is reported to remove significant quantities of stones, gravel and or boulders from fishing grounds (Bradshaw *et al.*, 2002; Beukers-Stewart *et al.*, 2009), which leads to the creation of a degraded habitat with reduced three-dimensional structure, homogenised sediments, and seabed topography (Bradshaw *et al.* 2003; Beukers-Stewart *et al.*, 2009) occupied by smaller, fast growing, opportunistic and encrusting species.

Effort restrictions, spatial management and gear modifications are three management tools employed to protect sea floor integrity from scallop fisheries. Examples of these include seasonal closures, spatial restrictions within protected areas and newly developed dredges, such as the ‘N-Virodredge (see 2.2.1.2.1 Biodiversity is maintained for more information).

2.2.1.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Rare	Low	Moderate	Low

Although a wide variety of marine litter and debris may impact marine taxa (Bergmann *et al.* 2015; Barbosa *et al.* 2019), the impacts of ghost-fishing[11] via ALDFG are undoubtedly the most serious (Allsopp *et al.* 2009). There are a range of causes for fishing gear from marine capture fisheries to be abandoned, lost or discarded unintentionally (Gilman *et al.* 2016). It is widely reported that gear may be lost due to a physical interaction between active and passive gears (gear conflict), and or, when active gear is snagged on the seafloor e.g., trawlers or dredgers (Gillman *et al.* 2016; Richardson *et al.* 2018).

The full impact of ALDFG on marine taxa within the UK, is difficult to ascertain as the majority of studies focus on beached and or floating ALDFG within coastal areas, with much less emphasis on underwater surveys (Ten Brink *et al.* 2009; Mouat *et al.* 2010; Allen *et al.* 2012).

There has been substantial effort to summarise the degree to which different types of fisheries produce ALDFG. The types of ALDFG most often cited in recent literature are gillnets; trammel nets, pots and traps, bottom trawl nets, and longlines (Gilman *et al.* 2016; Barboza *et al.* 2019; Lively and Good 2019; Richardson *et al.* 2019), with limited references to dredges. Gillman *et al.* (2016) states that authorities make limited use of the possible measures available to tackle issues of ALDFG e.g., gear marking, gear tracking and incentivised responsible disposable. This can be said for the UK where few management measures have been rolled out on a national scale.

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[11] The term ‘ghost fishing’ refers to abandoned, lost, or discarded fishing gear in the marine environment that continues to ensnare and capture marine organisms without any economic benefit. Lost fishing gear, also known as ‘ghost gear,’ can keep fishing for many decades, causing severe environmental damage to the marine ecosystem.

2.2.1.2.6 Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	High	N/A	High

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al.*, 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by fishing gears.

In a study characterising the underwater noise levels in UK waters, recordings made in the southern North Sea suffered periodically from noise caused by colliding fishing gears deployed in proximity of the recording device (Marchant *et al.*, 2016). Although the noise did not propagate far from the location, it was prominent in the data showing sustained periods of heightened noise. Daly and White (2021) further highlight that seabed sourced sounds (i.e., from the interaction between bottom gear and the seabed) are reported to be of more potential harm to marine fauna, in particular resident and transient mammals, than noise created at the surface.

Given the lack of empirical evidence and considering the continuous interaction between dredging gear and the seabed it could be suggested that noise levels emitted from dredges are of potential harm to proximal marine fauna with a need for further research, potential regulation, and mitigation (Daly and White 2021). No known measures have been identified that are currently in place to mitigate the introduction of underwater noise from fishing gears.

2.2.1.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Almost certain	Medium	Moderate	Medium

Commercial fish bycatch and discards are important considerations in the sustainable management of shellfish fisheries. In general, dredges have been termed relatively “clean” when compared to other types of mobile fishing gear, such as beam trawls, with limited capacity to inflict large scale mortalities on bycatch species of commercial value (Kaiser 2007; Beukers-Stewart *et al.*, 2009, Szostek *et al.*, 2017). Hinz *et al.*, 2012 reports that for every scallop captured by a boat dredge, four individuals of bycatch were caught. Further, a recent study quantifying bycatch species that occur in the English Channel king scallop fishery where 19% of the overall wet weight of dredge catches were comprised of bycatch. Across studies (Craven *et al.*, 2012; Szostek *et al.*, 2017) it is reported that the selectivity of dredgers means that bycatch tends to be dominated by larger benthic species (e.g., European place (*Pleuronectes platessa*), Common cuttlefish (*Sepia officinalis*), Monkfish (Lophius piscatorius) and European spider crab (*Maja squinado*)) with abundance varying amongst catches both spatially and temporally.

On some vessels, king scallops are the only species retained, regardless of the commercial value of any bycatch species caught (Beukers-Stewart *et al.*, 2009). For example, Szistek *et al.*, 2017 reports the mean proportion of finfish and shellfish of commercial value (excluding king scallops) discarded ranged from 18-100%, the majority damaged, dying, or dead (Jenkins *et al.*, 2001; Howarth and Stewart 2014).

Management measures employed to prevent and or mitigate commercial fish bycatch include certain gear specifications e.g., interconnecting ring diameter (≥ 72 mm), top net mesh size (≥ 100 mm), tooth number (< 10) and tooth spacing (≥ 75 mm) (Howarth and Stewart 2014). However, it can be concluded from the current management of UK scallop dredge fisheries generally is composed of measures that encourage the promotion of the stock (e.g., spatial closures, effort restrictions), as opposed than considering the wider ecosystem effects.

2.2.1.2.8 Additional risk factor 2. Protected (ETP) species bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	Strong	Low

Protected species that forage on or near the sea floor e.g., pilot whales and common dolphins are at risk of being captured or injured in dredging gear in inshore areas. In addition, can become entangled in tow lines. However, injury and mortality for dredge fisheries is low, potentially due to the low tow speeds which allows species to avoid entanglement. For example, as part of the Cetacean Bycatch Observation Scheme (ME6044) conducted by Cefas, non-dedicated sampling was conducted under the English, Welsh and Northern Irish discard programme in order to provide estimates of the accidental catches by dredgers targeting scallops. Of the 53 hauls conducted in 2018, no ETP species (cetaceans or seal bycatch) were reported.

2.2.1.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Moderate	Medium	Moderate	Medium

Minimum landing size of scallops in the UK ranges from 40mm – 110mm, depending on species and ICES area[12]. Non-compliance with these regulations can have major direct effects on the stock status through reduced reproductive capacity and truncating age structures (Beukers-Stewart *et al.* 2005; Beukers-Stewart *et al.*, 2009; Howarth and Stewart 2014), threatening the sustainability of spawning in the future.

Previous incidents of non-compliance include the prosecution of the owner and master of 'Star of Annan OB 50' and the owner of 'Qvarl BM 29' for landing undersized scallops within the NEIFCA region between March 2019 and June 2019. Further, the prosecution of the master and owner of scallop dredger Honeybourne III (PD905), when upon inspection, 8.09% of the entire catch was below minimum landing size, equating to considerable 2.65 metric tonnes of undersized scallops[13].

2.2.1.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Moderate	High

Examples of gear and area restrictions relevant to dredgers are given in Table 12. Non-compliance with restrictions such as these has major negative impacts on the species and habitats their objective it is to protect. For example, when larger vessels fish illegally, they reduce the fishing opportunities for smaller, locally based inshore boats.

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[12] https://www.gov.uk/government/publications/minimum-conservation-reference-sizes-mcrs/minimum-conservation-reference-sizes-mcrs-in-uk-waters

[13] https://www.gov.uk/government/news/master-and-owner-fined-21746-for-fisheries-offences

Table 12 Examples of IFCA dredging gear restrictions[14]

IFCA Region	Byelaw	Description	Area (km^2)
North-Eastern	XXII Method and Area of Fishing (Dredged) Byelaw	Permitted access to specific scallop dredging areas within the districts. Remaining two-thirds of the directs is closed to scallop dredging.	2,196 km^2
Sussex	Fishing Instruments	Prohibits the use of scallop dredges in the inner 3nm limit of the district.	959 km^2
North-western	Restrictions on the use of a dredge	Permit byelaw prohibiting the use of a dredge without a permit.	3,354 km^2

Within English waters there have been three reported incidents of enforceable infringements against area and gear restrictions between 2018 - 2019, suggesting offences by dredgers are likely to occur. Detected on the wrong side of Guernsey's territorial limit, a Scottish vessel 'Georgia Dawn' was fined £1000 in June 2019 for scallop dredging illegally[15]. Further, in addition to the discussed non-compliance against minimum landing size of the 'Star of Annan OB 50' and Qvarl BM 29' were prosecuted for further breaches of local scallop dredging regulations and national fisheries legislation including operating in a closed season; using scallop dredges without the authority of a permit; exceeding the permitted number of dredges and failing to operate a fully functioning vessel identification system[16]. Finally, Cornwall Inshore Fisheries and Conservation Authority prosecuted the 'Pamela Jill' for using a vessel larger in length that the law allows for during two fishing trips in May and June 2018[17]. Dredging vessels targeting scallops in the Cornwall IFCA district are restricted to a maximum overall length of 16.46m, but the Pamela Jill was significantly larger than that, being 26.15m.

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[14] Management of Inshore Marine Protected Areas by the IFCAs 2011 - 2018

[15] https://theferret.scot/scallop-dredging-guernsey-fine/

[16] http://www.association-ifca.org.uk/news/record-fines-imposed-for-inshore-scallop-dredging-offences-off-the-yorkshire-coast

[17] https://www.cornwalllive.com/news/cornwall-news/brixham-fishing-boat-owners-fined-2469871

2.2.1.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Serious	Likely	High	Moderate	Medium

Seafloor habitats that exhibit three-dimensional structure (e.g., dead shells, gravel, and upright taxa such as maerl, hydroids and bryozoans) provide essential habitat for the settlement of scallop spat and a range of other organisms and epi-fauna (Howarth *et al.*, 2011; Howarth and Stewart 2014). Such locations are often referred to as nursery areas as they tend to be areas of high productivity that support the growth and survival of species.

The removal and or damage to such areas from towed fishing gears, such as dredgers, has been reported to negatively impact scallop recruitment in comparison to areas where towed gear is excluded (Howarth *et al.*, 2011). For example, in Lamlash Bay, Isle of Arran, United Kingdom, where bottom towed gear is excluded, Howarth *et al.*, (2011) reported a statistically significant increased abundance of juvenile scallops within the reserve than that outside. Further, when comparing age structure, the mean age of *P. maxiumus* was 1.3 times higher and individuals were 1.2 times larger in size in the reserve than outside.

There are 72 inshore marine protected areas subject to bottom towed fishing gear closures. Approximately 4,325 km^2 of which is permanently closed to trawling and or all methods of shellfish dredging, the greatest proportion of which is located within the Devon and Severn IFCA region. The Devon and Severn IFCA region is also where the largest number of DRB vessels (36) are registered. Within these area closures, benthic habitats, and species of conservation interest, such as biogenic reefs, hydroids, and bryozoans, are protected, providing essential fish habitat for scallops and a range of other commercially important fish and shellfish species. Additionally, effort restrictions have shown to allow limited recovery time to benthic species, such as fast-growing hydroids, during fishery closures. This provides essential fish habitat for newly arrived scallop spat and larvae of other benthic invertebrate species (Bradshaw *et al.*, 2003).

2.2.1.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Unlikely	Medium	Moderate	Medium

The majority of wind farms in the UK are located in the offshore region. A major issue posed to fishers within the inshore region, however, is the occurrence of supporting sub-sea cables. The target burial depth for cables in inshore regions is 0.6 – 1.0m (OSPAR, 2012). Natural disturbances causing shifts in sediments and tidal scour pose a risk that may leave cables exposed and vulnerable to interaction with bottom towed fishing gear. Further, the use of cable armour or debris from seabed construction can cause obstruction to fishing gears. In particular, dredges can interact with subsea cables by landing on top, dragging over or snagging them, causing danger to the fishers themselves (Catherall *et al.*, 2014).

In attempt to avoid these risks, the presence of sub-sea cables has the potential to cause permanent or temporary displacement of fishers. As calculated using QGIS, currently, cable boundary areas occupy approximately 4% of the English inshore region. Eastern IFCA has the highest percentage area of cable boundaries at 10.8%. Other IFCA regions that have offshore wind cables present are North-Eastern (3.65%), North-Western (2.38%), Kent and Essex (1.64%), Northumberland (1.49%) and Sussex (0.06%). Devon and Severn, Cornwall, Isles of Scilly and Southern IFCA regions do not have any offshore wind farm cables present.

In a one-year study on the impacts that Round 2 windfarms may have on fishing activities of fishers in the UK, it was reported that over 700 small inshore vessels made up three-quarters of the vessels fishing in the three identified wind farm strategic areas; Greater Wash; North-West and Thames (Mackinson *et al.*, 2006). Shellfish dredgers were present in all three areas. Interviews with fishers revealed that fishing activity issues were the most dominant theme raised with concerns regarding displacement, reduced fishing areas and greater competition on remaining grounds amongst those most heavily weighted.

Mitigation measures applied to wind farm and construction and operation include the full involvement and engagement (Hooper *et al.*, 2015; Reilly *et al.*, 2015; Haggett *et al.*, 2020) of fishing industry representatives, for example through the use of Fishing Liaisons (Hagget *et al.*, 2020). However, there are mixed reports on their success, with poor relationships and inadequate communication between fishers and wind farm developers (Gray *et al.*, 2016).

2.2.2 Pots and traps (FPO)

Pots and traps (FPO) (Table 13) are static demersal fishing gear, usually in the form of cages or baskets, which are baited and set on the seabed to catch a wide variety of crustaceans, finfish and molluscs (Figure 4 Pots and traps (FPO) ©Seafish. Reproduced with permission: www.seafish.org Source: Seafish).

Across the UK, the main target species include lobsters (*Homarus gammarus*), crabs (e.g., the brown or edible crab, *Cancer pagurus*), Norway lobster (*Nephrops norvegicus*), cuttlefish (*Sepia officinalis*), whelk (*Buccinum undatum*), prawns (*Paleamon serratus*), several wrasse species (e.g., ballan wrasse, *Labrus bergylta*) and various other species to a lesser extent (Coleman *et al.*, 2013). Depending on the species and local fishing practices, the shape, size, and construction materials of the traps tend to differ, however the basic design of a funnel style entrance which encourages entry, but limits escape is found in all structures (Slack-Smith, 2001).

Pots are baited and can be deployed individually or set in strings of varying numbers, known as a 'fleet', with a marker buoy at each end to flag the location of the gear (Stephenson *et al.*, 2016). Pots are usually weighted to maintain their static position and prevent dragging on the seabed. After a set period of time, usually 24 hours, the traps are harvested using a mechanical creel hauler on one side of the vessel, or hauled by hand, and the catch is sorted according to species and size. The traps will then be re-baited and stowed in the correct order until the whole fleet is ready to be shot again.

Table 13 Classification of pots and traps (FPO)

Métier	
Level 1	Fishing
Level 2	Traps
Level 3	Traps
Level 4	Pots and traps (FPO)

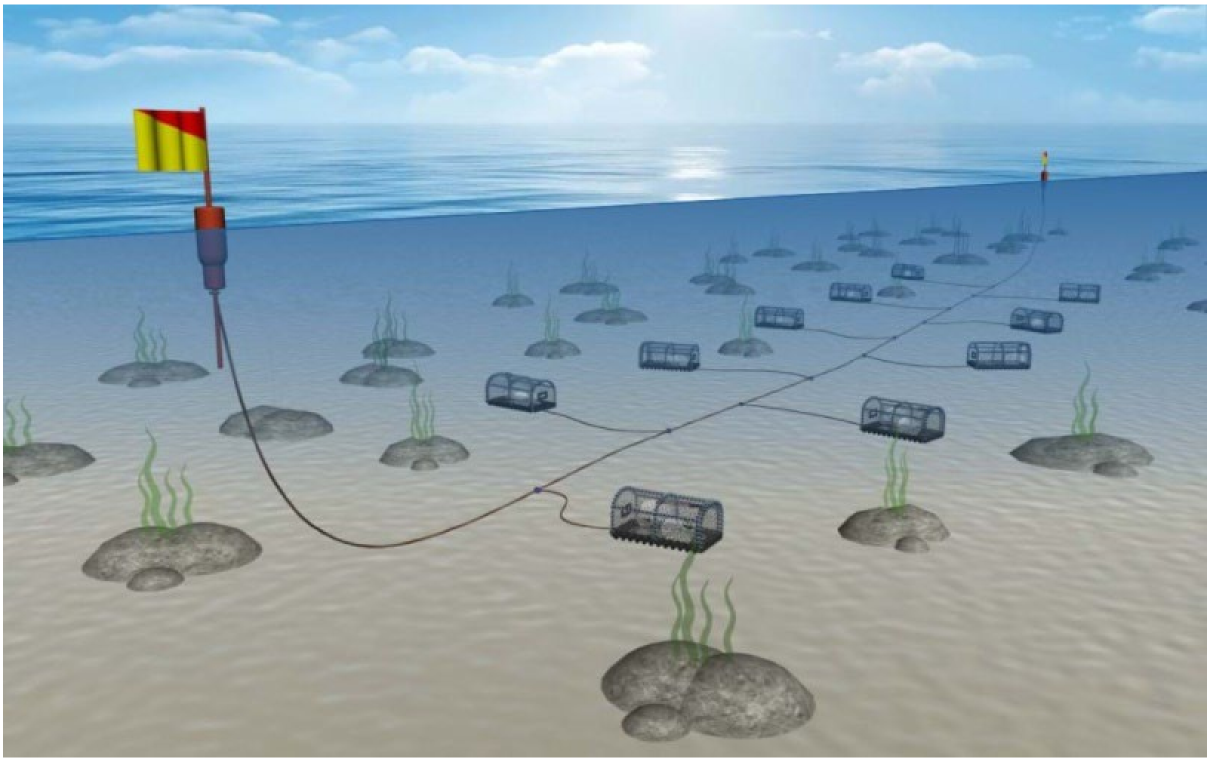

Figure 4 Pots and traps (FPO) (©Seafish. Reproduced with permission: www.seafish.org[18])

2.2.2.1 Distribution of vessels

In total, there are 2692 licensed FPO vessels operating within UK waters (Appendix 2), of which the significant majority (96%) are UK vessels and only 4% are EU vessels, 72 French, 52 Irish, two Portuguese, two Dutch and one German flagged.

Throughout the UK, 2577 FPO vessels are registered at different ports, with the highest numbers registered in Scotland (909), and Wales (188). Cornwall (155), North-Eastern (132), Devon and Severn (118) IFCA regions and Northern Ireland (144). UK under 10m vessels make up the majority of the fleet (89%) as commercial potting mainly operates in inshore waters and therefore the spatial distribution of the fishing activity of these vessels is local to their registered port.

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[18] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/pots-and-traps-general/

2.2.2.2 **Risk ratings**

In the UK, many high value commercial species targeted by potters are non-quota species and spatial management is generally less restrictive compared to bottom towed fishing gear. As such, fishing effort has increased over the years and more vessels are classifying pots and traps as their main fishing method (Rees *et al.*, 2019). Yet while there have been many studies on the physical impact of mobile gears on benthic habitats, very little research has focused on the ecosystem effects of pots and traps (Eno *et al.*, 2001, Coleman *et al.*, 2013., Stephenson *et al.*, 2016 and Rees *et al.*, 2019, 2021).

Traditionally viewed as a benign and low-impact fishery, recent research has demonstrated there is a “threshold” for commercial potting effort and if high potting densities occur, this can negatively affect reef building epibiota and commercially targeted species (Rees *et al.*, 2019 and 2021 and Gall *et al.*, 2020).

2.2.2.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	Medium	Moderate	Medium

The biodiversity impacts of pots and traps are considered to be relatively low due to the highly selective removal of target species, immediate release of non-target species and localised fishing disturbance to the sea floor.

Within UK waters, the main commercial species for potting are the brown or edible crab (*Cancer pagurus*) and European lobster (*Homarus gammarus*). The sustained removal from the fishery could be having a direct impact on their local abundance and a recent study has shown the average weight of brown crabs can decline by 9% over three years of high fishing pressure (Rees *et al.*, 2019). Over time, the reduced abundance and size of these species may affect their functional role as top predators and lead to indirect destabilising effects on the ecosystem (Eno *et al.*, 2001, Wootton *et al.*, 2015).

Potential bycatch in potting gear is minimal and any non-target and undersized target species are quickly returned to sea after the pots are hauled (Roberts *et al.*, 2010). To mitigate this, the selectivity of the gear is increased through the use of appropriate mesh sizes and escape gaps for juvenile species. Depending on the target fishery, specific gear design and fishing grounds will be used to increase the efficiency of fishing effort.

Direct impact on the sea floor is confined to the local area of contact with the seabed unless strong currents shift the position of the pots. However, communities of reef building taxa are vulnerable to fishing disturbance and these benthic habitats typically overlap with prime fishing grounds for lobster and crabs. These habitats are characterised by slow-growing and relatively stable communities which are slow to recover from physical damage, potentially reducing the species richness under high fishing pressure (Stephenson *et al.*, 2016).

While potting may have a direct impact on sessile benthic fauna, there is little evidence to show any impacts on associated mobile species and communities (Rees *et al.*, 2019). A study conducted by Rees *et al.*, (2021) found no discernible trend in sedentary reef associated species (common starfish, *Asterias rubens*, or grouped large anemones), but did observe a declining, but not significant, abundance in parchment worm (*Chaetopterus variopedatus*). Similarly, none of the mobile reef associated indicator species (poor cod, *Trisopterus minutus*; ballan wrasse, *Labrus bergyita*; and velvet swimming crab, *Necora puber*) showed any significant difference between the different potting intensities (Rees *et al.*, 2021). This is supported by similar observations made by Gall et al. (2020) who noted that mobile taxa were moved out of the way of the pot due to the pressure wave caused as it approached the seabed. This suggested mobile benthic species were less susceptible to damage than sessile species (Gall et al., 2020).

2.2.2.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	Medium	Strong	Low

In 2019, the total landings of crab by UK and foreign vessels were the second highest for shellfish species at 30,070 tonnes, with UK vessels making up 30,028 tonnes of the total (MMO, 2021). For lobsters, 3,328 tonnes were landed in the UK, of which 3,324 tonnes were UK flagged (MMO,2021).

Both lobsters and crabs are non-quota species and therefore there is no catch limit in place. The stock status of these species can be directly impacted by localised overfishing due to increased potting intensity as the number of pots and traps are not generally regulated. In England and Wales, crab and lobster stock assessments have been undertaken by Cefas since 2012 (Cefas, 2020a and Cefas, 2020b). The latest stock assessments are described below:

1. **Edible crab** (*Cancer pagurus*): The stock status of four out of five regional areas (Crab Fishery Units, CFU) are reported in the latest Cefas report (2019), with the exception of the Eastern English Channel in which the stock is currently unknown, yet landings appear stable for the years 2010-2018 (Cefas, 2020a). In four CFUs, the status of the stock has not changed since 2017. Estimates of spawning stock biomass are close to the level required to produce maximum sustainable yield for females and males in the Central and Southern North Sea, yet this is only the case for females in the Western English Channel and Celtic Sea due to insufficient data on males. Furthermore, exploitation rates were moderate in the Central North Sea, Western English Channel and Celtic Sea, but high in the Southern North Sea.

2. **European lobster** (*Homarus gammarus*): The Cefas stock status report (2019) is divided into six Lobster Fishery Units (LFU), with the exclusion of the Northwest LFU due to insufficient data. The main findings show the exploitation rate is high in three LFUs where the estimated biomass status is low, with particularly high fishing pressure on animals around the minimum landing size (MLS) in Yorkshire and East Anglia. In the Southeast South Coast and Southwest area, the stock status is moderate and exploitation levels are below the maximum reference point limit for both sexes. In three LFUs, the stock status has not changed since 2017 with one LFU exhibiting improvements in status (Southeast South Coast), yet low sampling levels in the East Anglia LFU make the uncertainty on stock status high.

The potting fishery is mainly conducted within six nautical miles of the shore and is therefore under the jurisdiction of the local IFCAs and subject to regional byelaws. In order to keep fishing at sustainable harvest levels, various management measures are in place, including the setting of minimum landing sizes, shellfish permits, maximum pot limits (800 in Northumberland; 300 for vessels <3m, 600 for vessels <6m vessels in Sussex), escape gaps, maximum vessel length and an Inshore Potting Agreement Area in the Devon and Severn IFCA[19].

2.2.2.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	Medium	Moderate	Medium

Within temperate marine ecosystems, the removal of top predators, such as lobsters and large edible crabs, may result in alterations to food web interactions and could impact the structure of benthic communities (Stephenson *et al.*, 2016). Over a sustained period of time, local depletion of the larger individuals could negatively impact ecosystem function and stability if there are no similar species in the same 'functional group' to replace the apex predator niche and exert top-down control (Wootton *et al.*, 2015).

Increased minimum landing size can help maintain larger individuals in the ecosystem before they enter the fishery. This has been introduced for brown crab by Devon and Severn and Cornwall IFCA which stipulated the MLS for females is 150mm and 160mm for males, which is higher than the EU and UK MLS of 140mm for ICES divisions VIIf (Cefas, 2020a). Additionally, the Devon and Severn, Cornwall, and Isles of Scilly IFCAs also enforce a higher MLS for lobster (90mm) compared to the EU MLS of 87mm (Cefas, 2020b).

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[19] https://www.devonandsevernifca.gov.uk/Enforcement-Legislation/South-Devon-IPA-Trawling-Crabbing-Chart-2021

Additionally, sessile epifauna play an important role in creating biogenic reefs which provides nursey grounds and settlement opportunities for larvae of commercially important, and other, species, thus supporting commercial pot fisheries. These complex structures are highly vulnerable to fishing disturbance and the physical removal or damage could have ecological consequences for the survival and predator-prey interactions of juvenile species, reducing recruitment into the fishery (Pirtle *et al.*, 2012).

2.2.2.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	Medium	Strong	Low

Static gear is considered less damaging on the seafloor due to the stationary nature of the gear and smaller area of contact on the seabed (Eno *et al.*, 2001). However, due to the increasing extent and ubiquitous distribution of potting in inshore waters, the cumulative impact of pots and traps on the benthic environment may be somewhat underestimated, raising concerns for features and species of conservation interest.

During the fishing process, there are three stages where pots and traps are likely to cause physical damage to the seabed (Coleman *et al.*, 2013):

1) During deployment, when pots land on the seafloor, epibenthic organisms and communities may be crushed, damaged, or removed in the process (Eno *et al.*, 2001).
2) During soak time (when pots are left on the seabed), rough weather or strong tides may cause pots to ‘bounce’ along the seabed, especially if the buoy lines are relatively short, resulting in the physical abrasion of a greater surface area (Clark *et al.*, 2007).
3) During retrieval, pots may drag laterally along the surface as they are being lifted which may cause snagging of lines, weights or pots on the benthos and require greater force to free the gear (Eno *et al.*, 2001). However, this would also damage the gear and therefore fishers are more likely to lift the gear vertically to minimise any wear and tear (Coleman *et al.*, 2013).

In temperate marine environments, the conservation species most at risk to the physical abrasion of commercial potting are sessile, reef building taxa such as the pink sea fan (*Eunicella verrucose*), ross coral (*Pentapora foliacea*), dead man’s fingers (*Alcyonium digitatum*) and Neptune’s heart sea squirt (*Phallusia mammillata*) (Rees *et al.*, 2019). These erect, and sometimes branching, benthic fauna are slow-growing and typically abundant in rocky reef habitats, the same habitat targeted for crab and lobster potting (Coleman *et al.*, 2013). Observed declines in the abundance of *P. foliacea* and *P. mammillata* under medium and high potting intensity within the Lyme Bay and Torbay SAC was recently reported by Rees *et al.*, (2019) and later supported by Rees *et al.*, (2021). However, other studies have shown some epifauna, such as *E. verrucose*, to flex under the weight of creel pots and spring back when the pots are hauled (Eno *et al.*, 2001). This shows some species are relatively resistant to potting activities.

Current mitigation measures in place to reduce fishing disturbance on sensitive benthic habitats include IFCA Fishing byelaws which prohibit larger vessels within their district and therefore restricts the number of pots worked on inshore reefs, reducing the potting intensity. Additionally, many marine protected areas (MPAs) are partially protected and allow low-impact fishing, such as potting, to operate within the MPA boundary. The locations and spatial extent of protected features are clearly mapped out and local fisher knowledge of the seabed will also help mitigate any damage to sensitive habitats and species.

2.2.2.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Unlikely	Medium	Strong	Low

Lost or abandoned fishing gear can continue to fish without human control in a phenomenon termed “ghost fishing” (Matsuoka *et al.*, 2005). Unaccounted mortality of target and non-target species is a huge concern as ghost gear has the potential to fish for many years, impacting marine life through entrapment and entanglement (Garside, 2005).

Field studies in Wales quantified the number and mortality of animals caught in a fleet of crustacean pots (12 pots) and calculated an annual catch of 7.08 spider and 6.06 brown crabs per pot and minimum mortality of 6.06 brown crabs and 0.44 lobsters per pot (Bullimore *et al.*, 2001). Other species caught included velvet swimming crab, lobster, ballan wrasse, dogfish, and triggerfish.

Pots and traps can be lost due to several reasons, bad weather, pots getting snagged or lodged on the seabed, submerged buoys making pots more susceptible to drift or inadvertently towed away by mobile gear (Garside, 2005). The rate of lost fishing pots across the UK is unknown, yet off the coast of Northumberland it occurs at <1% per month (Garside, 2005). Under the authority of the Northumberland IFCA, all fishers must tag any pots, creels, traps, and cages as part of a shellfish permit scheme and each month report any lost gear, indicating the tag numbers and pay the replacement cost of each tag[20].

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[20] NIFCA Byelaw 13. Permit to Fish for and Sell Lobsters, Crabs, Velvet Crabs, Whelks and Prawns

While not a legal requirement, incorporating the use of a biodegradable escape panels or trap hooks is recommended as a novel solution to release any trapped catch after a certain length of time (Bullimore *et al.*, 2001). A pilot trial in Pembrokeshire demonstrated pot hooks with Ghost Buster hog rings (made of annealed steel) lasted for between 11-17 months and were considered a success by the local fishing industry (Burton, 2017). The widespread use of similar devices would improve the sustainability of fishing and reduce mortality of trapped species.

2.2.2.2.6 Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al.*, 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by fishing gears.

Although pots and traps come into contact with the seafloor during setting and retrieval, the nature of these interactions and resultant noise are likely to be brief and very discrete and therefore pose a low risk in terms of their effect on the ecosystem. No known mitigation is reported for the reduction of underwater noise by fishing gears.

2.2.2.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	Strong	Low

Pots and traps catches are highly specific, with little by-catch of non-target organisms (Stevens 2021). In a study investigating the fish and invertebrate by-catch in the crab pot fishing in the Irish Sea, it was reported that from 2,489 pots 43 bycaught species were encountered, with by-catch increasing with distance inshore potentially driven by habitat complexity (Öndes *et al.*, 2017). Not surprisingly Crustacea, specifically the velvet crab (*N. puber*) was the most abundant by-caught species with a mean bycatch per unit effort (BPUE) of 17.56 +/- 2.82 indiv. 100 pots$^{-1,}$ followed by small spotted cat shark (*Scyliorhinus canicula*) (4.65 +/- 1.41 indiv. 100 pots^{-1}) and squat lobster (*Galathea spp.*) (4.58 +/- 1.13 indiv. 100 pots^{-1}). Other invertebrate species by-caught included spiny starfish (*Marthasterias glacialis*), European edible sea urchin (*Echinus esculentus*) and common starfish (*Asterias rubens*). With the exception of the Spotted cat shark, by-caught fish species (e.g., cod, haddock, pollack, hake and whiting) were in very low abundance, with all specimens alive at point of removal (Öndes *et al.*, 2017; Gravestock *et al.*, 2017). However, these species, excluding the Spotted cat shark, are quota species and would need to be considered against the Landing Obligation.

Mitigation measures that reduce by-catch, such as escape gaps or panels, can be effective as they allow undersized species to exit the pots. In an experimental study conducted by NIFCA investigating the efficacy of escape gaps in the crustacea fishery on North-East coastline, the use of escape gaps resulted in a decrease of caught undersized lobsters from 76.2% to 36.4% (Wallace and Rae 2017). Similarly, 73.6% of brown crabs caught by pots with escape gaps were of legal size whereas only 46% were of legal size without escape panels. In some IFCA districts, this measure is already in place, such as the Devon and Severn IFCA whereby between 1 April and 31 December, all pots constructed from netting must be fitted with an escape gap or, where a chamber is present, the chamber is fitted with an escape gap. As stated in the Potting Permit Conditions[21], for both commercial and recreational permit holders, escape gaps must be located at the bottom of the exterior wall with the dimensions of 84 mm wide by 46 mm high by 100 mm long in order to allow undersize shellfish a significantly better chance of leaving the pot.

2.2.2.2.8 Additional risk factor 2. Protected (ETP) species bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	Moderate	Low

Lines connecting traps to one another, or to the surface buoy have the potential to tangle or capture marine mammals. The main species of concern in the UK are minke whale, humpback whale and basking shark (Leaper 2021). One of the only estimates of fatal entanglement in the UK are amongst minke whales off the west coast of Scotland (MacLennan *et al.* 2020; Leaper 2021). In Swedish waters, Königson *et al.*, (2015) reports 13 grey seals (*Halichoerus grypus*) and 13 harbour seals (*Phoca vitulina*) entangled in cod pots, in depredation attempts. There are no estimates or evidence of these types of interactions in English inshore waters.

Unlike other fishing métiers, entanglements in traps and pots involve interactions with parts of the gear not associated with the capture of target species, which often leave greater scope for technical modifications to reduce entanglement risk without affecting catch efficiency. These include modifications to the way the gear is set (e.g., minimising the amount of rope in the water), weighted ground line, and rope less technologies.

2.2.2.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Rare	Low	Moderate	Low

Edible crabs and lobsters are non-quota species and therefore there is no restriction on the quantity of species landed under a full shellfish permit, as issued by the local IFCA. Monthly catch reporting is a legal requirement of the permit, but only applies to vessels over 10m in length, of which the majority of the potting fleet is not.

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[21] https://www.devonandsevernifca.gov.uk/Enforcement-Legislation/Current-Permit-Byelaws-Permit-Conditions

Species targeted by pots and traps are predominantly managed through minimum landing sizes with the intention of allowing individuals to reach sexual maturity and avoid being removed when functionally immature. For example, the minimum landing size for lobster (*Homarus gammarus*) and edible crab (*Cancer pagarus*) is 87mm and 115mm – 160mm (varying spatially) carapace length, respectively. Recent reports of non-compliance against the minimum landing size of lobster have occurred in the North-Eastern IFCA with one vessel retaining five undersized lobsters out of a total of eight while another had onboard nine juvenile lobsters and ten lobsters above that allowed by a Limited Shellfish Permit[22]. Both vessel owners were prosecuted and charged for landing undersized lobsters and breaching the Limited Shellfish permit of only two lobsters allowed to be landed per day. Additionally, in Northumberland IFCA, a vessel owner pleaded guilty to landing 60 undersized lobsters and was fined £2,912 for breaching the regulation prohibiting the landing of lobsters below the legal size of 87mm[23].

In the Devon and Severn IFCA district, six fishermen were prosecuted in 2017 for catching and retaining undersized shellfish, including edible crab, lobsters and spider crabs, and berried lobsters. All fishermen pleaded guilty and were charged a total cost of £24,057[24].

Enforcement patrols are carried out by IFCA officers to monitor onboard vessel catches and control non-compliance with permit allowances.

2.2.2.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Rare	Low	Moderate	Low

In England, there are three no-take zones (NTZ) where all forms of fishing, including pots and traps, are not permitted, covering a total area of 17.1km^2. This includes the Lundy NTZ where compliance is monitored by residential wardens and enforced by the Devon and Severn IFCA; Medway Nursery Area NTZ within the Kent and Essex IFCA; and Flamborough Head NTZ which is within the North-Eastern IFCA district. Sea patrols are governed by routine checks and received intelligence to monitor all activities and ensure compliance with area restrictions.

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[22] http://www.ne-ifca.gov.uk/news/proscutions-taken-by-north-eastern-inshore-fisheries-and-conservation-authority/

[23] https://www.nifca.gov.uk/wp-content/uploads/2016/01/Paul-Todd-for-website.pdf

[24] https://secure.toolkitfiles.co.uk/clients/15340/sitedata/4G/Press_release/Prosecutions-Press-Rel-Nov-2017.pdf

There are no reports of fishing offences or legal prosecutions for the use of pots and traps in restricted areas. This is assumed to result from the limited spatial extent of area closures to pots and traps which cause less damage than bottom towed gear.

2.2.2.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Moderate	Low

Rocky reef habitats comprised of long-lived sessile epifauna, such as soft-corals (e.g., dead men's fingers, *Alcyonium digitatum)* and erect sponges (*Axinella dissimilis* and *Raspalia ramose*), provide essential habitat to many commercial crustacea targeted by pots and traps (Hoskins *et al.*, 2009). These benthic features are typically protected under UK conservation measures. However, as the majority of UK MPAs still allow static gears to operate, the chance to assess the environmental impact of pots and traps on essential fish habitat is limited.

Highly protected marine areas such as NTZs therefore provide a unique opportunity to monitor the recovery of commercial and protected species and habitats from the effects of potting. For example, the designation of the Lundy NTZ in 2003 has had a rapid and significantly positive effect on lobster populations, increasing the abundance of legal-sized lobsters (at the time ≥90mm) by 427% and average size by ~5% by 2007, relative to control and reference locations (Hoskin *et al.*, 2009). Additionally, the mean abundance of undersized lobsters increased within the NTZ (up to 97%) and in nearby control sites (up to 124%), suggesting evidence of a 'spillover effect' from the NTZ (Hoskins *et al.*, 2009).

In contrast, the impact of shellfish potting on sessile epifauna was shown to have no effect on the abundance of individual species or benthic assemblages, neither increasing within nor decreasing outside the Lundy NTZ (Hoskin *et al.*, 2009, Coleman *et al.*, 2013). The lack of disturbance caused by commercial potting in the control locations suggests a high resilience or negligible impact of pots and traps on epifaunal species (Hoskins *et al.*, 2009). However, recovery of benthic habitats may take longer than 4 years of sampling to distinguish any conservation benefits.

In general, while pots and traps have shown to have no direct impact on essential fish habitat, fishermen will typically avoid areas of erect or branching epifauna to reduce the risk of snagging or wear and tear of their gear.

2.2.2.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Moderate	Medium	Strong	Low

The majority of wind farms in the UK are located in the offshore region. Exceptions to this, that are currently active or in operation include Blyth Demo Phase 1 (NIFCA), Teesside (NIFCA), Westermost Rough (NEIFCA), Humber Gateway (NEIFCA), Inner Dowsing and Lincs (EIFCA), Scromby Sands (EIFCA), London Array (KEIFCA), Thanet (KEIFCA), Kentish Flats (KEIFCA), Gunfleet Sands (KEIFCA), Rampion (KEIFCA), Burbo Bank (and Burbo Bank Extension) (NWIFCA), West of Duddon Sands (NWIFCA), Barrow (NWIFCA), Ormonde (NWIFCA) and Waldney 1, Waldney 2 and Waldney Extension 4 (NWIFCA). Given the spatial overlap with potting occurring in the inshore region, there is potential for conflict of use and / or displacement of fishing due to loss of fishable areas. It could be suggested this risk is more prevalent in the NEIFCA region where potting intensity of over 15m vessels is higher[25]. However, as a passive fishing method, the use of pots and traps within wind farm sites may profit from the larger abundances of crustaceans inside due to increased scour protection (Krone *et al.*, 2017), providing new opportunities to specific types of fisheries (Gill *et al.*, 2020).

Mitigation measures applied to wind farm and construction and operation include the full involvement and engagement (Hooper *et al.*, 2015; Reilly *et al.*, 2015; Haggett *et al.*, 2020) of fishing industry representatives, for example through the use of Fishing Liaisons (Hagget *et al.*, 2020). However, there are mixed reports on their success, with poor relationships and inadequate communication between fishers and wind farm developers (Gray *et al.*, 2016).

2.2.3 Gillnets (GN) and set gillnets (GNS)

For this work, there is no distinguishable difference between gillnets and set gillnets. All gillnets are assumed to be “fixed” to the seabed, unless described otherwise; therefore, risk scores for each métier have been assigned simultaneously.

Gillnets (GN) and set gillnets (GNS) (Table 14) are a mesh wall of netting hung vertically in the water, with floats on the headline and weights at the bottom, to target a variety of demersal fish (Figure 5 **and** Figure 7) (He, 2006). Fish will swim into the net and get caught in the mesh by their gills (Tank, 2005). Depending on the target

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[25] Fishing Activity for over 15m United Kingdom Vessels 2019

fishery, nets can either be anchored to the seabed (set gillnets) or allowed to drift with the tide or current (drift nets) resulting in fish becoming entangled in the fine netting. Gillnet is a collective term for a wide variety of styles of net such as trammel nets, wreck nets and tangle nets. All modern nets will be made of monofilament and specific mesh sizes depending on the target species, in accordance with EU and UK legislation for each fishery. This allows smaller species to pass through unharmed and deflects larger species.

In the UK, the main commercial species include cod (*Gadus morhua*), dogfish (*Squalus acanthias*), haddock (*Melanogrammus aeglefinus*), hake (*Merluccius capensis*), brill (*Scophthalmus rhombus*), Cornish sole (*Lepidorhombus whiffiagonis*), monkfish (*Lophius piscatorius*), pollack (*Pollachius pollachius*) and skates (e.g., thornback ray, *Raja Clavata*) (Seafish, 2021).

Gillnets, including set gillnets, are usually tied together, and fished in fleets, with each end anchored to the seabed and marked by a buoy or dhan flag on the surface. The length of a fleet can reach up to 2000m and there can be up to 30km of netting in the water when multiple fleets are deployed (Tank, 2005). Nets are shot in the direction of the tide to prevent drifting or entanglement with the seabed and may be soaked up to 72 hours depending on target species. Net haulers are used to retrieve the nets and the catch is sorted onboard and made ready to shoot again.

Table 14 Classification of gillnets (GN)

Métier	
Level 1	Fishing
Level 2	Nets
Level 3	Nets
Level 4	Gillnets (GN) / set gillnet (GNS)

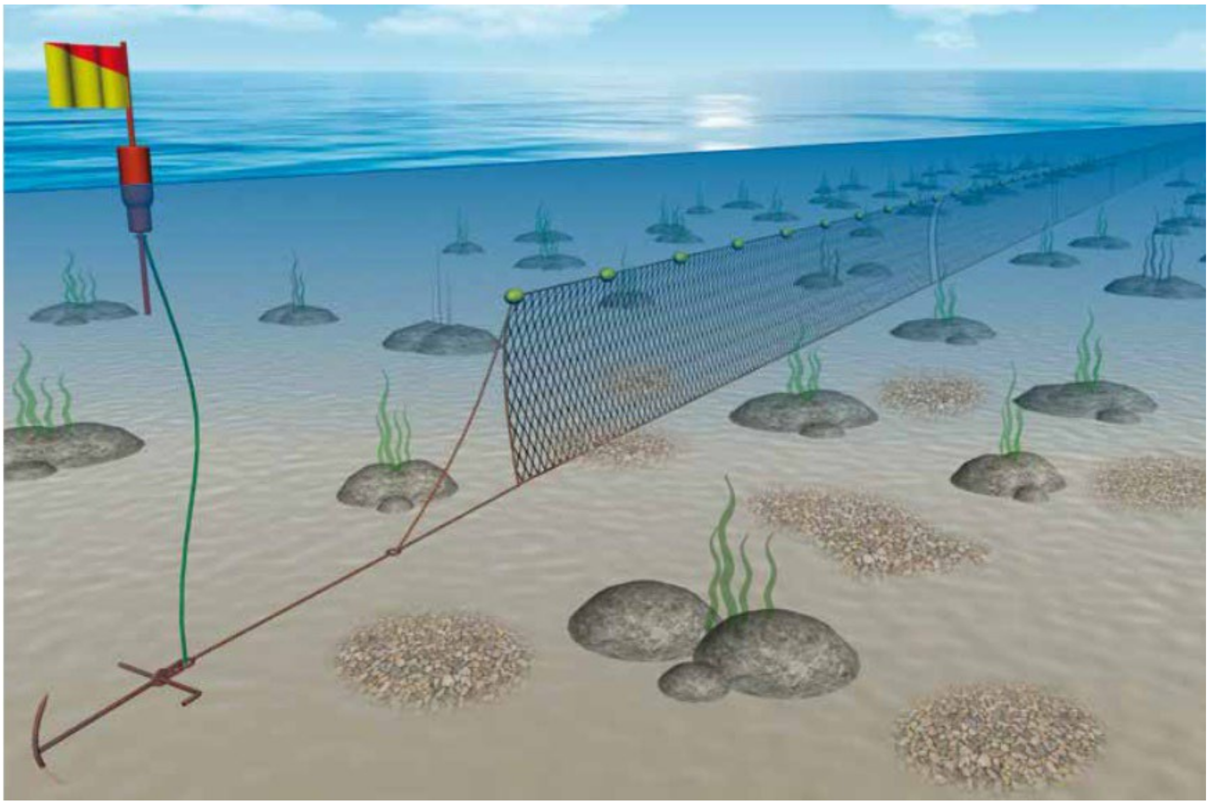

Figure 5 Gillnet (GN) anchored to the seafloor (©Seafish. Reproduced with permission: www.seafish.org[26])

2.2.3.1 Distribution of vessels

In the UK, there are 420 licensed GN vessels (Appendix 2), all of which are UK flagged. Much of the fleet are <10m vessels (97%) which are mainly distributed in the Cornwall, (75), Sussex (48) and Devon and Severn (37) IFCA regions. Gillnets make up 8% of the UK fishing fleet, ye it is important to note that set gillnets and drift nets are subcategories of gillnets described under 2.4 and 2.5.

In total there are 248 vessels using set gillnets to catch fish in UK waters. EU vessels make up 46% of the total fleet, two Belgium, two German, two Danish, 58 French, 26 Irish, four Dutch and three Portuguese flagged vessels.

2.2.3.2 Risk ratings

Gillnets are highly efficient and size selective yet are almost invisible in the water and often catch non-target species. Their limited species selectivity means they are

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[26] Via Cornwalll Good Seafood Guide https://www.cornwallgoodseafoodguide.org.uk/fishing-methods/gill-netting.php

a high-risk fishery for bycatch, especially small cetaceans, causing conservation challenges.

2.2.3.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Moderate	High

The primary environmental impact of gillnets is the incidental capture of non-target species, often leading to fatalities. As a result of long soak times (up to 72 hours), animals can be caught in the net for a long period of time, posing a serious threat to air-breathing animals (Moore *et al.*, 2009, Rogan and Mackey, 2007, Uhlmann *et al.*, 2005).

In UK waters, gillnets, including drift nets and trammel nets, incur the majority of marine mammal bycatch (Sewell and Hiscock, 2005). Harbour porpoise are considered to be the most vulnerable to entanglement due to the transparency of the net and failure to detect the net using echolocation (Kastelein *et al.*, 1999). These long-lived animals have a slow reproductive rate and therefore the mortality of these species could result in local declines of discrete populations (see Additional Risk Factor 2 for more information).

Seabird bycatch is commonplace in coastal gillnet fisheries, especially when nets are near the surface, adjacent to bird colonies and in shallow water (Forney *et al.*, 2001). Due to foraging behaviour, such as pursuit diving and benthic feeding, gillnets are more likely to incur mortality, compared to bycatch in longline and trawl fisheries, which was estimated to exceed 400,000 birds every year (Zydelis *et al.*, 2013). Recent data from the UK Bycatch Monitoring Programme (BMP) suggest static nets catch a higher species diversity than midwater trawls and longlines, with guillemots (267 recorded) accounting for approximately 75% of gillnet bycatch in 2018 (Northridge *et al.*, 2020). Per annum, preliminary estimates for guillemots lie between 1800 and 3300, majority from static nets, while fulmar bycatch in the offshore longline fishery was higher, yet less precise and could be anywhere between 2200 and 9100 birds.

Bycatch rates by vessel length showed convincing evidence of coastal fisheries (vessels under 10 m) having a greater impact on seabird mortality than offshore fisheries (over 10 m vessels). Based on observer data between 1996 and 2018, estimated bycatch rates (per 1000 hauls) were highest for guillemots (20.07), cormorants (2.88) and razor bills (1.02) from vessels under 10 m compared to higher bycatch rates of gannets (1.83), fulmar (1.55) and gull spp. (1.41) and a lower rate for guillemots (4.22) from over 10 m vessels (Northridge *et al.*, 2020).

Globally, effects to reduce bycatch have focussed on modifying gear design such as incorporating coloured net panels to increase net visibility, altering mesh sizes to increase species selectivity, and using acoustic deterrents to discourage marine mammals from coming near the net (Trippel *et al.*, 2003, Baer *et al.*, 2010). Recent field experiments in the demersal gillnet fishery of Constante, Peru, assessed the effectiveness of illuminating fishing nets with green light emitting diodes (LEDs) to reduce seabird bycatch (Mangel *et al.*, 2018). The use of LEDs represented an 85.1% decline in cormorant bycatch rate, without reducing target catch. The findings are supported by similar results to reduce sea turtle bycatch (Wang *et al.*, 2013). Due to the limited expense of LED lights, this could be a cost-effective solution to minimise bycatch of certain species on a global scale.

In the UK, the simultaneous use of active acoustic deterrent devices (ADD) is mandatory for vessels with an overall length of 12 m using any bottom-set gillnet or entangling net in certain ICES divisions i.e., the Celtic Sea (all year round); and the North Sea (all year round for net mesh size of 220mm or more, or from 1 August – 31 October for all nets of 400m or less). This technical conservation measure has been transposed into UK legislation from EU Regulation EU 2019/1241 to reduce the incidental capture or killing of cetaceans. However, during 2018, such vessels only represented 2.5% by number of those deploying static nets in the UK but were responsible for 45% of landings by weight (Northridge *et al.,* 2019).

For the under 12 m fleet, trials to assess the effects of ADDs, namely Banana Pingers (Fishtek Marine Limited), on inshore gillnets in Cornwall were conducted between 2012 and 2013. The results from 4 boats reported reduced detection rates of harbour porpoises by an average of 82%, compared to non-pingered nets (Crosby et al., 2013). In a parallel experiment by Oymer et al. (2020), a Banana Pinger was modified to become active for alternate 21-hour periods and showed a strong effect for reducing detections of harbour porpoise by 37% during an eight-month period. The study also concluded harbour porpoises did not habituate to the pinger or become displaced, providing strong evidence for their use in the small-scale fishery (Oymer *et al*., 2020). However, there has been no indication of when it will become a legal requirement for under 12 m vessels to install ADDs.

Overall, the primary mitigation measures to maintain biodiversity during gillnet fishing is to alter the mesh size or install ADDs, yet this does not prevent bycatch of sensitive species in under 12 m vessels. Conclusively, mitigation is weak for cetaceans and sea birds, yet the biodiversity of the wider marine environment is moderately sustained.

2.2.3.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Moderate	Medium	Moderate	Medium

The primary risk to commercial fish species targeted by gillnets is related to overfishing and high levels of discarding of both target and non-target species due to poor selectivity of nets.

Gillnets target a range of demersal species, most notably cod (*Gadus morhua*), dogfish (*Squalus acanthias*), haddock (*Melanogrammus aeglefinus*), hake (*Merluccius capensis*), Cornish sole (*Lepidorhombus whiffiagonis*), monkfish / anglerfish (*Lophius piscatorius*), pollack (*Pollachius pollachius*), bass (*Dicentrarchus labrax*), grey mullet (*Mugilidae* spp.) and skates (e.g., thornback ray, *Raja Clavata*) (Seafish, 2021). The most recent published UK port landings by "drift and fixed nets" totalled 11,800 tonnes, valued at £26.9 million, of which demersal species accounted for 8,800 tonnes.

The UK landing quantities of commercial species are not reported by gear type. However, ICES advice (2021) estimated gillnets accounted for 53.4% (equal to 1206 tonnes) of pollack landings in the Celtic Sea and English Channel[27]; 32% (equal to 23,225 tonnes) of hake landings of its northern stock area[28]; 13 % (equal to 2,620 tonnes) of both monkfish species of the Celtic Sea and Bay of Biscay stock area[29]; 10.5% (equal to 2,050 tonnes) of cod landings from the North, eastern English and Skagerrak[30]; 3% (equal to 236 tonnes) of haddock landings in the southern Celtic Seas and English Channel[31].

The stock status of the majority of these species is healthy. Since the introduction of a hake recovery plan in 2004 (Council Regulation (EC) No. 811/2004)[32], the stock biomass has increased, and fishing pressure is below FMSY[33]. Monkfish are also

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[27] ICES advice pollack Celtic Sea and English Channel 2021

[28] ICES advice hake Greater North Sea, Celtic Seas, and the northern Bay of Biscay 2021

[29] ICES advice anglerfish Celtic Seas, Bay of Biscay 2021

[30] ICES advice cod North Sea, eastern English Channel, Skagerrak 2021

[31] ICES advice haddock southern Celtic Seas and English Channel 2021

[32] https://eur-lex.europa.eu/eli/reg/2004/811/2011-01-01

[33] ICES Advice Hake, Northern Stock 2021

being sustainably fished, with the UK catching 85% of their allocated quota for 2019 (MMO, 2021). Catches of cod have severely declined in recent decades and while fishing pressure is still above FMSY, it is below the precautionary limit. A precautionary management plan exists for cod stocks, setting reduced catch limits in all stock areas to help recover spawning stock biomass.

Furthermore, skates and rays are targeted using gillnets, although they are also landed as bycatch from mobile gears (Chevolot *et al.*, 2006). The current stock status and fishing pressures of these species is unknown, and they are currently managed under a collective quota for various species such as thornback, spotted, cuckoo, blonde and small-eyed rays. Due to their biological characteristics of low fecundity and slow growth rates, coupled with generally large size and aggregating behaviour, skates and rays can be susceptible to bycatch and potential local depletion (Ellis and Walker, 2000, Ellis *et al.*, 2010) (see Additional risk factor 1 for more information). However, in some areas of the UK, local abundances and catching landings are increasing, such as thornback ray in ICES Division 7e (Burt *et al.*, 2013, Silva *et al.*, 2014)[34].

Presently, there is no national MLS for ray species, although the following IFCAs do mandate an MLS between 40 and 45cm (disc width) for all skates and rays: Kent and Essex, North-Western and Southern. Additionally, specific ray nets must be used if over 70% of the catch is comprised of rays, in accordance with EU Regulation No. 2019/1241[35] which stipulates a minimum mesh size of 220mm. Smaller mesh sizes are allowed if the catch is below 30%. Further steps are being taken by the Devon and Severn IFCA which introduced its Fisheries Research and Management Plan for skates and rays in May 2021, as well as a long established voluntary closed area in the Bristol Channel known as “The Ray Box”[36]. This site is closed for six months of the year to protect known nursey sites and allow successful spawning to take place, benefiting other demersal species as well.

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[34] ICES advice thornback ray western English Channel 2020

[35] This regulation has now been transposed into UK law under the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019.

[36] https://www.devonandsevernifca.gov.uk/Environment-and-Research/Fisheries-Research-Management-Plans/FRMP-Documents

2.2.3.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Moderate	Medium	Moderate	Low

In gillnet fisheries, the removal of target and non-target species is likely to pose the highest risk to the long-term abundance and reproductive capacity of local species. Removal of top predators or prey-fish for predatory fish species and seabirds can offset the equilibrium of the ecosystem and result in destabilising local food webs.

For example, gillnets have been found to have a major influence on population trends of seabirds. The closure of eastern Canadian northern cod (*Gadus morhua*) and Atlantic salmon (*Salmo salar*) gillnet fisheries in 1992 provided a unique opportunity to assess the removal of gillnets on seabird population trends. The study found breeding populations of divers, such as auks and gannets which are more susceptible to entanglement in fixed gear, increased, whereas seabirds which typically scavenged on the surface, such as gulls, decreased owing to the elimination of discards and offal during fishing operations (Regular et al., 2013). This shows how bycatch mortality can slow population growth, especially when gillnets operate within the foraging range of seabird colonies (Davoren, 2007).

Best practice methods to reduce unwanted bycatch include altering mesh size, visual alerts to increase net visibility, acoustic alerts, increased distance from breeding colonies (e.g., seabirds and seals) and subsurface setting at greater depths to reduce interactions with seabirds and surface-breathing mammals (Løkkeborg, 2011; Mangel *et al*., 2018; Luck *et al*., 2020). In the UK, the seasonal use of high visibility netting has been successful at drastically reducing the number of incidental deaths of nearby nesting seabirds, namely razorbills and guillemots, in the sea trout and salmon fishery in Filey Bay, east Yorkshire (Quayle, 2015). Introduced under a byelaw in 2010 by the Environment Agency, netters must record all bycatch, release any live seabird as quickly as possible and – during the month of June – fish only from 5.00am to 9.00pm using high visibility corline in the leader/tailpiece of the net, restricting the monofilament to 70 metres or less and always ensuring net attendance. Since the introduction of these mitigation measures, monitoring results show bycatch to remain low in the area, demonstrating the potential application of these measures on a larger scale (Quayle, 2015).

Presently, existing regulations to reduce seabird bycatch include the EU Birds Directive and the voluntary EU Seabird Plan of Action. The EU Birds Directive has been transposed into UK law by amending the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019 to ensure the strict protections afforded to seabirds continue. In addition, Defra is currently developing the English Seabird Conservation Strategy outlining actions to mitigate direct and indirect pressures on seabird populations which is intended to be published in 2022[37]. Until this is issued, local byelaws and voluntary codes of conduct are still in place for certain net fisheries such as in Filey Bay and St Ives Bay[38].

2.2.3.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Moderate	Low

Pelagic gillnets, such as drift nets, have minimal impacts on seabed habitats. However, there is evidence of demersal gear becoming entangled and breaking bottom features such as coral, albeit on a much smaller scale than mobile gear such as dredges and trawls (Baer *et al.*, 2010). In southern Portugal, the impact of bottom set nets on cold-water corals and coral gardens was assessed and the results showed that 85% of the gillnet deployments caught coral (Dias *et al.*, 2020). This small-scale fishery was targeting monkfish, *Lophius budegassa,* (also caught in the UK) and incidentally captured 4,326 coral fragments and 22 colonies of different species, of which 32% were pink sea fans, *Eunicella verrucosa*. In the UK, pink sea fans are listed as a species of principal importance and a designated feature of multiple MPAs, such as the Lyme Bay and Torbay SAC. Here, gill netting is still allowed to occur and may cause similar damage via abrasion (Sheehan, 2017).

Static nets are more likely to have a damaging impact on sea floor integrity when they become lost or abandoned as they have the potential to damage fragile benthic communities (Sheehan, 20217), obstruct water flow and abrade the sea floor and associated vulnerable communities when dragged by high currents or tides (see Descriptor 10 for more details).

Precautionary management of sensitive areas is in place to promote environmental protection. For example, a few area closures and designated no-take zones are scattered across the UK to protect spawning grounds e.g., the River Medway Nursery Area No-Take Zone in the Kent and Essex IFCA; breeding grounds e.g., seasonal and zonal restrictions of netting gear in the Kingmere MCZ; and vulnerable benthic fauna e.g., the Flamborough Head No Take Zone (NTZ) Spatial and temporal restrictions are also in place under some IFCA byelaws such as the Devon

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[37] Marine Strategy Part Three: UK Programme of Measures. September 2021

[38] Fishing nets used in & adjacent to St. Ives Bay, Cornwall IFCA.

and Severn IFCA Netting Permit Byelaw[39] which stipulates the coordinates and authorised gear permitted in these defined areas under Section 3 and 4.

2.2.3.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Moderate	High

Ghost fishing is a huge concern as monofilament nets will continue to persist in the water for many years after being lost or abandoned (Brown and Price, 2005). It is most problematic in gillnets and other passive gear types as fish swim into the net and become entangled. This can cause a vicious cycle as entangled fish act as bait to other marine predators. Quantifying fish mortality is nearly impossible. Ghost fishing also has indirect fisheries impacts as it continues to remove species from commercial fisheries [40].

On a global scale, set and fixed gillnets ranked the joint highest gear-specific relative risk score from abandoned, lost, or otherwise discarded fishing gear (ALDFG) according to their rate of production, fishing effort and adverse ecological and socioeconomic impact due to ghost fishing, plastic pollution, and habitat degradation (Gilman *et al.*, 2021). The rate of abandonment, loss and/or discarding of gillnets is hard to calculate yet a few studies have conducted studies in the North-East Atlantic. MacMullen *et al.*, (2003) estimated the UK gillnet fishery discards 500 m of net per vessel per year (1 km of lengths of net were lost of which 0.5km per vessel was retrieved by the vessel which temporarily lost it).

ALDFG can also entangle larger marine animals and seabirds, disturb spawning grounds and smother habitats (Gilman *et al.*, 2013; Wilcox *et al.*, 2013). The synthetic fibres can also breakdown and eventually accumulate in marine ecosystems, causing significant biochemical impacts on marine biota (Moore, 2008).

Efforts to retrieve ALDFG are increasing, and the Global Ghost Gear Initiative (GGGI) has spearheaded a global movement to collect ALDFG and reduce future mortalities and environmental impacts[41]. Additionally, research to manufacture biodegradable nets are underway. By replacing synthetic monofilament nets with biodegradable resin-based monofilament, Kim *et al.* (2016) found the biodegradable net was degraded by microorganisms within 2 years of submersion. These findings

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[39] Devon and Severn IFCA Netting Permit Byelaw

[40] http://www.fao.org/3/i5051e/i5051e.pdf

[41] https://www.ghostgear.org/

are also supported by Grimaldo *et al.*, (2020). During the fishing trails, Kim *et al.*, (2016) reported biodegradable nets caught almost as many fish (98.6%) as the nylon monofilament nets. This may be a result of reduced flexibility in the resin-based twine but may subsequently allow smaller fish to pass through as the risk of entanglement is lower (Kim *et al.*, 2016). Reduced catch efficiency was also found in biodegradable gillnets targeting Atlantic cod (*Gadus morhua*) in Norway as they progressively caught fewer fish over three fishing seasons: 18.4%, 40.2% and 47.4% (Grimaldo *et al.*, 2020). For the successful update of biodegradable nets, the catch efficiency must be comparable to conventional nets, however Grimaldo *et al.* (2010) stated fishermen would normally exchange sheets of nets at the end of each fishing season instead of repair them due to greater costs involved in repair. This would provide an opportunity for the use of biodegradable nets as their short life span would still operate effectively during this time frame, although more work is needed to improve catch performance.

In the UK, recent efforts to reduce marine litter from the fishing industry have centred around various initiatives encouraging net recycling e.g., Netcycle and Odyssey Innovation. These innovative projects have a direct impact on reducing marine litter and prevent nets ending up in landfill, incinerators or discarded at sea. Established in 2014, Odyssey Innovation now has 17 southwest harbours signed up to the Net Regeneration Scheme[42] which offers free recycling of all types of fishing nets, alleviating the high financial costs for fishermen, and is now supported by the Welsh government to roll out a pilot scheme in Welsh fishing communities[43].

Overall, mitigation of marine litter is considered moderate as while there are local initiatives working with the fishing industry to minimise the impact of ALDFG, there is no national programme in England to support or action net recycling or encourage the use of biodegradable nets. However, research projects, such as the Innovative Fishing Gear for Oceans (INdIGO), are currently underway to develop completely biodegradable fishing nets. INdIGO is a collaborative project between the UK and France which aims to reduce marine plastic in the Channel area by 3% and produce a commercially viable product by June 2023[44]. Working with the fishing industry and other research partners, INdIGO intends to create the first biodegradable fishing gear with a controlled lifespan to be adopted by the fishing and aquaculture sector.

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[42] https://www.odysseyinnovation.com/net-regeneration

[43] https://www.circularonline.co.uk/news/welsh-government-supports-the-expansion-of-the-net-regeneration-scheme/

[44] https://www.channelmanche.com/en/projects/approved-projects/innovative-fishing-gear-for-ocean/

When widely available, the uptake of biodegradable fishing gear should be a priority in future fishing legislation.

2.2.3.2.6 Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al.*, 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by fishing gears.

Although GN and GNS interact with the seafloor during setting and retrieval, the nature of these interactions and resultant noise are likely to be brief and very discrete and therefore pose a low risk in terms of their effect on the ecosystem. No known mitigation is reported for the reduction of underwater noise by fishing gears.

2.2.3.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Almost certain	High	Moderate	High

Within the gillnet fishery, different mesh sizes are used depending on the target commercial species. For example, under EU Regulation 850/98, smaller mesh sizes used to capture sole must be greater than 90 mm (applicable only in ICES Divisions VIId and IIIa and in the North Sea), whereas nets must exceed 100 mm mesh size when catching plaice or haddock and 220 mm for skates and rays such as thornback rays.

However, gillnet fisheries are typically classified as mixed demersal fisheries, and therefore the catch composition is likely to be made up of multiple species. This means discarding is highly likely and therefore fishers must employ a precautionary approach, such as targeting certain fishing grounds at different times and depth, to avoid commercial fish bycatch. For example, sole exhibit a habitat preference for finer sediment (Rochette *et al.*, 2010), whereas thornback ray prefer gravel and pebble banks with mid to strong currents (Ellis *et al.*, 2005; Martin *et al.*, 2012). Additionally, different life stages of fish species will aggregate in varying depths and habitats, such as juvenile rays and sole will remain closer to shore in shallow waters between 10-30 m and 1-2 m depths, respectively (Walker *et al.*, 1997, Kent and Essex IFCA, 2021). Estuarine habitats also act as nursey grounds for juvenile sole (Rochette *et al.*, 2010) and area closures have been designated to protect spawning grounds such as the Medway Nursery Area No Take Zone in the Kent and Essex IFCA district.

Additionally, while all quota species must be landed under the EU Landing Obligation, which has been transposed into UK law under Part 3 of The Common

Fisheries Policy and Animals (Amendment etc.) (EU Exit) Regulations 2019[45], there are exemptions in place. This may apply to certain species with high discard survival rates or when a *de minimis* exemption is active[46]. In the UK, this applies to skates and rays, plaice and sole (dover) (Table 15)[15] due to their high chance of survival after release; 95% for thornback ray (Catchpole *et al.*, 2017), 73% for plaice in the eastern channel trammel net fishery (Catchpole *et al.,* 2015) and 50% for sole (Cefas, 2015), reducing potential ecological impact on local populations.

Overall, spatial closures and the Landing Obligation contribute to mitigating commercial fish bycatch as undersized fish are protected in designated areas and fishermen are incentivised to implement measures, such as altering mesh size and targeting specific fishing grounds, to avoid catching choke species or landing discards which generates additional handling costs of unwanted catch.

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[45] https://www.legislation.gov.uk/uksi/2019/1312/part/3/made

[46] The *de minimis* exemption occurs when it is too difficult to completely avoid unwanted catches and a small percentage may be discarded until discard levels become too high

Table 15 Landing Obligation exemptions 2021. Applicable to gillnet, trammel net and drift net fishing in UK waters[47]

Species able to be discarded	Gear type	UK ICES Area	Exemption Type
Skates and Rays	**Gill, Trammel and Drift nets**	**IIa, IV, VI and VII**	**Survival**
Plaice	Gill and Trammel	IV, VIId-g (VIId-g for trammel only)	Survival
Sole (dover)	Gill, Trammel and Drift nets	IIa, IV, VIId-g (VIId-g excludes drift nets)	*De minimis*

2.2.3.2.8 Additional risk factor 2. Protected (ETP) species bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Serious	Likely	High	Weak	High

Where there is an overlap in spatial distribution between target fisheries and protected ETP species, bycatch is commonplace in gillnet fisheries. Due to the transparency of monofilament nets, species are unaware of their presence and can easily get caught. Additionally, depredation on target species caught within the net can also lead to entanglement, as well as a loss of catch and damage to fish and gear.

Bottom-set gillnets pose a high risk of bycatch, especially for small cetaceans in coastal areas, and is subsequently considered a high anthropogenic pressure in UK waters. The degree of risk varies on a spatial scale, with the south-west being of greatest concern, followed by the North Sea (Northridge *et al.*, 2016). Harbour porpoise are the most vulnerable species to gillnet bycatch and their rate of bycatch is relatively high despite being listed as a European Protected Species (EPS) on Annex IV of the Habitats Directive. In 2018, Northridge et al., (2019) estimated harbour porpoise bycatch in all UK gillnet fisheries to be between 845 and 1633 animals (best estimate 1151; CV=0.087) if there was no pinger use (Table 17), but if all over 12 m vessels used pingers where required, it would be reduced to 660 and 1464 animals (best estimate 948; CV=0.108) (Table 18). Similar estimates for common dolphins and seals are 248 (range 171-452) and 474 (range 376-691) respectively. In all cases, tangle/trammel nets had the highest estimated number of bycatch, although it is important to note these estimates included several assumptions due to the limited data on effort.

Additionally, one study reported seal bycatch in static net fisheries in Ireland varied significantly depending on the season due to the turbidity and clarity of the water and

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[47] https://www.gov.uk/government/publications/technical-conservation-and-landing-obligation-rules-and-regulations-2021

decreased with greater distance from major seal colonies (Luck *et al.,* 2020). Increasing net visibility in turbid waters would therefore be a novel method to reduce certain protected species bycatch (Luck *et al.,* 2020).

As a result of ecological concern for protected marine species, set nets are the focus of the UK Bycatch Monitoring Programme. In 2018, observers onboard gillnet vessels recorded the number of species of possible conservation concern caught as bycatch (Northridge et al., 2019) (**Table 16**). Marine mammal bycatch in gillnets targeting hake in ICES Division 7g consisted of one harbour porpoise and two common dolphins, both incidences occurred in nets with pingers.

Table 16 Species of possible conservation concern caught on gillnet vessels, recorded as part of the UK Bycatch Monitoring Programme (2018)

Species	Number of species (n)
Cormorant (*Phalacrocoracidae*)	**1**
Guillemot (*Cepphus grylle*)	3
Blue shark (*Prionace glauca*)	8
Porbeagle shark (*Lamna nasus*)	10
Spurdog (*Squalus acanthias*)	323
Tope (*Galeorhinus galeus*)	17
Common skate (*Dipturus batis*)	9
Undulate ray (*Raja undulata*)	3
Small-eyed ray (*Raja microocellata*)	8
Allis shad (*Alosa alosa*)	20
Shad (spp. ind)	1
Total	**403**

Table 17 Estimated bycatch rate of porpoises per haul between 2010 and 2018 and estimated total annual bycatch of porpoises in UK gillnet fisheries in 2018, assuming no pinger use (Northridge *et al.*, 2019)

Métier	Number of hauls observed	Observed porpoises caught	Mean bycatch rate: animals per haul	Estimated total annual
Driftnet	**164**	**2**	**0.012**	**33**
Gillnet	1389	8	0.006	86
Gillnet Hake	303	14	0.046	164
Gillnet Light	541	7	0.013	346
Gillnet Light Flatfish	995	1	0.001	50
Tangle/Trammel	3599	67	0.019	472
Total	**6991**	**99**	**0.109**	**1151**

Table 18 Estimated bycatch rate of porpoises from over 12 m vessels with pingers between 2010 and 2018 (at least one pinger per 2km)

Métier	Number of hauls observed	Observed porpoises caught	Mean bycatch rate: animals per haul	Estimated total annual
Driftnet	0	-	-	33
Gillnet	371	0	0.000	78
Gillnet Hake	86	0	0.000	27
Gillnet Light	5	1	0.200	345
Gillnet Light Flatfish	5	0	0.000	50
Tangle/Trammel	244	1	0.004	415
Total	711	1	0.2	948

Overall, Northridge *et al.*, (2019) estimated approximately 1151 porpoises might be caught as bycatch in UK gillnet fisheries in 2018, without the use of pingers, compared to 948 porpoises caught by over 12 m vessels using pingers (in all areas) (Table 17 and Table 18).

To provide a level of protection, five Special Areas of Conservation (SACs), where harbour porpoises are a qualifying feature, in England, Northern Ireland and Wales were designated in February 2019 to conserve threatened populations and their associated habitats (Figure 6) (JNCC, 2019).

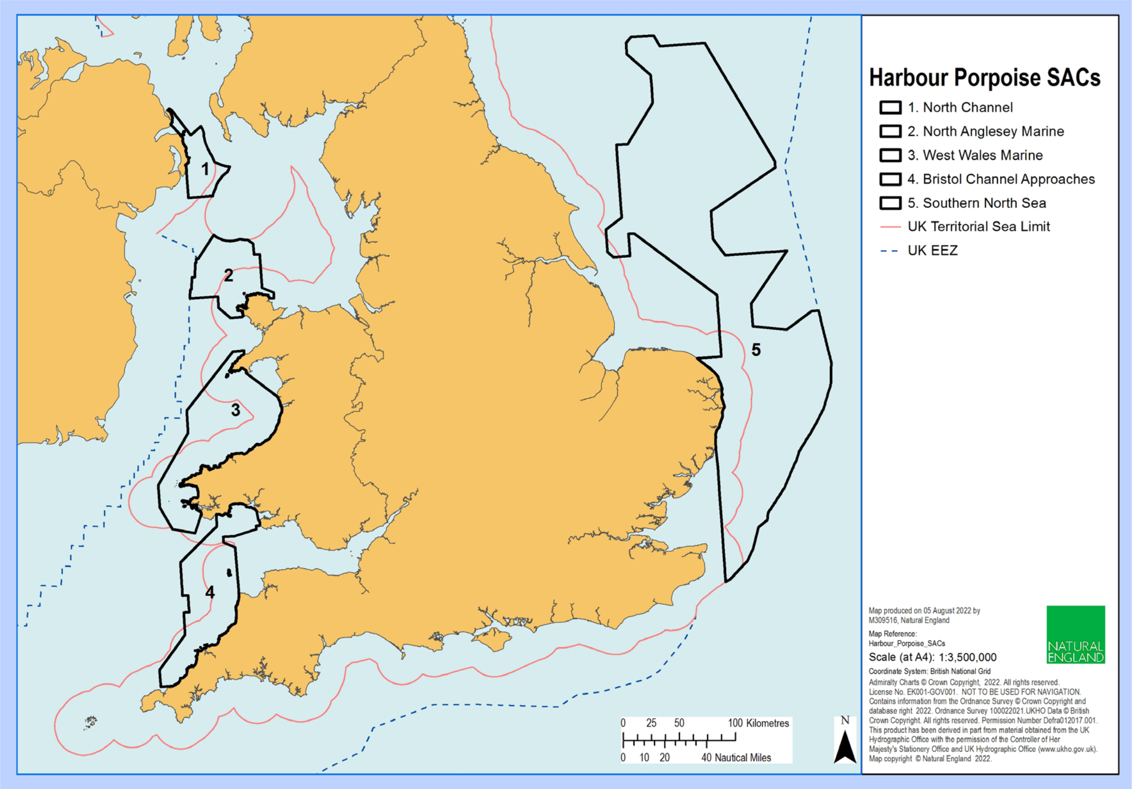

Figure 6 Geographic location of SACs designated for Harbour porpoise in England and Wales. (Source: Natural England. © Natural England 08/2022)

These intersect the North-Eastern, Eastern, Kent and Essex, Cornwall and Devon and Severn IFCA regions. However, static net fishing is still allowed to occur and therefore these spatial areas provide little protection. Furthermore, a Review of Harbour Porpoise bycatch in UK waters stated deep water gillnet fisheries to the west of the British Isles was a high-risk area as these fisheries are poorly documented and may have significant bycatch (Calderan and Leaper, 2019). The review considered these fisheries to be a priority to increase monitoring using observer programme and install EM camera systems to ensure the effective use of pingers, as required by Regulation (EU) 2019/1241. This has been transposed into UK law by the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019[48] to reduce the incidental capture or killing of cetaceans.

Under this conservation regulation, all vessels over 12m using any bottom-set gillnet in a specified area for a given period must install acoustic deterrent devices (ADD). In 2018, Northridge *et al.*, (2019) concluded 24 over 12 m UK registered vessels were required to use pingers. A review of harbour porpoises in UK waters stated that

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[48] The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019

nets properly equipped with pingers since 2008 have substantially reduced bycatch by 83% (Calderan and Leaper, 2019). This is partially supported by the reduced total estimate of porpoise bycatch in nets with pingers (difference of approximately 203 individuals) (Northridge *et al.*, 2019). However, many vessels deploying gillnets are under 12 m and there are no legal requirements to install pingers to reduce incidental catches of sensitive species. Therefore, current mitigation for the whole fishing fleet is scored as weak.

In addition to the ETP species mentioned above, migratory salmonids are also at risk to accidental bycatch as they transit through estuaries and harbours to their spawning grounds upstream. Key examples of anadromous species (i.e., adults migrate from the sea to breed in freshwater rivers) include Atlantic salmon, *Salmo salar,* and brown/sea trout, *Salmo trutta*. Atlantic salmon are a registered as UK Biodiversity Action Plan priority species and Species of Principal Importance under the Natural Environment and Rural Communities Act 2006, as well as listed under Schedule 4 of The Conservation of Habitats and Species Regulations 2017 as an animal which may not be captured or killed in certain ways (except in freshwater). In response to their declining population trend, IFCAs are under pressure to develop and implement netting regulations to protect salmonids during the marine phase of their migratory runs, as required under Section 153 of the Marine and Coastal Access Act (2009). To date, the Devon and Severn IFCA Netting Permit Byelaw has closed all estuaries to fixed and drift netting opportunities, except seine nets. Additionally, Cornwall IFCA has undergone a formal consultation to develop the Fixed and Drift Nets (Salmonid Protection) Byelaw 2021[49] which intends to restrict, and in some cases, prohibit the use of fixed and drift nets in specific areas around the Cornish coastline. For adult salmon and brown/sea trout, this will help reduce the risk of capture by non-target fisheries.

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[49] Fixed and Drift Nets (Salmonid Protection) Byelaw 2021

2.2.3.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Rare	Medium	Moderate	Medium

There are few reports of non-compliance for gill netters in the UK. However, a number of illegal gillnets have been found within rivers and estuaries, targeting quota species. For example, in 2020, the Environment Agency launched an investigation regarding an illegal gillnet found on Holy Island off the Northumberland coast[50]. Believed to have been set to target salmon and sea trout, a number of fish were found entangled in the 50 m gillnet (exact number not reported), yet the offending fisher was not identified. This was the fourth incident of illegal and unlicenced gillnets found in recent weeks, with other nets discovered in the River Blyth (75 m and 15 m) and another set on the beach at Lynmouth measuring 100 m. In partnership with the North-Eastern IFCA, another illegal 40 m net was seized the previous week at Skinningrove in Redcar and Cleveland[51]. A press release by the MMO stated, "In recent years a number of significant prosecutions have taken place in the region with one individual being fined nearly £7,000 for illegal netting in the Tyne & Wear area". No record of the court proceedings can be found.

Regular patrols by enforcement officers and tip-offs from the public contribute to the identification and removal of illegal gillnets. Most IFCAs will have a compliance and enforcement strategy in place to deter and institute prosecution proceedings if a fishery offence is filed e.g., the KEIFCA Compliance and Enforcement Strategy[52]. The resultant fines would reduce the financial gain or benefit from non-compliance and deter future non-compliance.

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[50] https://www.northumberlandgazette.co.uk/news/people/environment-agency-investigation-launched-after-fourth-illegal-fishing-net-found-northumberland-coast-2881521

[51] https://www.thenorthernecho.co.uk/news/18488381.40-metre-illegal-fishing-net-seized-skinningrove/

[52] https://www.kentandessex-ifca.gov.uk/wpcontent/uploads/2014/03/keifca_compliance_and_enforcement_strategy_final.pdf

2.2.3.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Rare	Medium	Moderate	Medium

In the UK, fishery restrictions in marine protected areas often only apply to destructive mobile gear and therefore static gear, such as gillnets and pots and traps, are permitted to operate in these areas, e.g., the Lyme Bay Reserve. However, there are a few areas closed to all forms of fishing, where the use of gillnets is therefore banned. For example, in 2009, the Environment Agency seized an illegal 185 m net fishing on the Camel estuary (a designated BNA site) in Cornwall. The net contained 24 large mullet, five small bass and a flounder[53]. Netting is prohibited in this area under the Cornwall IFCA River and Estuarine Fishing Nets Byelaw to conserve migrating salmon, sea trout and important bass nursery grounds (Hyder *et al.*, 2018[54]).

Enforcement patrols are regularly carried out by IFCA fisheries officers with the aim of reducing fishing infringements. Most IFCAs will have a compliance and enforcement strategy in place to deter and institute prosecution proceedings if a fishery offence if filed e.g., the KEIFCA Compliance and Enforcement Strategy[44]. The resultant fines would reduce the financial gain or benefit from non-compliance and deter future non-compliance.

2.2.3.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Moderate	Low	Moderate	Low

Gillnets are likely to have a smaller impact on essential fish habitat compared with other gear types due to their static nature and smaller footprint on the seabed. However, damage to erect or branching epifauna caused by abrasion can occur during deployment or retrieval of gear (Sheehan, 2017). The cumulative effect of exposure to netting may result in adverse impacts to sessile, benthic communities, particularly protected species such as pink sea fans (*Eunicella verrucosa*) which are characteristic of temperate rocky reefs and provide habitat for commercial species (Sheehan,2017). In order to prevent damage to the seabed and fishing gear (wear and tear of netting snagging on benthic structures or losing gear), fishermen tend to

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[53] https://www.falmouthpacket.co.uk/news/4095106.illegal-fishing-net-seized-in-cornwall/

[54] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/996213/Presence_of_European_sea_bass__Dicentrarchus_labrax__and_other_species_in_proposed_bass_nursery_areas.pdf

avoid known areas of emergent or protected biogenic reefs. Additionally, ALDFG can also cause habitat degradation as netting may snag on benthic structures (Gilman *et al.*, 2021); however, efforts to introduce biodegradable materials are underway (Kim *et al.*, 2016, Grimaldo *et al.*, 2020) (see Descriptor 10).

Within many UK MPAs, static gear in the form of gill netting is still allowed to occur. It is therefore difficult to describe the environmental impact of gillnets on protected habitats and species. However, where spatial closures exist, the potential impact can be indicated during MPA assessments. A recent assessment of the South Dorset Marine Conservation Zone (2020) described the assessment outcome of gillnets on 'Subtidal coarse sediment' and 'Subtidal chalk' and 'Moderate energy circalittoral rock' and 'High energy circalittoral rock' as "Not capable of affecting (other than insignificantly)" [55]. However, VMS data indicated only 8 instances of gillnet fishing trips occurred within the area and there were no reports of netting operating within the MCZ on 'Fishermap'[56].

Nevertheless, precautionary management of essential fish habitat is in place to promote environmental protection. For example, a few area closures and designated no-take zones are scattered across the UK to protect spawning grounds e.g., the River Medway Nursery Area No-Take Zone in the Kent and Essex IFCA; breeding grounds e.g., seasonal, and zonal restrictions of netting gear in the Kingmere MCZ; and vulnerable benthic fauna e.g., the Flamborough Head No Take Zone (NTZ).

2.2.3.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Moderate	Medium	Moderate	Medium

The majority of wind farms in the UK are located in the offshore region. Exceptions to this, that are currently active or in operation, include Blyth Demo Phase 1 (NIFCA), Teesside (NIFCA), Westermost Rough (NEIFCA), Humber Gateway (NEIFCA), Inner Dowsing and Lincs (EIFCA), Scromby Sands (EIFCA), London Array (KEIFCA), Thanet (KEIFCA), Kentish Flats (KEIFCA), Gunfleet Sands (KEIFCA), Rampion (KEIFCA), Burbo Bank (and Burbo Bank Extension) (NWIFCA), West of Duddon

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[55] https://consult.Defra.gov.uk/mmo/formal-consultation-mmo-mpa-assessments/supporting_documents/South%20Dorset%20MCZ%20MMO%20Assessment%202021.pdf

[56] Fishermap data: 2012 Marine Conservation Zone Project Stakmap Commercial Fishing under 15m vessels

Sands (NWIFCA), Barrow (NWIFCA), Ormonde (NWIFCA) and Waldney 1, Waldney 2 and Waldney Extension 4 (NWIFCA).

In a study, conducted by the Crown Estate, investigating the extent of change in fishing activity within six operating offshore wind farms (OWF) and export cable routes in the Eastern Irish Sea (Gray *et al.*, 2016), netters targeting flatfish, rays and bass in the vicinity of Burbo Bank, located in Liverpool Bay (3.5 nautical miles offshore), reported concerns included snagging gear on cables, rock armour and general seabed debris, as well as the risk of turbine collision in the event of engine failure. The financial risk of damage to nets also deterred fishermen. The construction of Burbo Bank has reportedly displaced two drift netters; however, there was no response regarding displacement of fixed gear.

In contrast, another study reported fishermen may perceive OWF to create opportunities for nursery and protected areas as well as fishing opportunities for fixed nets and anglers where conflict with other mobile gear would be minimised (Mackinson *et al.*, 2006).

In order to mitigate displacement of fishing activity, stakeholder consultation and capacity building is essential to provide dialogue opportunities and ensure all relevant stakeholders are involved in the process. This is implemented during the initial stages of development to mitigate conflicts and improve co-existence. However, one of the issues raised by a fisherman in Gray et al. (2019) was the inaccurate information on the importance of fishing grounds which are developed into wind farms. Here, improved consultation and information flow between wind farm developers and fishermen would help better inform decision-making on construction sites with the least risk of disruption and environmental impact to fishing activities. In regard to the scoring for mitigation for this descriptor, whilst there are potential benefits and reduced risk for some mitigation, it may also increase risk for others. The potential changes from mitigation are low and therefore the mitigation remains as “Moderate” and the residual risk would remain as “Medium”.

2.2.4 Drift net (GND)

Drift nets (GND) (Table 19) are a type of gillnet which are suspended in water, usually held at the sea surface or a certain distance below it, to target small pelagic species. These passive nets have a buoyant floatline at the top and a weighted leadline at the bottom of the net, allowing the net to hang vertically in the water column and drift with the tides. Compared to other gillnets, the soak time for drift nets is much shorter and is often for a few hours or a full tidal soak (six hours). Nets should not exceed 2.5 km in length and must always be accompanied by a vessel when fishing, as required under EU and UK legislation (EC Regulation No 894/97)[57].

Within the UK, drift nets are typically used by small day boats within the inshore region to target small pelagic fish such as sea bass (*Dicentrarchus labrax*), herring (*Clupea harengus*), mackerel (*Scomber scombrus*), salmon (*Salmo salar*) and sea trout (*Salmo trutta*). Fishing is highly seasonal depending on the migrations of target species. For example, 99% of herring landings are caught and landed between June and September (MMO SFS, 2019). Drift nets are therefore viewed as an opportunistic fishing method.

Table 19 Classification of drift net (GND)

Métier	
Level 1	Fishing
Level 2	Nets
Level 3	Nets
Level 4	Drift net (GND)

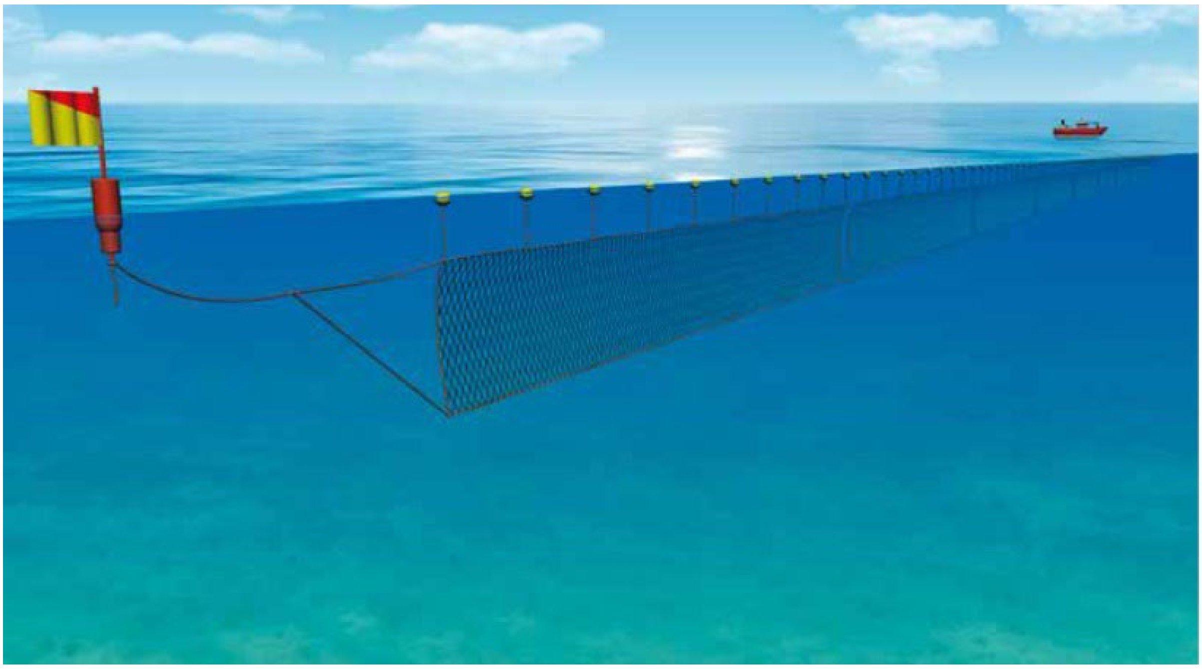

Figure 7 Drift net (©Seafish. Reproduced with permission: www.seafish.org[58])

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[57] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A31997R0894

[58] Via Cornwall Good Seafood Guide https://www.cornwallgoodseafoodguide.org.uk/fishing-methods/drift-netting.php

2.2.4.1 Distribution of vessels

Within the UK, there is a small-scale drift net fishery, chiefly comprised of inshore vessels under 10 m. The distribution of drift net fishing effort varies across the UK with no GND vessels registered in Scotland, Northern Ireland, or the Channel Islands, whereas the Eastern coast of England (Eastern and Kent and Essex IFCA region) has a high number of vessels, including three over 10m vessels. Only a small number of EU vessels use drift nets in UK waters: one French and 12 Irish flagged (Appendix 2).

2.2.4.2 Risk ratings

Environmental issues with large scale drift nets (over 2.5km in length) are widely documented, namely increased fishing effort on target species, high discard rates and significant incidental mortality of protected species, in particular cetaceans, sea birds and sea turtles (Northridge, 1991; Raykov and Triantaphyllidis, 2015; Sala, 2016). Increased international concerns of their environmental impact led to the United Nations adopting Resolution 46/215 to implement a ban on large-scale pelagic drift nets on the high seas by 31 December 1992[59]. However, small scale drift nets (under 2.5km) can still occur in national waters (Lewison *et al.*, 2004).

In the UK, the risk of drift nets is considered low due to the relatively low numbers of vessels and associated fishing effort. However, as a result of drift nets usually operating near the surface of the water, they have the potential to cause serious harm to air-breathing animals such as marine mammals and turtles, as well as other marine life including sharks and seabirds (Moore *et al.*, 2009, Rogan and Mackey, 2007, Uhlmann *et al.*, 2005).

2.2.4.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Moderate	Medium	Moderate	Medium

The removal of target and non-target species (bycatch) is the primary risk to biodiversity. However, drift net fishing is considered to be an effective, targeted fishery, with mesh sizes tailored to provide a degree of size and species selectivity (Sala *et al.*, 2018). Therefore, bycatch is generally low, and any trapped animal is quickly seen and released due to constant supervision of nets, as required under EU legislation (EC Regulation No 894/97), and transposed into UK regional byelaws e.g., under the Devon and Severn IFCA Netting Permit Byelaw, the permit holder or

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[59] https://digitallibrary.un.org/record/82553?ln=en

named representative must remain within 100m of the net for the entire duration of the fishing period.

Drift nets are also fished at the surface of the water, reducing their interaction with benthic species and communities. Their reduced soak times also limits the likelihood of interactions with known vulnerable species such as marine mammals and seabirds. However, bycatch incidences do occur. For example, recently in summer 2020, two sperm whales were found entangled in illegal driftnets in the Aeolian Archipelago waters, Southern Italy (Blasi *et al.*, 2021) and before pelagic drift nets were banned on the high seas, they had a substantial impact on seabird populations with estimates of 500,000 seabird mortalities per year in the North Pacific drift net fishery alone (Northridge *et al.*, 1991).

During the period of 1990 to 2000, a study estimated the bycatch from Irish and other drift net fleets in the eastern North Atlantic which mainly consisted of 778,452 (622,520–934,384) blue sharks (*Prionace glauca*), 11,723 (7670–15,776) common dolphins (*Delphinus delphis) and* 12,635 (10,009–15,261) striped dolphins (*Stenella coeruleoalba)* (Rogan and Mackey, 2013). *Other species reported by observers included* seabird species (e.g., Northern gannet (*Morus basanus)*, Northern fulmar (*Fulmarus glacialis),* Manx shearwater (*Puffinus puffinus)*, Atlantic puffin (*Fratercula arctica)*) and two species of turtles. The removal of megafauna biomass from the ecosystem likely caused indirect effects on the ecosystem functioning and potentially accelerated the decline of blue sharks in the area (Rogan and Mackey, 2013).

In the UK, due to the small size of the UK fishing fleet (74), there is very limited data on the rate and impact of drift net bycatch and the subsequent effects on biodiversity. Drift nets are usually pooled under “gillnets” in research studies, apart from the Cetacean Bycatch Observation Scheme (ME6044) (see Additional risk factor 2), and therefore there is a knowledge gap on the specific impact of this fishing method on local ecosystems and associated biodiversity.

2.2.4.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Moderate	Medium	Strong	Low

Traditionally, the main commercial species of interest in drift net fisheries are herring, sea bass and mackerel. However, sea bass have undergone serious declines due to overfishing and fishing restrictions have been in place since 2015[60] (see Section 2.2.4.2.7). Due to the seasonality of these fisheries, effort fluctuates during the year,

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[60] https://www.gov.uk/government/publications/bass-industry-guidance-2020

with the main fishing period for herring between June and September (MMO SFS, 2019).

While herring and mackerel may be the main target species for drift nets, they are also caught by other fisheries and therefore the UK port landings are not representative of drift net fishing effort. However, recent stock assessments report North Sea herring are fished at sustainable levels and at full reproductive capacity, although recruitment has been low in recent years (MMO, 2020). North-east Atlantic mackerel stocks have undergone fluctuations in previous assessments yet have remained at full reproductive capacity since 2009 and have been harvested sustainably between 2013 and 2015 and since 2017 (MMO, 2020). ICES advice for this stock shows fishing pressure is below FMSY and the stock size is healthy[61].

In England, regional byelaws are in place to manage the sustainable harvesting of target species i.e., in the Kent and Essex IFCA district, drift nets targeting herring must have a mesh size of at least 54mm and the length of the net must not exceed 250m. Herring and mackerel are quota species and therefore catch limits are in place to prevent overfishing. Due to the current status of sea bass, strict fisheries management measures have been carried over from 2020 and are detailed in the Bass Fishing Guidance 2020, applicable to recreational and commercial fishers[62].

2.2.4.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Unlikely	Medium	Strong	Low

The primary risk associated with drift nets is the removal of target and non-target species, particularly the removal of megafauna biomass. The species are likely to be top predators in the food web and their decline can have destabilising effects on the ecosystem. In the eastern North Atlantic, Rogan and Mackey (2003) stated the substantial number of incidental catches of blue sharks (~778,452) in Irish and other drift net fleets between 1990 and 2000 likely exacerbated the population decline of blue sharks in the area. Alongside the bycatch of other marine mammals, seabirds, and sea turtles, this may have an ecological impact on the abundance of lower

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[61] ICES advice mackerel Northeast Atlantic 2020

[62] https://www.gov.uk/government/publications/bass-industry-guidance-2021/bass-fishing-guidance-2021

trophic level populations due to the shift in predator-prey interactions (Rogan and Mackey, 2003).

Additionally, fishery management of pelagic fish such as the North Sea mackerel stocks can have knock-on effects on smaller prey-fish such as sand eel populations due to their high consumption rate (Furness, 2002). This can also have an impact, albeit small, on seabird populations as a result of reduced prey availability.

National legislation and regional fisheries regulations are in place to govern the best practice of fishing methods and limit the removal of non-target species taken as bycatch. Catch limits and minimum landing sizes are also enforced to ensure the sustainability and reproductive success of target fish stocks.

2.2.4.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	Moderate	Low

Unless used to target demersal species, drift nets have limited interaction with the sea floor and therefore little to no abrasion, disturbance, or penetration on the seabed. As defined under Article 11 in Council Regulation (EC) No. 894/97: *“Drift net” means: any gillnet held on the sea surface or at a certain distance below it by floating devices, drifting with the current, either independently or with the boat to which it may be attached. It may be equipped with devices aiming to stabilise the net or to limit its drift*.

However, drift nets may impact the seabed if they become lost or abandoned. Constant supervision of gear means this is unlikely to occur, yet precautionary measures such as fishing in open water, away from shallow water, can minimise the risk. This is further explored in Section 2.2.4.2.5.

2.2.4.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Unlikely	Medium	Moderate	Medium

Similar to other gillnet fisheries, lost or discarded drift nets can persist in the water for many years and continue to fish and trap animals (Brown and Price, 2005). Drift nets are one of the most problematic ghost gears and were ranked the highest relative risk score according to their global adverse effects from ALDFG (alongside set and fixed gillnets) in terms of rate of production (quantity of derelict gear), geo-spatial fishing effort and adverse ecological and socioeconomic impacts i.e., “ghost fishing” (Gilman *et al.*, 2021).

In the UK, the risk score is assumed to be lower due to the small-scale nature and reduced fishing effort. Additionally, unlike other net fisheries, drift nets have minimal contact with the seabed and therefore the risk of snagging and entanglement with benthic structures is lower.

Fishing regulations also enforce strict limits on net length e.g., any net or group of drift nets must not exceed 250 m in length in parts of the Kent and Essex districts, and require constant supervision of gear e.g., Devon and Severn IFCA Netting Permit Byelaw and under EC Regulation No 894/97, reducing the chance of ALDFG.

Testing of biodegradable materials is growing attention from industry. Recent research (Kim *et al.*, 2016) reports promising results of biodegradable nets decamping after two years, reducing ghost fishing and the capture of immature fish. More information on this study is given under Section 2.2.3.2.5.

2.2.4.2.6 Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem.

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Unlikely	Low	N/A	Low

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al.*, 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by fishing gears.

Drift nets are set on the sea surface with no interaction with the seabed; therefore, any risk of noise emitted from the interaction between gear and the seabed is negligible. No known mitigation is reported for the reduction of underwater noise by fishing gears.

2.2.4.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	Medium	Moderate	Medium

Drift nets are highly effective and efficient at catching fish which poses a high risk for bycatch. The primary commercial fish species of concern is sea bass. Traditionally targeted in the drift net fishery, sea bass stocks declined rapidly, and emergency measures were introduced by the EU in 2015, closing the fishery, increasing the MRCS to 42cm, and limiting recreational and commercial catches (Williams *et al.*, 2018). It is now prohibited to catch or retain bass caught by drift nets.

To reduce bycatch levels and allow the stock to recover further, UK regional byelaws are in place such as a bass nursey area within the Kent and Essex IFCA region and limits on the length of net (200m) under Area D Byelaw[63]. Additionally, there are bass nursey areas (BNA) designated in England and Wales in the 1990s to protect undersized bass from commercial and recreational fisheries[64]. In total 37 estuaries and other coastal sites are designated, of which 28 are in England, and there are currently proposals for 39 new site designations[28]. This includes the River Exe where fishing is banned between 30 April and 1 November in the Devon and Severn IFCA district[65].

2.2.4.2.8 Additional risk factor 2. Protected (ETP) species bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Serious	Unlikely	Medium	Moderate	Medium

In general, due to the indiscriminate nature of large-scale pelagic drift nets, there have been numerous incidences of unwanted catch of protected species (Rogan and Mackey, 2013). However, small-scale driftnets can provide a higher degree of selectivity, mainly through altering their mesh size, reduced soak times and seasonality of fishing grounds depending on the location of migrating fish stocks, which reduces the risk of potential bycatch of ETP species (Sala *et al.*, 2018). Furthermore, under EU and UK legislation, fishing drift nets must be tended at all times, (EC Regulation No 894/97), meaning any entangled animal can be quickly released and returned to the sea unharmed.

In certain fisheries such as fisheries for tuna and swordfish, the risk of catching non-target species is greater. In efforts to avoid adverse ecological effects, the EC Regulation No. 1239/98 was introduced, prohibiting the use of drift nets to catch tuna, swordfish and certain other species listed in Annex VIII[66]. For example, oceanic sea breams (*Brama rayi*), mahi-mahi or common dolphin-fish (*Coryphoena* spp.), sharks (e.g., thresher shark, *Alopiidae*) and all species of cephalopods. However, due to the position of the drift nets in the water column, bycatch is likely to occur, but mortality is generally low as nets are under constant supervision.

In the UK, herring drift net fisheries in Hastings were reported to have limited interactions with ETP species (Hough *et al.*, 2009). In 2018, the Cetacean Bycatch

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[63] https://www.kentandessex-ifca.gov.uk/i-want-to-find-out-about/regulations/keifca-byelaws

[64] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/996213/Presence_of_European_sea_bass__Dicentrarchus_labrax__and_other_species_in_proposed_bass_nursery_areas.pdf

[65] https://www.devonandsevernifca.gov.uk/Enforcement-Legislation/Bass-Compliance-Direction

[66] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31998R1239&from=EN

Observation Scheme (ME6044) estimated the bycatch rates of marine mammals and other protected species in UK drift net fisheries. Using nets without pingers, 164 hauls were observed between 2010 and 2018, incidentally catching two porpoises during this period (mean bycatch rate of 0.012 animals per haul). By extrapolating the data it was estimated that 20 (± 2) porpoises were caught as bycatch in pelagic drift nets in 2018. No hauls were observed for drift nets with pingers in over 12m vessels. For dolphins and seals, both grey and common / harbour, the estimated total bycatch was zero.

In order to mitigate incidences of bycatch, the overall length of drift nets is limited to 2.5km under EU and UK legislation, reducing potential interactions, and under constant observation (EU Regulation No 2019/1241). Monitoring and reporting of cetacean bycatch was first introduced under Council Regulation No. 812/2004 and further reinstated in EU Regulation No 2019/1241 for vessels with an overall length of 15 m or more deploying driftnets in ICES sub area 4, ICES division 6a, and ICES sub-area 7, with the exception of ICES divisions 7c and 7k. Additionally, the use of acoustic pingers is widely adopted in many fisheries to reduce marine mammal bycatch, however, in the UK it is not a legal requirement for driftnet fisheries to install pingers (Barlow *et al.*, 2003).

2.2.4.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Rare	Medium	Strong	Low

In the UK, the main commercial species targeted by drift nets are herring and mackerel. These species are quota species managed under set catch limits and minimum landing sizes to protect juveniles and ensure the sustainable exploitation of the stock. For example, the minimum landing size is 20cm for herring (*Clupea harengus*) and 20cm for mackerel (*Scomber Scombrus*), but 30cm in the North Sea.

The use of drift nets to catch sea bass is prohibited in UK water and EU waters. However, due to their high economic value and customer demand, the risk of non-compliance against sea bass is high. In 2016, the Angling Trust called upon the MMO to investigate reports of illegal drift netting for bass by licensed vessels off the Suffolk and Essex coast[67]. Recently in October 2020, two men pleaded guilty to deliberately fishing for bass within Southampton Water's Bass Nursey Area, as well as removing a number of undersized bass, and using an illegal net in another area of

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[67] https://anglingtrust.nemisys3.uk.com/news.asp?itemid=3108&itemTitle=Angling+Trust+calls+on+MMO+to+help+tackle+illegal+drift+net+fishing+for+bass+off+the+Essex+coast&section=29&sectionTitle=Angling+Trust+News

the district with a total catch valued at £1340[68]. The two men were fined £4,800 and ordered to forfeit their fishing gear worth £1,900. Bass are both recreationally and commercially important and there are strict fishing guidelines in places limiting the area, gear and catch limits of sea bass to protect and promote the recovery of the stock[69].

Occasionally there are reports of non-compliance in terms of misreporting. For example, in the North-East of England, a fisher was prosecuted in January 2019 for overstating his catch by over £17,000 and illegally setting a drift net in a conservation area. The fisher was ordered to pay £6,600 in fines and lost his licence due to failings to correctly complete and return the catch logbook issued to him[70].

2.2.4.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas.

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Rare	Medium	Strong	Low

Incidences of non-compliance against area restrictions are sporadic and mainly attributed to fishing for bass in designated Bass Nursery Areas. In 2009, a BBC News article reported a 360 m drift net was seized by police and the Environment Agency in the Fowey Estuary in 2009. Here, drift nets are banned in the estuary between May and December under a local byelaw due to the area being a designated bass nursey area. Several fish, including 28 mullet, six bass and four dogfish were caught in the net, however no one was prosecuted[71].

In order to reduce fishing offences in the southwest of Cornwall and Plymouth areas, Devon and Cornwall police and the Environment Agency work together under a programme called Operation Jetsam to conduct marine patrols with the aim of deterring or detecting marine crime and illegal fishing[72].

Additionally, in July 2019, a fisher was fined for breaching his fishing licence conditions by using a drift net which exceeded the allowed size and had extended

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[68] http://www.association-ifca.org.uk/news/fines-and-forfeiture-of-fishing-gear-for-visiting-illegal-net-fishers-in-southampton-waters-bass-nursery-area

[69] Bass fishing guidance 2021

[70] https://www.chroniclelive.co.uk/news/north-east-news/fisherman-fined-setting-net-conservation-16598821

[71] http://news.bbc.co.uk/1/hi/england/cornwall/8317785.stm

[72]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/793332/Devon__Cornwall_and_Isles_of_Scilly.pdf

into the Tyne Conservation Area A (all fishing is prohibited except rod and line) by 185m. The fisher was fined £3,000 and had to forfeit the excess drift net[73].

2.2.4.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

Drift nets typically operate at the surface of the water and therefore have minimal contact with the seabed. Unless in the form of ALDFG, drift nets are unlikely to cause any damage to essential fish habitat, resulting in a low relative score.

Mitigation is not relevant for this gear type.

2.2.4.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Moderate	Medium	Moderate	Medium

Wind power is one of the largest sources of renewable electricity in the UK and is expected to continue to grow to meet the UK government’s legally binding target of “Net Zero” greenhouse gas emissions by 2030. Offshore wind farms (OWF) will make a significant contribution to generate renewable energy, yet will likely displace vessels using towed, drift or static nets (Mackinson *et al.,* 2006). This may result in increased fuel costs and a reduction in earnings but would not impact the overall management of the area (Mackinson *et al.,* 2006).

As discussed in Section 2.2.3.2.12, in a study conducted by the Crown Estate, investigating the extent of change in fishing activity within six operating OWFs and export cable routes in the Eastern Irish Sea (Gray *et al.*, 2016), netters targeting flatfish, rays and bass in the vicinity of Burbo Bank reported concerns including snagging gear on cables, rock armour and general seabed debris, as well as the risk of turbine collision in the event of engine failure. Another fisher from the Wirral stated they had ceased drift netting in the Burbo Banks site after construction. A statement from this fisher reads:

“Initially was informed of the development and didn't receive any compensation despite the wind farm being built on my fishing grounds. The wind farm has significantly affected my drift net fishery (in the past drifting would begin 2 hr after

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[73] https://www.newsguardian.co.uk/news/man-fined-breaching-fishing-licence-144042

HW and over around 2 miles offshore, whereas now drifting covers 1.25 miles and begins 4 hr after HW".

In contrast, another study reported fishermen may perceive OWF to create opportunities for nursery and protected areas as well as fishing opportunities for fixed nets and anglers where conflict with other mobile gear would be minimised (Mackinson *et al.*, 2006).

In order to mitigate displacement of fishing activity, stakeholder consultation and capacity building is essential to provide dialogue opportunities and ensure all relevant stakeholders are involved in the process. This is implemented during the initial stages of development to mitigate conflicts and improve co-existence. However, one of the issues raised by a fisherman in Gray et al. (2019) was the inaccurate information on the importance of fishing grounds which are developed into wind farms. Here, improved consultation and information flow between wind farm developers and fishermen would help better inform decision-making on construction sites with the least risk of disruption and environmental impact to fishing activities. In regard to the scoring for mitigation for this descriptor, whilst there are potential benefits and reduced risk for some mitigation, it may also increase risk for others. The potential changes from mitigation are low and therefore the mitigation remains as "Moderate" and the residual risk would remain as "Medium".

2.2.5 Trammel net (GTR)

Trammel nets (GTR) (Table 20) are multi-layered monofilament gillnets consisting of three walls of netting: two outer layers of large mesh size and an inner net of smaller, fine mesh which is slacker to entangle the fish when they enter through the net (Montgomerie, 2015) (Figure 8). While in many gillnets fish may become wedged by the mesh around their body or caught by their gills, trammel nets also entangle fish in bags or pockets of netting. This occurs when a fish pushes the fine-mesh layer through the next layer of larger-mesh netting, creating a pocket outside the net and thereby trapping itself (Kaiser, 2014). Fishing methods are similar to the deployment and retrieval of other gillnets.

Different combinations of gear characteristics, such as mesh size, net length, floatation etc, are used to target species on different fishing grounds, depths, and seasons (Erzini *et al.*, 2006). Nets are set on or close to the seabed to target demersal fish such as brill (*Scophthalmus rhombus*), cod (*Gadus morhua*), dover sole (*Solea solea*), plaice (*Pleuronectes platessa*), turbot (*Scophthalmus maximus*) haddock (*Melanogrammus aeglefinus*), hake (*Merluccius merluccius*), monkfish (*Lophius piscatorius*) and pollack (*Pollachius Pollachius*) (Seafish, 2021).

Table 20 Classification of trammel net (GTR)

Métier	
Level 1	Fishing
Level 2	Nets
Level 3	Nets
Level 4	Trammel net (GTR)

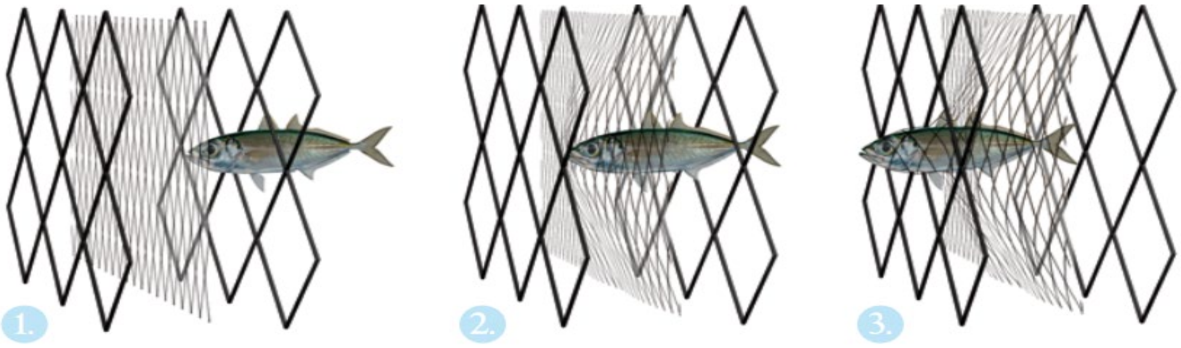

Figure 8 Trammel net fishing method (©Seafish. Reproduced with permission: www.seafish.org[74])

2.2.5.1 Distribution of vessels

Very few UK registered vessels operate trammel nets (49), of which the majority are less than 10 m (39) and are mainly distributed within the Sussex IFCA district (21). Only two EU Member States use trammels in UK waters, French (75) and Irish (2) flagged (Appendix 2).

2.2.5.2 Risk ratings

As a result of the entangling method of fishing, trammel nets have poor selectivity, and bycatch of non-commercial species such as epifauna and cetaceans is high risk. Secondly, ghost fishing of derelict nets as a result of snagging or incidental removal by mobile gear can continue to fish and threaten marine life.

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[74] https://seafoodacademy.org/pdfs/bmf-screen-version.pdf

2.2.5.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Moderate	High

Trammel nets are a mixed demersal fishery targeting mainly flatfish species such as plaice, and sole. In the past, this has led to high discard rates of non-target species. In one small artisanal fishery in Portugal using trammel nets, bycatch represented 59.6% of total catches, of which 41% (98 species) was discarded (Bastista *et al.*, 2009). In total, the study estimated the total volume of discards attributed to trammel nets was ca. 170 tonnes per year (Bastista *et al.*, 2009).

In UK waters, gillnets incur the majority of marine mammal bycatch (Sewell and Hiscock, 2005), with tangle/trammels net responsible for over 40% of UK harbour porpoise bycatch in 2018 (Northridge *et al.,* 2019). Harbour porpoise are considered to be the most vulnerable to entanglement due to the transparency of the net and failure to detect the net using echolocation (Kastelein *et al.,* 1999). These long-lived animals have a slow reproductive rate and therefore the mortality of these species could result in local declines of discrete populations. Similarly, species of skates and rays are slow growing and have a lower fecundity compared to commercially targeted fin fish. During 2018, the results from 172 dedicated protected species bycatch monitoring days suggest skates were more vulnerable to bycatch in trammel nets compared to other gear types (Table 21). Small eyed rays were the most at-risk species to trammel nets. This may be a result of their inshore, benthic distribution, making them vulnerable to capture in bottom-set netting.

Table 21 Species of possible conservation concern identified during 2018 bycatch observations-individuals by gear type (numbers of individuals observed) (Northridge *et al.,* 2019)

Skate	Gillnet	Tangle net	Trammel net	Total
Common skate complex	9	4	37	50
Common stingray			1	1
Undulate ray	3	13	39	55
Small eyed ray	8	23	480	511

Under EU Regulation No. 2019/1241, now transposed into UK law by the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019, all vessels over 12m using any bottom-set gillnet or entangling net in a specified area must install acoustic deterrent devices (ADD). These areas include the Baltic Sea, the North Sea, English Channel and Celtic Sea (ICES divisions 4, 3a – only from 1 August to 31 October - 7e, 7d, 7f, 7g, 7h and 7j). However, the data shows only two UK registered vessels over 10 m in length operate trammel nets (Table 117), although this is assumed to be an underestimate as trammel nets are a type of gillnet.

In order to mitigate non-commercial bycatch, fishermen tend to target fishing grounds, at certain depths and habitats, in their traditional fishing areas to obtain the highest catches and reduce bycatch of unwanted and undersized species. Specific mesh sizes are used to increase size and species selectivity, according to best practice. Additionally, since the enforcement of the discard ban on 1 January 2019, also known as the Landing Obligation, all catches must be landed, and it is therefore in the fishermen's interest to be more selective and considerate of where they deploy their nets. However, some species are exempt from the discard ban if they have high survival rates such as skates and rays, typically caught as bycatch in trammel net fisheries targeting flatfish. Scientific evidence to support the exemption is collated form various studies and programmes, including SUMARiS which collected data on skate and ray survival rates between 2017 and 2020 in the Eastern English Channel and North Sea. The results found the total survival rate of thornback ray (*Raja clavata*), blonde ray (*Raja brachyura*), spotted ray (*Raja montagui*) and undulate ray (*Raja undulata*) were 99.34%, 100%, 100% and 100%, respectively[75].

2.2.5.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Unlikely	Medium	Strong	Low

In the UK, while trammel nets are typically considered a mixed fishery, the main targeted commercial species are sole, plaice, brill, and white monkfish. The UK landings for these species in 2019 was 1,800 tonnes, 9,766 tonnes, 434 tonnes and 17,667 tonnes (combined landings value for white monkfish and black bellied monkfish), respectively.

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[75] https://www.nsrac.org/wp-content/uploads/2021/04/12-2021-NSAC_NWWAC-Advice-to-Scheveningen-Group-on-Skates-and-Rays_2021-1.pdf

Table 22 Stock status of top four commercial fish stocks targeted by trammel nets (by Landings, tonnes)

Species	Stock	Fishing pressure (F_{MSY})	Spawning Stock Biomass (B_{MSY})	Status
Sole	Eastern English Channel	Above	Below	Unsustainable
	Western English Channel	Below	Above	Sustainable
	North Sea	Above	Above	Over-exploited
	Bristol Channel, Celtic Sea	Above	Above	Over-exploited
Plaice	Eastern English Channel	Below	Above	Sustainable
	Western English Channel	Above	Above	Unsustainable
	Bristol Channel, Celtic Sea	Below	Above	Sustainable
	North Sea	Below	Above	Sustainable
Brill	North Sea, Skagerrak and Kattegat, English Channel	Below	Above	Sustainable
White Monkfish	Celtic Seas, Bay of Biscay	Below	Above	Sustainable

Set quotas apply to sole and plaice stocks, as well as an EU multiannual management plan for both species in the North Sea (Council Regulation (EC) No 676/2007) and additional EU multiannual management plan for sole in the Western Channel (Council Regulation (EC) No. 509/2007). Sole stocks have recovered well in recent years because of the EU sole recovery plan restricting fishing effort of mobile gears and spatial closures (e.g., the Trevose box closure) which protects spawning stocks during the winter months, increasing productivity for sole, cod, plaice and other species[76].

Brill is managed under a combined species TAC with turbot, preventing effective control of the exploitation of brill stocks. Additionally, there is no EU minimum landing size in place, although some IFCAs (e.g., Cornwall IFCA) enforce a minimum landing size of 30cm[77]. However, fishing effort is thought to be sustainable (Table 22) and brill are fast growing species and therefore have a relatively low vulnerability to overfishing[78].

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[76] https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2007/Special%20Requests/EC%20Trevose%20closure.pdf

[77] https://secure.toolkitfiles.co.uk/clients/17099/sitedata/Byelaws%20and%20orders/Cornwall_SFC/Specified-fish-sizes.pdf

[78] https://www.cornwallgoodseafoodguide.org.uk/fish-guide/brill.php

Management of white monkfish is combined with black bellied monkfish under a joint TAC which is not ideal and could lead to the overexploitation of one species according to ICES[79]. Monkfish catches are controlled by an EU multiannual Plan and while there is no minimum landing size, an EU Council Regulation (EC) No. 2406/96 lays down common marketing standards for certain fishery products fixes a minimum weight of 500g.

2.2.5.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Moderate	Medium	Moderate	Medium

Trammel nets are mainly set on the seabed and are very effective for catching demersal species due to their low-visibility netting. However, the primary risk associated with trammel nets is their indiscriminate fishing technique which results in the removal of a high number of non-target species. Additionally, nets may be set for up to 72 hours leading to a higher number of discards due to the restrictive movement of the net causing injury and potential suffocation due to constriction of gills (Uhlmann and Broadhurst, 2015, Breen and Morales Nin, 2017). High mortality rates of 97.5%, 76.6% and 54.4% for the following demersal species: European hake (*Merluccius merluccius*), longfin gurnard (*Chelidonichthys obscurus*) and common smooth hound (*Mustelus mustelus), respectively,* were recorded during experimental trammel net monitoring on a MPA in Portugal (Priester *et al.*, 2021). While this only made up 9.6% of the catch composition (total of 21,873 fish caught), the study reported hake were often found damaged or scavenged by invertebrates as they would move to shallower waters to feed in the evening and therefore remain trapped for a long period of time in the net (Priester *et al.*, 2021). Additionally, a high percentage of commercially important sole species (*Solea*, 86% and *Solea senegalensis,* 94%*)* and thornback ray (*Raja clavate, 97.9%)* were released alive, indicating the ecological impacts on these species is relatively low.

This can cause population-level concerns from the low survivability of released animals which are unaccounted for in the fishery, leading to reduced abundances and reproductive capacity (Uhlmann and Broadhurst, 2015).

However, in the UK, only 51 vessels are registered to operate trammel nets which are almost exclusively under 10 m vessels. Therefore, the high-risk potential of trammel nets on local abundances of inshore populations is likely to be lower than other gear types due to lower fishing effort. Nevertheless, the lack of research and

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[79] ICES advice white monfish 2021 Celtic Seas, Bay of Biscay

evidence on the long-term impacts of trammel nets means the risk was scored higher.

Efforts to reduce long-term impacts on population size have mainly focussed on increasing selectivity. This can be achieved through gear modifications such as altering mesh size, netting colour, thickness, and hanging ratio as well as changes in operation procedures such as reduced soak times and targeted fishing grounds where likely bycatch is low (Breen *et al.*, 2020).

2.2.5.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Moderate	Medium	Moderate	Medium

Trammel nets have direct physical contact with the sea floor; however, they do not penetrate the seabed and are only likely to cause benthic disturbance, albeit it small, during retrieval or gear movement induced by tides or wave action (Depestele *et al.*, 2009, Kaiser, 2014). Therefore, the environmental footprint is localised to the area of deployment and is much smaller than mobile, bottom towed gear. However, the cumulative effect of high fishing pressure could result in a higher risk of disturbance to benthic structures and communities (Kaiser, 2014). In general, fishers will often avoid areas where snagging is likely to protect their gear. Nevertheless, the lack of research and evidence makes it difficult to quantify their impact and therefore the associated risk is scored higher due to the unknown effects on sea floor integrity.

2.2.5.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Moderate	High

Within the UK, an increasing array of work has shown that the majority of impacts to marine taxa attributable to ALDFG (e.g., capture related stressors or inevitable mortality) are associated with the continued ’active’ fishing by ALDFG (i.e., where the physical structure of the ALDFG has not broken down), or through accidental entanglement (i.e., in ALDFG where the structure has broken down, but the materials are still present) (Breen *et al.*, 2020). The exact number of capture related mortalities from ALDFG has not been accounted for the UK but will likely have ecological and socio-economic consequences (FAO, 2016). In the western Mediterranean for example, Ozyurt *et al.* (2017) examined the mortality of commercially important and endangered species impacted by trammel nets and found 26 species of captured individuals, of which teleost and crustacean families formed the majority (98%).

In the UK, the rate of abandoned, lost and or discarded trammel nets was estimated to be 845 m length of net per vessel per year (not retrieved). The rate of lost gear is much higher (1.3 km length of net); however, 0.455 km is usually able to be retrieved by the vessel that temporarily lost it (MacMullen *et al.*, 2003).

Ghost gear maintains its fishing potential for many years and will continue to remove both marketable and non-market fish, including ETP species, as well as potentially cause damage to the seabed. This can be addressed through a series of mitigation measures such as modifying gears to include biodegradable components to reduce ghost fishing capacity, using less-durable materials (allows larger organisms to break free) and facilitating onshore gear disposal and recycling to avoid abandonment at sea (FAO, 2016).

2.2.5.2.6 Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al.*, 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by fishing gears.

Although trammel nets come into contact with the seafloor during setting and retrieval, the nature of these interactions and resultant noise are likely to be brief and very discrete and therefore pose a low risk in terms of their effect on the ecosystem. Mitigation is not relevant for this gear type.

2.2.5.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Almost certain	High	Moderate	High

Trammel nets target a range of species. However, commercial bycatch can make up a moderate proportion of the total catch. In addition, other commercial species may predate upon entangled fish, reducing fish marketability and increasing the likelihood of becoming entangled too. A common example of commercial fish bycatch is skates and rays due to their large size and food preference for smaller flatfish such as sole (Ford *et al.*, 2020). Nevertheless, an experimental study in Portugal reported very low mortality rates for commercially important species trapped in trammel rates with a high catch-release rate of 97.9%, 94% and 86% for thornback ray (*Raja clavate) and two sole species ((Solea*, and *Solea senegalensis,)* (Priester *et al.*, 2021). This indicates the ecological impacts on these species is relatively low.

Few studies have researched size selectivity in trammel nets which, compared to other categories of gillnets, is generally described as poor (Erzini *et al.*, 2006, Karakulak and Erk, 2008). A study by Erzini *et al.* (2006) experimented with different combinations of mesh size in four southern European areas and concluded larger mesh outer panels did not significantly affect species selectivity and catch rates;

instead, it was a function of the smaller mesh size of the inner panels. However, the opposite was reported in the southeast of England trammel fishery for common sole (*Solea solea*) where gear modifications were tested to reduce bycatch of thornback ray (*Raja clavata*). Here, reducing the mesh size of the two outer walls was successful in reducing thornback ray bycatch and increasing the number of marketable common sole by 87% compared to unmodified nets (Ford *et al.*, 2020).

Additional methods to achieve higher selectivity in trammel nets mainly consist of modifying gear characteristics such as netting colour, thickness, mesh size and hanging ratio (Breen *et al.*, 2020). The addition of a panel, known as a 'greca' or guarding net, at the bottom of the net can also prevent entanglement of unwanted catches such as crustaceans and other benthic invertebrates (Catanese *et al.* 2018).

Changing fishing practices can also reduce unwanted bycatch by targeting areas where target species are likely or known to frequent or reducing soak times to limit the exposure of animals to capture-related stressors and depredation by non-target species (Breen *et al.*, 2020).

2.2.5.2.8 Additional risk factor 2. Protected (ETP) species bycatch.

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	Medium	Weak	Medium

Trammel nets pose a moderate risk towards ETP species, such as small marine mammals and elasmobranchs (Sewell and Hiscock, 2005). Observer data collected on trammel net vessels as part of the UK Bycatch Monitoring programme is given in Table 23 (Northridge *et al.* 2019). Additionally, 2 harbour porpoises and 2 common dolphins were taken in trammel nets for ray and hake gillnets in ICES division 4c and 7g. The following year, 2 common dolphin and 8 grey seals were caught in trammel nets in ICES division 7e and 7f (Kingston *et al.,* 2021)

Table 23 Species of possible conservation concern caught on gillnet vessels, recorded as part of the UK Bycatch Monitoring Scheme 2018 (Northridge *et al.*, 2019)

Species	Number of species (n)
Guillemot (*Cepphus grylle*)	1
Blue shark (*Prionace glauca*)	6
Common stingray (*Dasyatis pastinaca*)	1
Spurdog (*Squalus acanthias*)	7
Tope (*Galeorhinus galeus*)	1
Common skate (*Dipturus batis*)	37
Undulate ray (*Raja undulata*)	39
Small-eyed ray (*Raja microocellata*)	480
Long-snouted seahorse (*Hippocampus guttulatus*)	3
Shad (spp. ind)	6
Total	581

Between 2010 and 2018, trammel nets were responsible for catching 68% of 99 observed harbour porpoise bycatch in net fisheries from over 12 m vessels for hauls without pingers and 50% in nets with pingers (2 observed in total) (Northridge et al., 2019). This highlights how trammel nets pose the highest risk to harbour porpoises and are estimated to take the highest number of porpoises per gear type in UK gillnet fisheries. It also showcases the effectiveness of pingers which are an established mitigation measure to discourage cetaceans from approaching trammel nets. This is supported by a study in north-eastern Majora (Balearic Islands), where the use of pingers reduced net damage from common bottlenose dolphins (87% fewer holes) without effecting the fishery target species (Gazo *et al.*, 2008).

In the UK, Northridge et al. (2019) estimated the difference between bycatch rates in trammel nets with and without pingers for 2018 (Table 24). The results show acoustic pingers reduced the likelihood of porpoise bycatch by 12%. However, there are several caveats with these estimates as they assume the net lengths to be the same, regardless of vessel size, which means bycatch from larger offshore vessels is likely to be underestimated while the inshore fleet is likely to be overestimated.

Table 24 Estimated bycatch rate and total annual bycatch of porpoises in trammel nets with and without pingers (based on data between 2010 and 2018) (Northridge *et al.*, 2019).

Métier	Number of hauls observed	Observed porpoises caught	Mean bycatch rate	Estimated total bycatch 2018
Trammel net (without pingers)	3599	67	0.019	472
Trammel net (with pingers on > 12m vessels)	244	1	0.004	415

Under EU Regulation No. 2019/1241, now transposed into UK law by the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019, it is mandatory for vessels over 12m using any bottom-set gillnet in a specified area to install acoustic deterrent devices (ADD). UK logbook records indicated that during 2018, this applied to 24 UK registered vessels (Northridge *et al.,* 2019). However, there are no legal requirements for under 12 m vessel to install pingers therefore current mitigation for the whole fishing fleet is scared as ‘Weak’.

2.2.5.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	Moderate	Low

The majority of commercial fish targeted by trammel nets are managed under agreed Total Allowable Catches (TACs) to control fishing effort and specific minimum landing sizes are in place to ensure only the sexually mature individuals are landed. For example, the minimum landing size for sole (*Solea* spp.), plaice (*Pleuronectes platessa*) and turbot (*Psetta maxima*) are 24cm, 27cm and 30cm, respectively.

Altering the mesh size of the trammel nets provides a higher degree of selectivity to catch the larger individuals and prevent incidental capture of undersized species. Incidences of non-compliance are few however in 2016, a fisher from Hastings received a cautionary letter from the local MMO due to failure to comply with catch composition requirements. A routine inspection of his vessel found 51% of his catch to be illegal due to the mesh size (90 mm) of his trammel net which was too small to land his catches of cod, plaice, and thornback ray[80].

Regular patrols and inspections are carried out to ensure maximum compliance with local byelaws. Procedures are in place to prosecute any individual found to disobey fishery regulations.

2.2.5.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Rare	Medium	Strong	Low

The majority of fishing offences involving nets are described as gillnets and are not classified as trammel nets. Therefore, for the purpose of this work, trammel nets have been assigned the same risk ratings at gillnets.

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[80] https://fishingnews.co.uk/news/half-catch-illegal-under-catch-composition-rules/

2.2.5.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Moderate	Low

Trammel nets have direct, physical contact with the seabed but are considered to be low impact due to their stationary nature, causing minimal benthic disturbance (Depestele *et al.*, 2009). Any damage to the seabed will likely occur during the deployment or retrieval of gear but may also take place under strong currents or inexperienced skippers dragging the net along the sea floor. This can result in emergent, epibenthic organisms becoming entangled and subsequently removed (Priester *et al.*, 2021). This may have a knock-on effect for visual predators such as plaice which use these benthic habitats for feeding due to the higher habitat complexity and prey diversity, resulting in reduced prey availability or successful feeding (Støttrup *et al.*, 2019). However, due to the lack of spatial restrictions on gillnet fisheries, including trammel nets, it is difficult to describe the environmental impact of netting gear on essential fish habitat.

In general, fishers deploying trammel nets will target soft, muddy or gravel sediments where target species such as sole, plaice and many ray species express a habitat preference (Priester *et al.*, 2021). These habitats also occur inshore in estuarine habitats or shallow coastal zones, providing important spawning and nursery grounds for commercial species such as plaice, sole and turbot. In order to protect these sites, conservation management is in place such as the River Medway Nursery Area No-Take Zone in the Kent and Essex IFCA. However, a greater coverage of designated no-take zones is needed to legally protect important spawning grounds, allowing juveniles to recruit into the fishery (Støttrup *et al.,* 2019). The mitigation score for this descriptor is ‘Moderate’ due to current management which would reduce the likelihood of an impact occurring on essential fish habitat.

2.2.5.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Moderate	Medium	Moderate	Medium

Within the literature, displacement of trammel net fishing effort due to the presence of an OFW is not often cited in aggregation with other net, and not distinguished as an individual métier. Therefore, for the purpose of this work, trammel nets have been assigned the same risk ratings as gillnets.

2.2.6 Hand and pole lines (LHP)

Hand and pole line (LHP) (Table 25) fishing is similar to recreational angling by the use of a rod or hand-held lines, but it also covers a range of different methods of fishing including jigging (Figure 9), trolling and pole and line fishing. All these fishing methods are typically deployed by a small inshore boat to target fish when they are feeding using artificial lures or live bait. UK commercial species include cod (*Gadus morhua*), mackerel (*Scomber Scombrus*), bass (*Dicentrarchus labrax*), pollack (*Pollachius pollachius*), saithe (*Pollachius virens*) and squid (*Loligo forbesi* and *Loligo vulgaris*). Due to the targeted nature and handling of the catch, this fishery produces high-quality products with minimal bycatch.

Jigging - Traditionally, this capture method would involve one person operating a single line with an artificial lure and barbless hook (the “jig”), usually resembling a small fish. The line would be moved in an up and down motion to attract nearby fish and hauled by hand or a gurdy (hand powered drum) once a fish is caught. Nowadays, most jig fisheries operate multiple jigs on each line to increase their catch rate and in the northern North Sea and west of Scotland, electronic jigging machines are used to operate several lines targeting squid, mackerel, saithe and pollack (MacDonald and Mair, 2017).

Trolling - When fishing for bass, small boats will tow a single or multiple lines (usually three) behind the boat, one from the stern of the boat and two on bamboo poles on either side of the vessel, at a speed of 1 knot [81]. These monofilament lines are weighted and approximately 50-60 m in length with an artificial rubber eel lure on the hook. When a fish is hooked, the line is hauled to the side of the boat by hand. For larger vessels, multiple lines will be deployed at once and rigged to allow individual lines to be hauled. This fishing method is popular in the south-west of England and occasionally larger UK vessels will use this method to target tuna, i.e., skipjack (*Katsuwonus pelamis*) and albacore (*Thunnus alalunga*), although the majority of vessels are French and Spanish flagged[82].

Pole and line fishing - Typically used to catch tuna in tropical waters, live bait, such as sardines or pilchard, are used to attract fish to the vessel. Minimal gear is used and mainly consists of a long pole, usually made of bamboo or modern fibreglass, with a short line and barbless hook (Montgomerie, 2015). Water is sprayed onto the surface to mimic a large shoal of fish which will send the tuna into a feeding frenzy, biting anything shiny such as a hook (Montgomerie, 2015). As many as 25 crew may

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[81] https://www.linecaught.org.uk/about/about-handline-fishing/

[82] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/trolling/

be onboard casting their rods into the water and once a fish is hooked, the fisherman will flick the line overhead onto the deck of the vessel to release the fish. The fish are put on ice and landed the same day to ensure a high sale and daily supply of fresh bait.

Additionally, fish caught using handline methods can be used as bait for other gears such as pots and traps. Different bait types include mackerel, herring and squid which can be caught by jigging to catch commercial species such as saithe, cod, whiting and haddock (MacDonald and Mair, 2017).

Table 25 Classification of hand and pole lines (LHP)

Métier	
Level 1	Fishing
Level 2	Hooks and Lines
Level 3	Rods and Lines
Level 4	Hand and pole lines (LHP)

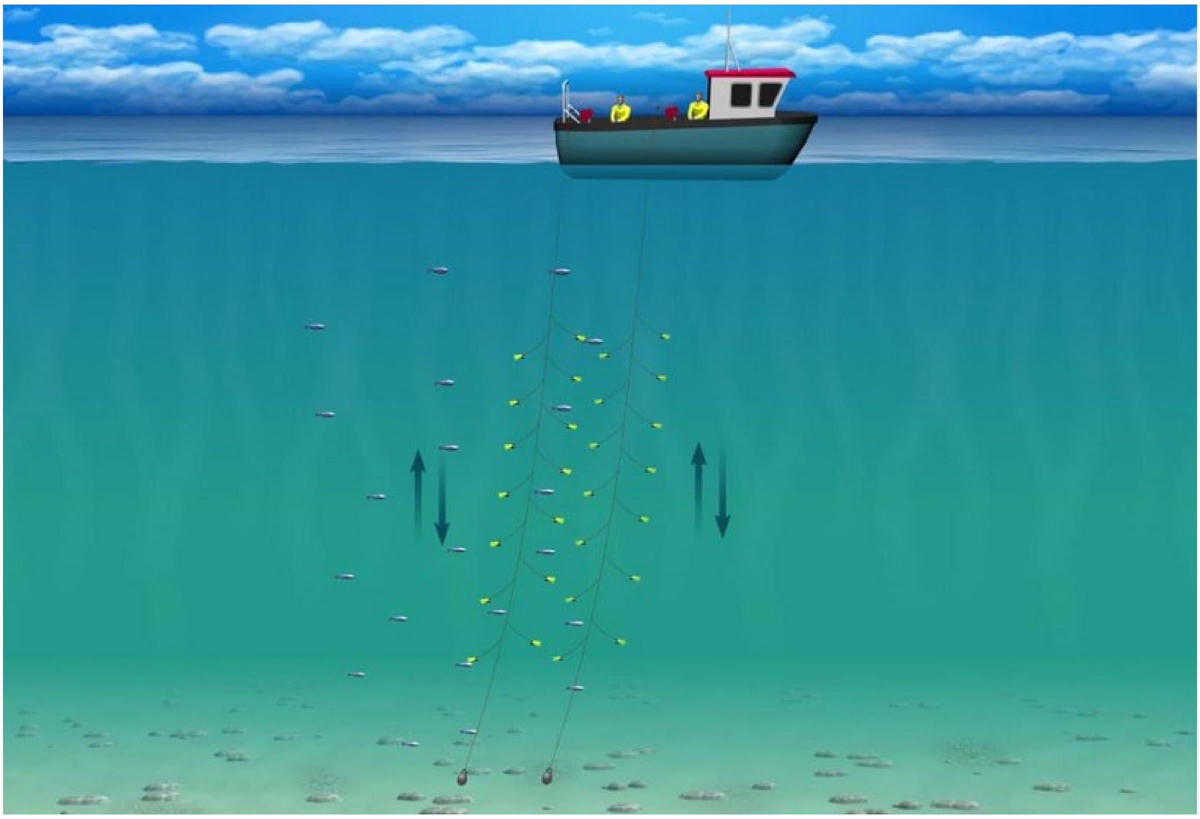

Figure 9 Jigging, a form of hand lining (LHP) (©Seafish. Reproduced with permission: www.seafish.org Seafish[83])

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[83] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/jigging/

2.2.6.1 Distribution of vessels

There is a total of 368 vessels operating hand and pole line gear in UK waters. The majority of which are UK flagged and under 10m, with a high concentration of vessels registered to ports in the Cornwall (159) and Devon and Severn (56) IFCA regions. A small number are registered in Scotland (36) and Wales (24) with no LHP vessels operating out of Northern Ireland. Furthermore, only 8% of the fleet is EU flagged, mainly Dutch (20), Irish (7), French (1) and Portuguese (1) (Appendix 2).

2.2.6.2 Risk ratings

The handline fishery is generally considered to be a very selective, low impact method of fishing due to negligible bycatch and no interaction with the seabed. Fishing usually operates on a seasonal basis and gear is deployed in specific areas where it is likely or known to be near a shoal of target commercial fish. The main risk associated with this gear type is as marine litter, due to the limited data and mitigation measures in place to reduce adverse effects on marine life.

2.2.6.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Moderate	Low

Hand lining is a selective, low impact gear targeting shoals of particular fish species and only catching a small percentage of the total quota for each species, due to a combination of limited allocated quota and generally low catch, but high-quality fish. Therefore, removal of target species by this fishing method is unlikely to have an impact on population abundance or demographic characteristics of commercial species (see Descriptor 3 for more information).

Within this fishery, the deployment of hooks may cause injury or mortality to seabirds, turtles, and marine mammals (see additional risk factor 2). However, bycatch is rare, and guidelines are available for the safe and humane handling of species (typically more focussed towards longlines but the general steps still apply)[84]. Fish discards associated with this fishing method, such as unwanted or undersized catch, exhibit relatively high survivability when released in accordance with best practice handling methods (Donald and Mair, 2016).

In UK fisheries, handlines and pole lines have no interaction with the seabed due to the majority of target fish being pelagic species. Therefore, there is no evidence of

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[84] https://www.bmis-bycatch.org/references?species_group=All&gear=1082&year%5Bmin%5D=&year%5Bmax%5D=&collection=13&keys=&mt=All&mc=All&pla=All

handlines damaging seabed habitats. However, in the Azores archipelago, a recent study reported two incidences of a single sponge caught as bycatch in a deep-sea handline fishery (Cyr, 2018). Overall, the study reported handline gears exhibited almost no associated bycatch as these incidences occurred during a total of 135 sets, representing 1-2% bycatch (Cyr, 2018).

2.2.6.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Unlikely	Medium	Strong	Low

Catch distribution by fleet is not reported to the métier level for hand and pole lines. However, UK landings for 2019 specified the quantity of demersal and pelagic fish caught by “gears using hooks” were 5,900 tonnes and 2,100 tonnes respectively, totalling 8,000 tonnes with a value of £17.3 million. This does not include landings by recreational anglers which in some cases, such as pollack stocks in the Celtic Sea and English Channel, can be substantial[85].

Mackerel stocks in the Northeast Atlantic have been decreasing since 2014 but fishing pressure is still above sustainable fishing levels due to lower catch limits[86]. Across all gear types, landings of mackerel by UK vessels in the UK and abroad exceeded 150,000 tonnes in 2019, however this is a 38.7% decrease from landings in 2015 (MMO, 2021). The UK handline fishery makes up a fraction of this, with the majority of hand lining occurring in the southwest where a special allocation of 1,750 tonnes of western mackerel is given to the South-West handline fishery, covering landings in ICES areas VII efgh[87]. On average, the total catch is approximately 900 tonnes for the local fishery in Cornwall, Devon, and Dorset[88]. Additionally, to protect Cornish stocks, a designated area covering 67,000km^2 in the southwest was set up in the 1980s and named the western mackerel box[89]. Here, all industrial scale fishing (pelagic trawling and purse seining) is prohibited to reduce fishing effort on juvenile mackerel.

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[85] ICES advice pollack Celtic Sea and English Channel 2021

[86] ICES advice Mackerel 2020

[87] UK Quota Management Rules for 2021

[88] https://www.cornwallgoodseafoodguide.org.uk/fish-guide/mackerel.php

[89] Western Mackerel Box

The latest ICES stock assessment for bass reported the stock biomass was increasing with fishing pressure at sustainable levels, of which “lines” (assumed hand lines) accounted for an estimated 45% (equal to 468.9 tonnes) of commercial landings in ICES divisions 4.b–c, 7.a, and 7.d–h[90]. However, commercial fishing restrictions are still in place to help restore population sizes. Under the current “Bass Fishing Guidance 2020”, vessels operating hooks and lines can retain and land a maximum catch of 5.7 tonnes per year between the months April to January (fishery closed February and March)[91].

For pollack stocks in the Celtic Sea and English Channel, the stock structure is unknown and current stock assessments rely solely on commercial catch data[49]. There is a multiannual management plan in place for EU stocks, however there is no shared management plan with the UK. When data is limited on fishing pressures, a precautionary approach is used and has been advised by ICES since 2013. It is important to note that recreational catches are estimated to be substantial, with annual estimates of approximately 3,500 tonnes (Radford *et al.*, 2018) compared to UK commercial landings of 1,534 tonnes in 2019 (MMO, 2021).

Currently, there is no management, quota, or assessment for squid stocks in the UK. A recent assessment by Malhomme *et al.,* (2015) showed both species of squid (*Loligo forbesii* and *Loligo vulgaris*) have been intermittently overfished in the English Channel since 1990, depicted as F/F_{MSY} above 1 and B/B_{MSY} below 1. However, handline fisheries targeting squid are small scale and are not likely to lead to overfishing compared to demersal trawls which are the primary gear type targeting squid across the UK- mainly North Sea, West of Scotland, Celtic Sea and English Channel- and more likely to have a damaging impact on stock size. Additionally, recreational anglers contribute to a high proportion of total landings (Lischenko *et al.* 2021), as well as create high demand for small ‘hook-size’ squid to use as premium bait[92]. As is the case for many cephalopod species, squid have a short life cycle, high reproductive rate, and rapid growth[93], making them both highly susceptible to recruitment overfishing[94], but capable of rapid recovery. They are also known to be influenced by environmental variations. Therefore, management measures should consider environmental conditions, their life history traits and additional fishing

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[90] ICES advice bass 2021

[91] Bass Fishing Guidance 2020

[92] Squid Fishing in UK Waters-Seafish 2009

[93] Sealifebase.org

[94] The rate of fishing above which the recruitment to the exploitable stock becomes significantly reduced.

pressure from recreational anglers to improve the accuracy and effectiveness of stock assessments and fishery regulations.

In the UK, handlining is conducted on a small scale and focusses more on quality than quantity of catch. It is also relatively inefficient and overall is likely to have little impact on stock size, depending on the stock status of target species and level of fishing effort. Additionally, in the southwest of England where the majority of handlining occurs, some fishermen are part of the South-West Handline Fishermen's Association, formed in 1987[95]. Here, fishermen follow best practice guidelines in fishing and handling methods and tag each fish to ensure full traceability of the catch. In 2000, the Association received accreditation from the Marine Stewardship Council (MSC) for its mackerel handline boats and now represents over 100 handline fishermen in southwest England catching mackerel, bass, pollack and squid.

2.2.6.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	N/A	Low

Handline fishing is a very precise fishing method, generally targeting one species and releasing any unwanted catch back into the sea. However, it is important to note that incidences of deep-hooking can occur during jigging, with one study reporting 4% of Atlantic cod were deep-hooked in which the likelihood of bleeding was significantly higher and resulted in the highest mortality rates (Weltersbach and Strehlow, 2013). Additionally, capture depth should be considered in catch-and-release mortality due to the potential consequences of hydrostatic effects (Weltersbach and Strehlow, 2013).

Hand-liners remove a very small percentage of the allocated quota per species and therefore there is a low risk of any long-term effects to the abundance and reproduction of target species, compared to gears such as pelagic trawlers.

Fishing can occur at various depths in the water column, depending on the location of the target species, but do not interact with the seabed. Therefore, habitat abrasion and penetration are unlikely, although there is a small chance of gear snagging on biogenic structures.

Mitigation is not relevant for this gear type.

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[95] https://www.linecaught.org.uk/

2.2.6.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

Hand line fisheries have no contact with the seabed as the majority of UK target species, such as mackerel and squid, inhabit pelagic waters. Therefore, there is no associated risk to the benthic ecosystems and its functioning from this fishing gear.

Mitigation is not relevant for this gear type.

2.2.6.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	Medium	Weak	Medium

Discarded or lost fishing lines can contribute to marine litter and incur entanglement and ingestion issues for marine organisms (Moore, 2008, Thiel *et al.*, 2018, Abalansa *et al.*, 2020). Fishing lines are made of synthetic monofilament fibres and are poorly degradable in the marine environment, continuing to threaten marine life for many years during which the total number of injuries and mortalities from bycatch cannot be readily known. Ingestion of lost hooks can cause internal bleeding and one study estimated a 16% chance of losing a hook a day during a field study of the northern cod fishery in Newfoundland (Rouxel, 2017).

Due to the limited number of studies on gear loss from line fisheries, it is hard to quantify the rate and volume of lost fishing lines. In the UK, a study by the European Commission reported fishing line (from anglers) to be among the top 10 items of beach litter found during every Marine Conservation Society (MCS) Beachwatch Big Weekend survey since 1998 (Veiga *et al.*, 2016). In 2017, Richardson et al (2019) estimated 29% of all lines were lost from global fisheries. This was further broken down into subcategories which predicated the percentage of gear loss was 23% for handlines, 65% for pole-lines, 20% for longlines including 17% loss for hooks from longlines and 22% for trolling lines (Richardson *et al.*, 2019).

Due to the widespread issue of derelict fishing lines, research into biodegradable monofilament line is underway. In the English Channel, a European funded project INdIGO, which started in 2019, is conducting a survey on fishermen’s willingness to use biodegradable fishing gear, as well as develop prototype biodegradable gear which best meets their needs and expectations and improve recycling of existing gear[96]. All UK interviews are being conducted by project partner Cefas[97].

2.2.6.2.6 **Descriptor 11.** Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al.*, 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by fishing gears.

Hand and pole lines have no interaction with the seabed and therefore there is no introduction of energy from this gear type to adversely affect the ecosystem during fishing. No known mitigation is reported for the reduction of underwater noise by fishing gears.

Mitigation is not relevant for this gear type.

2.2.6.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	Moderate	Low

Commercial fish bycatch associated with handline fishing is considered to be very low due to the targeted nature for catching a single species. Expert fisher knowledge and experience is utilised in this fishery to target specific areas where fish are known to congregate. Size selection of fish can be managed through the selection of different sized hooks to reduce capture of undersized fish[98]. In the event of non-target or undersized fish, discard survivability is likely to be high due to careful handling of hooks onboard or to the side of the boat. However, certain factors should be considered such as the depth of capture and the possibility of deep-hooking fish, both of which would result in higher mortality rates post catch-and-release (Weltersbach and Strehlow, 2013).

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[96] https://www.channelmanche.com/en/projects/approved-projects/innovative-fishing-gear-for-ocean/

[97] https://indigo-interregproject.eu/en/fishermen-survey/

[98] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/jigging/

2.2.6.2.8 Additional risk factor 2. Protected (ETP) species bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Moderate	Low

Handlines and pole-lines are a highly selective form of fishing and are therefore unlikely to take bycatches of ETP species.

In 2018, the Cetacean Bycatch Observation Scheme (ME6004) observed 41 days on hand line vessels targeting bass, mackerel and pollack in ICES are VIIe. No marine mammals were caught during the survey (Northridge *et al.*, 2019). Additionally, a report by the Working Group on Bycatch of Protected Species (WGBYC) classified hand and pole lines gear (LHP) as low risk for turtles, diving birds, surface birds, seals, dolphins, harbour porpoise and large whales (Bonanomi *et al.*, 2019).

Where bycatch does occur in hook fisheries (i.e., longlines, troll, jig, and handlines) it is usually when gear is baited or when species feed opportunistically on harvested fish caught on the hooks. In the Mediterranean, small groups (2-5) of cetaceans such as long-finned pilot whales, Risso's dolphins, striped dolphins and sperm whales have been observed feeding on illuminated handlines of squid fisheries (Mussei *et al.*, 1998). Seabirds are also vulnerable when hooks are near the surface, although this is more likely to occur in pelagic longline fisheries (Petersen *et al.*, 2008, EU N2K Group, 2015). In some cases, seabirds may be brought onboard and there are simple guidelines available on best practices for handling and releasing hooked individuals[99]. By reducing the accessibility of hooks to seabirds during setting and hauling, bycatch may be minimised.

2.2.6.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	N/A	Low

The minimum landing sizes[100] for target species are as follows: 42 cm for bass, 35 cm for cod, 20 cm for mackerel (30 cm in the North Sea), 30 cm for pollack and 35 cm for saithe. Currently, there is no minimum landing size for squid fisheries. Non-compliance with size limits can pose a significant risk to stock recruitment and have knock-on effects on the health and biomass of the adult population.

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[99] https://abcbirds.org/wp-content/uploads/2015/05/Seabird-Bycatch-Solutions_2016_InternetRequired_LowRes.pdf

[100] https://www.gov.uk/government/publications/minimum-conservation-reference-sizes-mcrs/minimum-conservation-reference-sizes-mcrs-in-uk-waters

There are no recent publicly available reports of non-compliance by LHP vessels against minimum landing size or quota species in English inshore waters.

2.2.6.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	N/A	Low

There are no recent reports of non-compliance against area restrictions.

2.2.6.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Unlikely	Low	N/A	Low

Potential impacts of hand and pole lines on essential fish habitat may include snagging and breaking of fragile biogenic reef structures (EU N2K Group, 2015). However, the scale of damage is very small and will have negligible effects on the ecosystem services provided by these benthic habitats, especially compared to other more destructive gears.

Mitigation is not relevant for this gear type.

2.2.6.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	Moderate	Low

The majority of wind farms in the UK are located in the offshore region. Exceptions to this, that are currently active or in operation include Blyth Demo Phase 1 (NIFCA), Teesside (NIFCA), Westermost Rough (NEIFCA), Humber Gateway (NEIFCA), Inner Dowsing and Lincs (EIFCA), Scromby Sands (EIFCA), London Array (KEIFCA), Thanet (KEIFCA), Kentish Flats (KEIFCA), Gunfleet Sands (KEIFCA), Rampion (KEIFCA), Burbo Bank (and Burbo Bank Extension) (NWIFCA), West of Duddon Sands (NWIFCA), Barrow (NWIFCA), Ormonde (NWIFCA) and Waldney 1, Waldney 2 and Waldney Extension 4 (NWIFCA). Hand and pole line vessels are usually small and operate within the inshore region. Given this spatial overlap, there is potential for conflict of use and / or displacement of fishing due to loss of fishable areas. However, there is no equivocal evidence in the literature that offshore wind farms (OWF) displace hand and pole line fishing activity.

During a study looking at changes to UK fishing practices due to OWF, it was noted there may be some commercial hand lining occurring on Burbo Bank (Gray *et al.*, 2016). However, most of the local vessels are under 10m and therefore data is limited as vessels did not have to complete fish log-books at the time the study was conducted.

In order to mitigate displacement of fishing activity, stakeholder consultation and capacity building is essential to provide dialogue opportunities and ensure all relevant stakeholders are involved in the process. This is implemented during the initial stages of development to mitigate conflicts and improve co-existence. However, one of the issues raised by a fisherman in Gray et al. (2019) was the inaccurate information on the importance of fishing grounds which are developed into wind farms. Here, improved consultation and information flow between wind farm developers and fishermen would help better inform decision-making on construction sites with the least risk of disruption and environmental impact to fishing activities. In regard to the scoring for mitigation for this descriptor, whilst there are potential benefits and reduced risk for some mitigation, it may also increase risk for others. The potential changes from mitigation are low and therefore the mitigation remains as “Moderate” and the residual risk would remain as “Low”.

2.2.7 Hook and lines (LX)

Hook and lines cover all gear types where the fish are attracted to a natural or artificial bait (lure) fixed to a hook at the end of a monofilament line (Figure 10 and Table 26). Hooks may be used singly or in large numbers and come in a variety of shapes and sizes, most commonly the traditional J-hook and circle hook (Taylor, 2002). These gears can be deployed at various depths and locations, including from the shore, and are applied during different fishing methods such as trolling (Taylor, 2002).

In England, most vessels operate on a small-scale basis, targeting species within the inshore region. These small vessels will usually operate the lines by hand or use a handed powered winch called a gurdy, typically used when handlining for mackerel. The line will then be hauled through a metal “stripper” to unhook the fish and then reshoot the line immediately after all the fish are harvested (Montgomerie, 2015). In larger-scale fisheries, powered line haulers are used to automatically haul the line to the surface (e.g., jigging machines), increasing the catch per unit effort by multiple lines being fished at once (MacDonald and Mair, 2017).

A range of pelagic, demersal, and benthic species can be targeted using a hook and line. Commercially important species include, but are not limited to, cod (*Gadus morhua*), mackerel (*Scomber Scombrus*), bass (*Dicentrarchus labrax*), pollack (*Pollachius pollachius*), squid (*Loligo forbesi*), skipjack tuna (*Katsuwonus pelamis*) and albacore tuna (*Thunnus alalunga*).

Table 26 Classification of hook and lines (LX)

Métier	
Level 1	Fishing
Level 2	Hooks and Lines
Level 3	Rods and Lines
Level 4	Hooks and lines (LX)

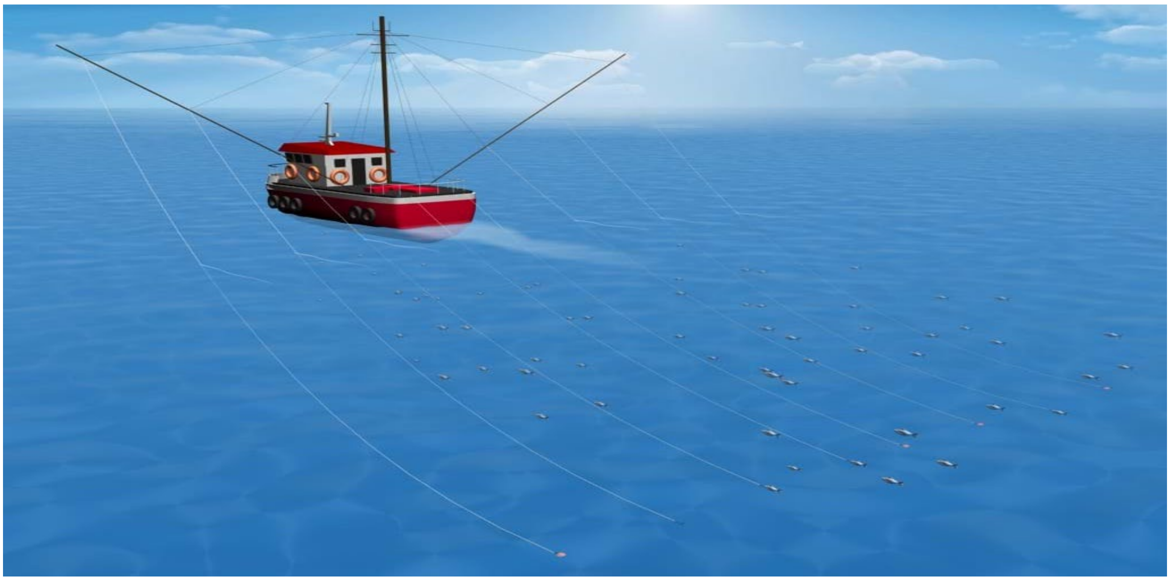

Figure 10 Trolling, fishing method using hooks and lines (LX) (©Seafish. Reproduced with permission: www.seafish.org[101])

2.2.7.1 Distribution of vessels

Within UK waters, there are no EU vessels registered to using hook and line gear. Nevertheless, other fishing methods using hook and lines, such as hand and pole lines (LHP) and set longlines (LLS), are in use and described under Sections 2.2.6 and 2.2.8 of this report.

For the UK fleet, hook and lines is almost exclusively made up of under 10 m vessels (bar one vessel of undetermined length), with the highest number of vessels registered to ports in England (70), of which the Southern (23), Devon and Severn (22) and Sussex (16) IFCA regions have the highest concentration. Wales and the Channel Islands are the only other countries with 24 and 8 vessels, respectively (Appendix 2). However, as previously mentioned, other forms of hook and line fishing gears are employed in the UK and not included under this métier.

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[101] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/trolling/

2.2.7.2 Risk ratings

Hook and line fishing is a very sustainable method of fishing with minimal impact on the surrounding environment due to low bycatch and no interaction with the seabed. Fishing generally operates on a small-scale basis due to the low numbers of larger vessels employing hook and line gear (within this métier and other related methods). The main concerns associated with this gear is marine litter and, to a limited extent, bycatch of non-target species such as seabirds.

2.2.7.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Moderate	Low

Hook and line fishing is a highly selective gear targeting a single species. A very small percentage of the population is removed due to limited quota and low fishing effort from UK vessels. Bycatch mortality is also low due to immediate hauling when a fish is hooked and quick release if it is a non-target species (Donald and Mair, 2016). Bycatch survival and size selectivity have been shown to increase through the use of different sized and shaped hooks. For example, the use of modern circle hooks has shown to increase the size, total catch, and survival of bycatch species due to the shallow hooking and subsequent easier removal of the hook (Taylor, 2002, Kerstetter *et al.*, 2006, Cambie *et al.*, 2012).

Hook and line fisheries are not generally associated with the seafloor and therefore there are little studies evaluating their impact on seabed habitats and species. Therefore, the biodiversity risk of this fishery has been scored as low.

2.2.7.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Unlikely	Medium	Strong	Low

Overall, passive gears, under which “gears with hooks” is classified, made up for only 13% of the total UK landings in 2019, of which gears, and hooks contributed 10%. This supports the general view of hook and line fishing being a very low impact and sustainable fishing method to catch fish.

The main fish stocks targeted by hook and lines (LX) have been described under Hand and Lines (LHP) which are the dominate fishing method under Hooks and Lines gear class. Therefore, the same risk score has been used.

2.2.7.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	N/A	Low

Hook and line fishing is a very precise fishing method, generally targeting one species and releasing any unwanted catch back into the sea. Commercial fishers remove a very small percentage of the allocated quota and therefore there is a low risk of any long-term effects to the abundance and reproduction of target species, compared to gears such as pelagic trawlers.

Fishing can occur at various depths in the water column, depending on the location of the target species, but do not interact with the seabed. Therefore, habitat abrasion and penetration are unlikely, although there is a small chance of gear snagging on biogenic structures.

Mitigation is not relevant for this gear type.

2.2.7.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

Hook and line fishing methods do not come into contact with the seabed. Therefore, there is a low risk associated with damage to the marine habitat. Snagging, pulling and breaking benthic structures such as biogenic reefs may occur but are likely to only have a small, localised impact on the seabed and will not affect the integrity of the ecosystem.

Mitigation is not relevant for this gear type.

2.2.7.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	Medium	Weak	Medium

Lost hooks and lines, from all forms of hook and line fishing gear, can cause serious biological threats for marine animals (Abalansa *et al.*, 2020). The main concerns include ingestion, entanglement and habitat damage compared to other static gears which are more likely to “ghost fish” (FAO, 2009). One study reported hooks and lines, long-line gear and bait hooks made up 4%, 12% and 2%, respectively, of the fishing gear ingested or entangling a survey of 386 stella sealion (*Eumetopias jubatus*) in Northern British Columbia and Southwest Alaska (Raum-Suryan *et al.*, 2009). However, the rate of injury or mortality caused from hooks and lines is often an underestimate of what is actually happening.

When ingested, hooks can become lodged inside the animal and cause damage to the mouth and lower digestive system, affecting the animal’s ability to forage and feed effectively (Butterworth, 2016). On the other hand, monofilament fishing lines is a very dangerous form of marine litter as it represents a large portion of entanglement records (Consoli *et al.*, 2018). Entanglement in fishing lines can affect an animal in many ways, depending on the severity of the restriction or damage inflicted. Incisive wounds, trauma, skin lesions or an inability to forage, feed or breathe will have a profound influence on the outcome of interactions with marine debris (Butterworth, 2016). Injury’s characteristic of monofilament lines can often be clearly defined on an animal’s body. These chronic wounds can lead to tissue damage and infection, with debilitating consequences on fitness and welfare (Campagna *et al.*, 2007). For sessile benthic fauna, such as habitat-forming sponges or reef-building corals, entanglement in fishing line can eventually lead to pulling, skin abrasion, epibiosis and infection, which Yoshikawa and Asoh (2004) suggested could result in the mortality of whole coral colonies.

Initiatives to reduce the volume of ALDFG mainly comprise of appropriate disposal and recycling units for monofilament lines, such as the Anglers National Line Recycling Scheme (ANLRS)[102] and Odyssey Innovations which provides waste bins for fishing lines and nets to be recycled[103]. Additionally, the development of resistant and biodegradable monofilament line is underway in France (Deroine *et al.*, 2019), but current efforts in the UK are mainly focussed on gillnets such as the INdIGO project[104]. Overall, while recycling initiatives help reduce marine litter, it does not prevent it and greater focus on designing biodegradable fishing equipment should be a priority.

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[102] https://www.anglers-nlrs.co.uk/

[103] https://www.odysseyinnovation.com/

[104] https://www.channelmanche.com/en/projects/approved-projects/innovative-fishing-gear-for-ocean/

2.2.7.2.6 Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al.*, 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by fishing gears.

Hook and line fishing has no interaction with the seabed and therefore there is no introduction of energy from this gear type to adversely affect the ecosystem during fishing. No known mitigation is reported for the reduction of underwater noise by fishing gears.

Mitigation is not relevant for this gear type.

2.2.7.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	Moderate	Low

Hook and line fishing is a highly selective fishing method, often targeting a single species in a targeted area. For example, commercial vessels often use sonar to find schooling mackerel and set their lines at the appropriate depth, usually between the surface and 40 m (Godø *et al.*, 2004). Bycatch is therefore reduced, but undersized and non-target species can still be hooked (Miller *et al.*, 2017). Nevertheless, most commercial bycatch can be utilised or released alive, depending on the depth and where the fish was hooked which can affect catch-and-release mortality (Weltersbach and Streholw, 2013).

Minimising bycatch is a significant challenge in all fisheries and is mainly achieved in hook and line fishing by targeting specific fishing grounds or depths and changing the size or type of hook. One study reported modern circle hooks resulted in both a higher CPUE for yellowfin tuna (2.5 times higher) and lower mortality for all species (31%) compared to traditional J-hooks (42%) (Taylor, 2002).

2.2.7.2.8 Additional risk factor 2. Protected (ETP) species bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Moderate	Low

Bycatch is low for hook and line fisheries and is likely to be more prevalent when they occur in the marine environment as marine debris. In this case, the risk of entanglement is much higher and is described in further details under Descriptor 10.

However, during fishing operations, bycatch can occur, with longline fisheries posing the highest threat to ETP species, especially seabirds. In the UK, the most frequently recorded seabird caught in longline fisheries were fulmars (*Fulmarus glacialis*) with preliminary estimates of overall bycatch lying between 2200 and 9100 per annum (Northridge *et al.*, 2020). Additional species overserved during the UK Bycatch Monitoring Programme included gannets (*Morus bassanus*) and great black-backed gull (*Larus marinus*), gull spp. (*Laridae*), kittiwake (*Rissa tridactyla*) (Northridge *et al.*, 2020). Methods to mitigate seabird bycatch in the UK offshore longline fleet mainly consist of tori lines[105] and offal disposal routines. The overall effectiveness is increased when used in combination with other measures such as line weighting and night-setting[106].

Other measures employed to prevent significant injury to target, or non-target species include the use of circle hooks instead of traditional J-hooks. Circle hooks are more likely to result in shallow hooking which makes the hook removal much easier (Zollett and Swimmer, 2019). It also reduces the frequency of hooking fish in the throat or gut as compared to J-hooks, simultaneously increasing the value of target species and survival of bycatch species (Taylor, 2002, Kerstetter and Graves, 2006).

Safe handling of bycatch species is also important for protecting vulnerable marine populations. Three strategies to increase post-capture survival of marine species include: reducing immediate mortality, minimising injury that results in delayed mortality, and reducing stress that can lead to death (Zollett and Swimmer, 2019). An example of safe handling in hook fisheries includes the use of de-hooking tools or if the hook is ingested, the line should be cut as close to the hook as possible and the animal should be released away from the gear to reduce the likelihood of recapture (Zollett and Swimmer, 2019).

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[105] A tori line is a line with streamers towed from a high point, ideally 8 m above the water, near the stern to scare birds away from baited hooks

[106] https://www.birdlife.org/sites/default/files/attachments/ENG%20FS_7a%20Pelagic%20streamer%20lines%20EM%20mods_SEPT14_w.pdf

2.2.7.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	N/A	Low

There are no recent reports of non-compliance against minimum landing size or quota species.

2.2.7.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	N/A	Low

There are no recent reports of non-compliance against area restrictions.

2.2.7.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

Hook and line fishing methods have minimal contact with the seabed and therefore there is a low risk associated with damage to essential fish habitat. Potential impacts include snagging, pulling, and breaking of benthic structures such as fragile biogenic reef structures. However, the scale of damage is very small and will have negligible effects on the ecosystem services provided by these benthic habitats, especially compared to other more destructive gears.

Mitigation is not relevant for this gear type.

2.2.7.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	Moderate	Low

The majority of wind farms in the UK are located in the offshore region. Exceptions to this, that are currently active or in operation include Blyth Demo Phase 1 (NIFCA), Teesside (NIFCA), Westermost Rough (NEIFCA), Humber Gateway (NEIFCA), Inner Dowsing and Lincs (EIFCA), Scromby Sands (EIFCA), London Array (KEIFCA), Thanet (KEIFCA), Kentish Flats (KEIFCA), Gunfleet Sands (KEIFCA), Rampion (KEIFCA), Burbo Bank (and Burbo Bank Extension) (NWIFCA), West of Duddon Sands (NWIFCA), Barrow (NWIFCA), Ormonde (NWIFCA) and Waldney 1, Waldney 2 and Waldney Extension 4 (NWIFCA). Hook and line vessels are predominantly under 10m and most likely operate within the within the inshore region. Given this spatial overlap, there is potential for conflict of use and / or displacement of fishing due to loss of fishable areas. However, there is no equivocal evidence in the literature that offshore wind farms (OWF) displace hook and line fishing activity.

In order to mitigate displacement of fishing activity, stakeholder consultation and capacity building is essential to provide dialogue opportunities and ensure all relevant stakeholders are involved in the process. This is implemented during the initial stages of development to mitigate conflicts and improve co-existence. However, one of the issues raised by a fisherman in Gray et al. (2019) was the inaccurate information on the importance of fishing grounds which are developed into wind farms. Here, improved consultation and information flow between wind farm developers and fishermen would help better inform decision-making on construction sites with the least risk of disruption and environmental impact to fishing activities. In regard to the scoring for mitigation for this descriptor, whilst there are potential benefits and reduced risk for some mitigation, it may also increase risk for others. The potential changes from mitigation are low and therefore the mitigation remains as “Moderate” and the residual risk would remain as “Low”.

2.2.8 Longlines (LL) and Set longlines (LLS)

Longlining activity in UK fisheries tends to be dominated by set demersal longlines, whereas pelagic longlines are more prevalent in tropical fisheries where there are concentrations of large pelagic species. For the purpose of this work, longlines and set longlines (LLS) have been aggregated together and scored simultaneously.

Longlines are a static sub-set of the gear class hooks and lines (Table 27), which consists of a long length of line, termed the main line, made from light rope or heavy nylon monofilament. To this main line, multiple branch lines with baited hooks on are attached at regular intervals. This rig can be set on the seabed or in midwater, depending on the target species, with a buoy at either end (Table 27, Figure 11). Longlines are usually baited and set in open water untended for a period. The number of hooks and the length of the mainline depend on the scale of the operation and the area of fishing grounds.

Table 27 Classification of Longlines (LL) and Set longlines (LLS)

Métier	
Level 1	Fishing
Level 2	Hooks and Lines
Level 3	Longlines
Level 4	Longlines (LL) / Set longlines (LLS)

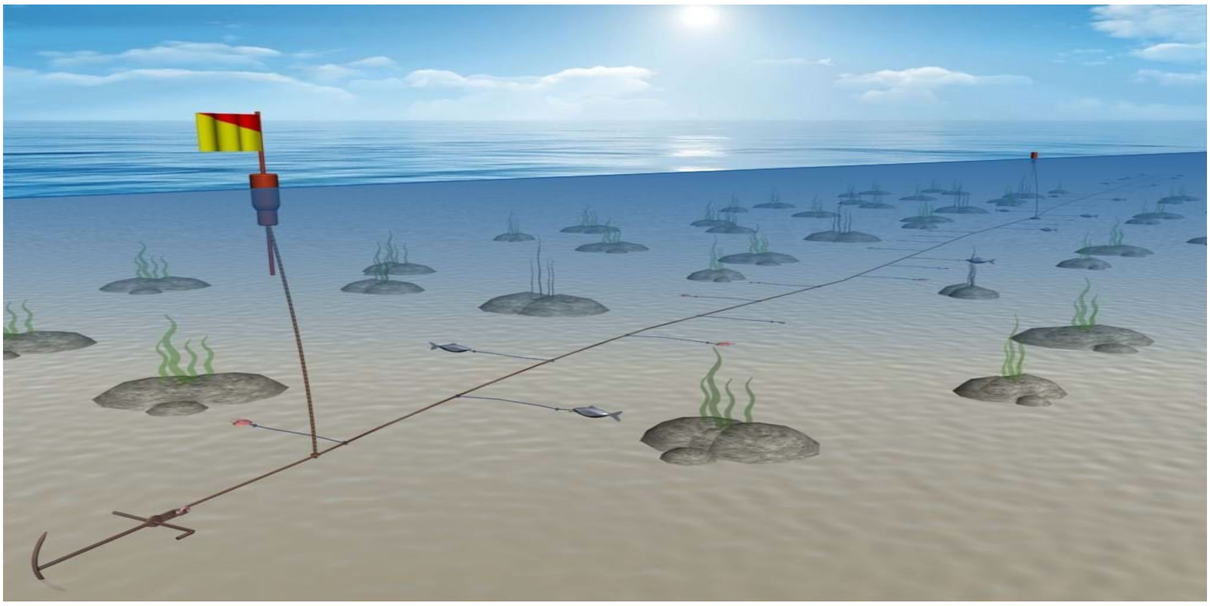

Figure 11 Example of a demersal longline (LL) (Source: Seafish[107])

2.2.8.1 Distribution of vessels

There are 63 longline (LL) vessels and 122 set longlines (LLS) licensed to fish in UK waters. Over 50% of which are EU vessels, the majority of which Spanish set longlines. Longline fishing makes up a small proportion of UK vessels. Longline fishing operations take place on a small scale by a low number of vessels across several IFCA regions, usually on a seasonal basis (Appendix 2), and primarily focused offshore, north of Scotland.

2.2.8.2 Risk ratings

Numerous studies and reviews have examined and reported the effects of longline fisheries across a global scale (Glass *et al.*, 2000; Lewison and Crowder 2007; Bull 2007; Pon *et al.*, 2007; Anderson *et al.*, 2011; Piere and Goad 2013; Pham *et al.*, 2014). The specific focus of this literature is on the impacts of longline fisheries on seabird bycatch and mortality. However, very few studies focus on UK longline fisheries, which may be reflective of the low numbers of longline vessels fishing in English waters and low environmental impact in comparison to other métiers.

2.2.8.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Very Strong	Low

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[107] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/long-line/

Longline vessels can affect biodiversity through the removal of target species, non-target species (bycatch) and abrasion on the seafloor during the process of setting and hauling lines. Due to the low numbers of LL vessels the risk to biodiversity through the removal of target species and abrasion on the seafloor are reported not to be significant and unlikely. However, the removal of non-target species, especially birds, is the most widely reported threat to biodiversity amongst longline fisheries (Anderson *et al.*, 2011; Miles *et al.*, 2020).

Belda and Sanchez (2001) reported a bycatch rate of (0.16±0.69 birds per 1000 hooks set) in the longline fishing fleet around the Columbretes Islands (Spain) which was extrapolated to estimate that c. 656-2829 birds were killed annually, of which 66% were Cory's shearwaters (*Calonectris diomedea*). The majority of observed seabirds were sexually mature which could affect the breeding success of the local population, with the number of breeding pairs of Cory's shearwaters declining by 45% in two years (Belda and Sanchez, 2001). During the rearing season, adult mortality can result in the other parent deserting the chick leading to breeding failures and exacerbating population decline (Belda and Sanchez, 2001).

Actual data on seabird bycatch for UK fisheries in limited, outside of those UK-registered longline vessels operating in the Falkland Islands, South Georgia, and other UK Overseas Territories such as Tristan da Cunha (Anderson *et al.*, 2011). A recent study conducted by Northridge at al., (2020) investigating seabird bycatch mortality in three UK fishing sectors reported five bird species caught by UK offshore longline fisheries; fulmar, gannet, great black-backed gull; gull sp.[108] and kittiwake, over 90% of which were fulmars and dead upon inspection. However, all longline bycatch observations occurred outside of the English 12nm limit in Scottish and Irish offshore waters and therefore there is a lack of information for the inshore region where bycatch may be higher closer to breeding colonies. Additionally, these figures only provide insights into the potential bycatch levels within UK fisheries operating in the UK and adjacent waters and therefore not reflective of the known non-UK effort within the same areas.

Løkkeborg 2008 describes an array of mitigation measures that have been developed, tested, and proved to have potential in reducing incidental capture of seabirds in longline fisheries. For example, a two-year research programme comparing seabird bycatch in demersal longline fisheries reported that adding weight to longlines reduced seabird bycatch relative to the control by 76% in a cod fishery (Melvin *et al.*, 2001). Streamer lines proved most effective in the north-east Atlantic longline fishery where only two birds were caught from a total of 185,000 hooks, a 99% reduction from hooks with no mitigation (Løkkeborg and Robertson, 2002**;** Løkkeborg 2008).

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[108] Could not be identified to species level

2.2.8.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Moderate	Low

Scores assigned under this descriptor are reflective of the three demersal species with the highest landings into the UK by UK and foreign vessels 2019[109]; haddock; cod and saithe.

According to ICES Advice 2021 on fishing opportunities, catch and effort, both the southern Celtic Seas and English Channel and North Sea, West of Scotland haddock stocks are reported to be sustainably fished (i.e., below MSY) and of good reproductive capacity (i.e., above spawning stock biomass), based on ICES MSY or Management Plan approach (Table 28). Similar advice revealed that all cod and saithe stocks are unsustainably fished stocks. However, 'gears with hooks' only contributed to 3.61% of all demersal species landed into the UK by UK and foreign vessels in 2019. Therefore, it could be suggested that the status of stocks is not entirely reflective of the risk posed by longline vessels.

Table 28 Stock status of top three commercial fish stocks targeted by longline vessels, by landings (tonnes)

Species	Stock	Fishing pressure (F_{MSY})	Spawning Stock Biomass (B_{MSY})	Status
Cod	North Sea and eastern English Channel	Above	Below	Unsustainable
	Celtic Sea and western English Channel	Above	Below	Unsustainable
Haddock	southern Celtic Seas and English Channel	Below	Above	Sustainable
	North Sea, West of Scotland, Skagerrak	Below	Above	Sustainable
Saithe	North Sea, Rockall and West of Scotland, Skagerrak and Kattegat	Above	Below	Unsustainable

2.2.8.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

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[109] https://www.gov.uk/government/statistics/uk-sea-fisheries-annual-statistics-report-2019

There is no empirical evidence to suggest that longlines pose a risk to food web interactions that would impact the long-term abundance and reproduction of target and non-target species.

Mitigation is not relevant for this gear type.

2.2.8.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	N/A	Low

The interaction between longlines and the seafloor is minimal due to the small spatial footprint of the gear. Anchors located at the end of longline gear are reported to cause minor impacts to the seafloor (Pham *et al.*, 2014) in terms of the spatial extent distribution of physical loss and primarily occur only when the gear is hauled.

Mitigation is not relevant for this gear type.

2.2.8.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Weak	Low

Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG) can contribute to unaccounted mortality of target and non-target species through ghost fishing, habitat alteration and degradation and dispersal of microplastics into marine food webs.

The full impact of ALDFG on marine taxa within the UK, is difficult to ascertain as the majority of studies focus on beached and or floating ALDFG within coastal areas, with much less emphasis on underwater surveys (Ten Brink *et al.* 2009; Mouat *et al.* 2010; Allen *et al.* 2012).

There has been substantial effort to summarise the degree to which different types of fisheries produce ALDFG. The types of ALDFG most often cited in recent literature are gillnets; trammel nets, pots and traps, bottom trawl nets, and longlines (Gilman *et al.* 2016; Barboza *et al.* 2019; Lively and Good 2019; Richardson *et al.* 2019). In reviewing studies that contain quantitative information on fishing gear losses globally, Richardson *et al.*, (2019) reports that publications reporting on lines (n=8) (1975 – 2017) to be considerably lower than those reporting on traps (n=49) and nets (n=20). Further, a study assessing gear-specific relative risks from derelict gear revealed that demersal longlines are one of the lowest risk gears with scores in the 25% percentile based on derelict gear production rates, gear quantity indicators of catch weight and fishing grounds area, and adverse consequences from derelict gear (Gilman *et al.*, 2021).

Gillman *et al.* (2016) states that authorities make limited use of the possible measures available to tackle issues of ALDFG e.g., gear marking, gear tracking and incentivised responsible disposable. This can be said for the UK where few management measures have been rolled out on a national scale.

2.2.8.2.6 Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	N/A	Low

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al.*, 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by fishing gears.

Although longlines come into contact with the seafloor during setting and hauling, the nature of these interactions and resultant noise are likely to be brief and discrete and therefore pose a low risk in terms of their effect on the ecosystem. No known mitigation is reported for the reduction of underwater noise by fishing gears.

Mitigation is not relevant for this gear type.

2.2.8.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Strong	Low

Demersal longline fisheries, although target a plethora of species, can be very size selective by variation in hook size and species selective by regulation on where the gear is set, water depth and bait used (Pérez Roda *et al.*, 2018). However, the quota issued for demersal species can often vary substantially (Table 29). In the absence of quota for a particular species, that species can choke the fishery limiting their ability to continue fishing due to the regulations of the Landing Obligation (LO). This increases the risk of non-compliance through regulatory discarding to continue fishing practises and avoid consequential loss in revenue. Limited estimates for demersal longline fisheries exist, with quantitative data focusing on discard rates amongst pelagic longline fisheries.

Table 29 Total quota, catch (tonnes) and uptake (%) by EU Member States: 2019

Species	Stock	Adapted Quota (tonnes)	Catch Total (tonnes)	Uptake (%)
Cod	North Sea and eastern English Channel	1,911	38	2
	Celtic Sea and western English Channel	1,951	1,054	54
Haddock	southern Celtic Seas and English Channel	3,733	3,505	94
	North Sea, West of Scotland, Skagerrak	8,950	6,928	77
Saithe	North Sea, Rockall and West of Scotland, Skagerrak, and Kattegat	49,868	37,419	75

2.2.8.2.8 Additional risk factor 2. Protected (ETP) species bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	Moderate	Low

When longlines are set, the baited hooks may remain on the surface for a short period of time before they sink. Foraging seabirds are drawn to the fishing vessel through association with food (Bull 2007). Seabird injury, mortality and or bycatch occurs when the seabirds seize the baited hooks during line setting, either at the surface or below the surface if seabird species can dive several meters.

As discussed under Descriptor 1, there is a minor risk associated with longline fisheries to the incidental bycatch of seabirds within the English inshore region. In showing the relative risk of UK seabird species to bycatch from fishing operating in UK waters, Bradbury *et al.*, (2017) reported that demersal longlines posed less threat to vulnerable bird species, in both summer and winter seasons, than pelagic and surface gears and pelagic longlines less than that of surface longlines. Hotspots of vulnerability in surface gears included the Northumberland, North-Eastern, Devon and Severn and Cornwall IFCA regions. In 2018 as part of their dedicated sampling programme under the Annual report on the implementation of Council Regulation (EC) No 812/2004, CEFAS conducted 19 hauls over 25 days between January and September in ICES Divisions 4c and 4a (North Sea and West of Scotland), where one and 20 seabirds were bycaught by under and over 15m vessels respectively. All birds caught as bycatch were released alive.

Observer data collected onboard UK longline vessels report seabird mitigation measures, such as tori lines and offal disposal routines, are used routinely which is likely to reduce bycatch rates (Northridge et al., 2020). Additional measures are currently under investigation such as gear adaptations to increase the sink speed of fishing gear in a floated demersal longline, maximising conservation and economic benefits (Rouxel et al. in prep[110]).

Despite the existence of a number of measures to reduce bycatch in surface longline fisheries detailed in Løkkeborg 2008, continued captures in these fisheries demonstrate that the available measures do not preclude the existence of significant bycatch risk (Richard 2013; Pierre and Goad 2013).

2.2.8.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Rare	Low	Strong	Low

Non-compliance against TAC and quota regulations poses a threat the stock of the affected species. However, there is no publicly available evidence of non-compliance against minimum landing size and misreporting of quota species amongst domestic and foreign longlines vessels. Further, the risk of non-compliance against minimum landing size amongst longline vessels is reduced by the selective nature of varying hook sizes.

2.2.8.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	N/A	Low

There is no publicly available evidence of non-compliance against area restrictions amongst domestic and foreign longline vessels. Mitigation is not relevant for this gear type.

2.2.8.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	N/A	Low

Anchors located at the end of longline gear are reported to cause minor impacts to the seafloor in terms of the spatial extent distribution of physical loss and primarily occur only when the gear is hauled (Pham *et al.*, 2014). In combination, the low numbers of longline vessels operating within the English inshore regions presents a very low risk to essential fish habitats. Mitigation is not relevant for this gear type.

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[110] Summary of results in: https://www.seafoodinnovation.fund/projects/developing-a-floated-demersal-longline-design-that-minimises-seabird-bycatch-fs031/

2.2.8.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	N/A	Low

Fishing effort from LL and LLS vessels is concentrated across ICES Divisions VIa and IVa[111], which fall outside of the English inshore region. As a static gear, the risk of displacement of longline vessels due to wind farm developments within this region is considered minor and rare. Mitigation is not relevant for this gear type.

2.2.9 Bottom otter trawl (OTB) and Multi-rig otter trawl (OTT)

A bottom otter trawl (Table 30) is comprised of a cone-shaped net, towed on the seabed to target demersal fish species (Figure 12). The mouth of the trawl is held open by a pair of trawl doors, often made out of steel or wood. Trawl doors are designed to be towed through the water at an angle, causing them to spread away from each other, to open the net in a horizontal direction. As the trawl doors are towed along the seabed, they kick up a sand cloud that initiates the herding of fish towards the mouth of the trawl. The cone-shaped net tapers down to the cod-end where fish are collected until the net is hauled. Twin otter trawls have been deployed to increase the horizontal net opening without increasing the headline height and drag of the gear, which has proved to be an effective gear to target non-herded species like nephrops and monkfish (Eigaard *et al.*, 2011).

Bottom otter trawls and multi-rig otter trawls operate and interact with the marine environment in a similar way and often not distinguished within the literature; therefore, have been aggregated and scored simultaneously for the purpose of this work. Where discrete references to each métier are made, this will be distinguished within the presented evidence.

Table 30 Classification of bottom otter trawl (OTB) and multi-rig otter trawl (OTT)

Métier	
Level 1	Fishing
Level 2	Trawls
Level 3	Bottom trawls
Level 4	Bottom otter trawl (OTB) / Multi-rig otter trawl (OTT)

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[111] MMO - Fishing Activity for over 15m United Kingdom Vessels 2019

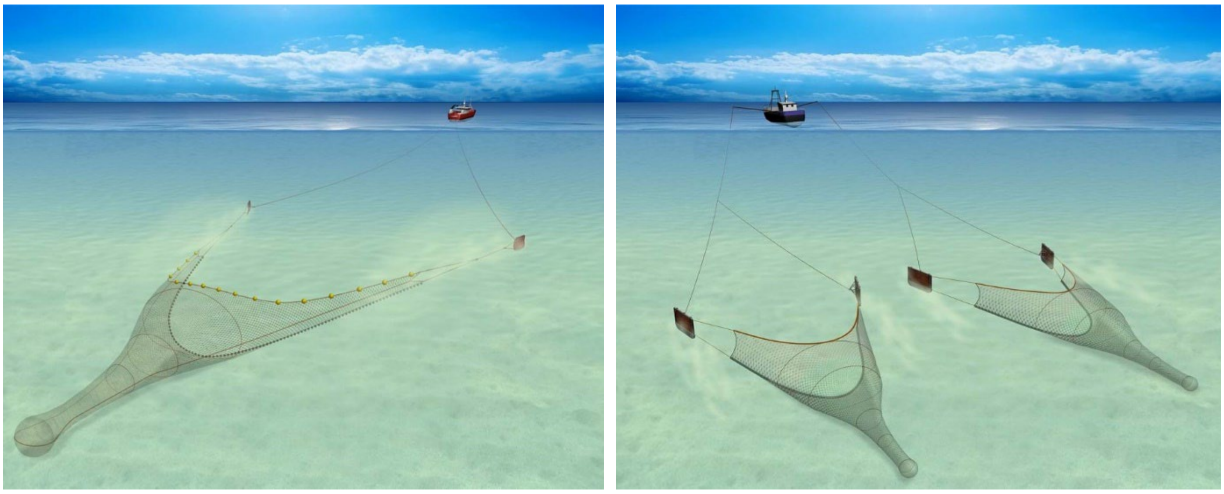

Figure 12 Bottom otter trawl (OTB) and multi-rig otter trawl (OTT) (©Seafish. Reproduced with permission: www.seafish.org[112])

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[112] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/demersal-trawl-general/

2.2.9.1 Distribution of vessels

Otter trawlers (OTB) are the second most abundant métier with a total of 1,264 vessels potentially operating across the English inshore region (Appendix 2). Of those, 518 are EU vessels, the majority of which French flagged (280), and 641 are UK vessels. Of those over 10m, the majority are registered in Scotland (142).

Within England, under 10m OTB vessels are more common than over 10m and generally evenly distributed across the IFCA regions, with the exception of the Isles of Scilly IFCA.

Multi-rig otter trawlers (OTT) are less abundant than OTB vessels, with a total of 116 vessels. Of those, 47 are EU vessels and follow a similar distribution to OTB vessels in that the majority are French flagged (36). Similarly in UK waters, the majority of OTT vessels are registered in Scotland with limited vessels registered in England.

2.2.9.2 Risk ratings

There is a plethora of studies that investigate and review the impacts of bottom otter trawling, many of which include other bottom trawl gear types (e.g., beam trawls (TBB) and boat dredges (DRB)) within their scope. The most widely reported environmental impacts of OTB activity includes physical damage to the seafloor and benthic communities (Armstrong *et al.*, 2008; Cook *et al.*, 2013; Diesing *et al.*, 2013; Hiddink *et al.*, 2017; Hiddink *et al.*, 2020; Jac *et al.*, 2020) and bycatch of non-target species (Kennelly and Broadhurst 2021) as a result of little size and species selectivity.

2.2.9.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Almost certain	High	Moderate	High

Pressures from otter trawling that impact biodiversity include; the removal of target species, non-target species and physical disturbance / abrasion on the seafloor.

The extent of abrasion on the seafloor is determined by the footprint of an OTB fishing operation, which includes: trawl doors; sweeps; trawl ground gear (Eigaard *et al.*, 2016;). Of the métiers examined in Eigaard *et al.*, (2016), OTB vessels targeting nephrops and mixed demersal fish are reported to have the largest estimated surface and subsurface impact per hourly swept area of almost 1.25 km^2.

OTB activity reduces benthic biodiversity primarily through the reduction of biomass. Reductions in biomass and species richness can be attributed to high levels of trawling activity (Ramalho *et al.*, 2018) due to high faunal damage and mortality rates (Hiddink *et al.*, 2006; Ramalho *et al.*, 2020). For example, depending on substrate vulnerability, there is a 20-50% mortality rate amongst benthic invertebrates that encounter towed bottom-fishing gears (Collie *et al.*, 2017). This can lead to changes in community production, trophic structure, ecological function, and reductions in prey population abundance of commercial fish species (Hiddink *et al.*, 2006; Collie *et al.*, 2017; Hiddink *et al.*, 2020). When compared to other bottom towed gear, Sciberras *et al.*, (2018) in an analysis of 122 experimental gear impact studies, reports a mean 3% decrease (95% CI for mean response: -32% to +38%) in benthic community abundance and 9% decrease (95% CI for mean response: -22% to +6%) in community species richness for otter trawls, the lowest amongst bottom trawling gears, albeit high variance in the responses. However, these results are based on experimental studies, therefore the actual impact of chronic exposure to otter trawls will be different as the spatial scales at which otter trawls operate in commercial fisheries is much greater than the other gear types (Sciberras *et al.*, (2018).

Further, while community recovery time was faster for otter trawls, this is likely to be an underestimation due to the larger spatial scale of fishing effort. Nevertheless, it may also be a consequence of shifts in community structure towards species with faster life histories in more frequently fished areas, resulting in faster recovery rates (Hiddink *et al*., 2017). In Sciberras et al., (2018), recovery rates were predicted within days in comparison values of 0.61 – 20 years for other demersal trawls, compared with 1.9 and 6.4 years reported by Hiddink et al., (2017), highlighting the huge variation within the literature, depending on the environmental variables used.

The likelihood of these effects occurring is driven by the intensity of fishing activity amongst otter trawlers and substrate type. Given the dominance of OTB vessels across IFCA regions and high proportions of OTB in the EU fleet licensed to fish in UK waters, it is almost certain that these impacts are occurring across the English inshore regions.

Mitigation measures employed to reduce impacts on seabed habitats and biota mainly include spatial and effort controls. The prohibition of bottom trawling on a spatial scale provides the most comprehensive protection of commercially important areas and/or areas of conservation interest and can also improve harvests by competing gears. The Lyme Bay Reserve is a prime example of a spatial closure to mobile gear which resulted in a positive recovery for many benthic and commercial species, as well as increased landings and quality of catch (Rees, 2019). Licensing permits to OTB and OTT vessels is another way to monitor fishing activity and control effort through nearshore zoning to reduce trawling in shallow sensitive habitats and minimize gear conflicts, as authorised under the Devon and Severn IFCA Mobile Fishing Byelaw Permit Conditions[113].

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[113] Devon and Severn IFCA Mobile Fishing Permit Byelaw

2.2.9.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Serious	Likely	High	Weak	High

The major risk to commercial fish species from single boat bottom otter trawls is related to over-exploitation i.e., high levels of fishing pressure and the capture and frequently discarding of non-target sizes and species both of fish and non-fish species.

Fisheries that employ the use of OTB gear tend to be mixed demersal fisheries targeting commercial species such as cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*) and flatfish species e.g., European plaice (*Pleuronectes platessa*), that are often caught together. The weight of UK vessel landings (tonnes) from UK waters of these species is given in Table 31.

Table 31 Vessel landings (tonnes) from UK waters of species targeted by bottom otter trawls (OTB)

Species	Landings (tonnes)
Cod	15,827
Haddock	29,232
Whiting	12,170
Plaice	4,662

According to ICES Advice 2020 on fishing opportunities, catch and effort, both the Irish Sea haddock and North Sea plaice stocks are sustainably exploited and at full reproductive capacity, categorised as ‘healthy’, based on ICES MSY or Management Plan approach. Similar advice revealed that North Sea and English Channel cod, Celtic Sea and Western English Channel cod and Irish sea whiting as unsustainably fished stocks, with stock size labelled as ‘critical’. North Sea cod stock spawning biomass has been in decline since 2014, estimated in 2019 at 55,000. The average discard rate among OTB vessels for Irish Sea cod is reported to be around 30% (ICES, 2019).

Mixed demersal fisheries such as these are managed through the setting of total allowable catch. It could be suggested that ill stock health within these fisheries is due to the disparity in scientific advice and the management prescribed. For example, North Sea cod has had a TAC set above scientific advice in most recent years. Similarly, whiting has had a TAC set 20% higher than scientific advice for 2016 – 2019, consistent with over exploited status. Further, fishing mortality rates of the EU cod recovery plan have not been met largely due to the continuation of overfishing, discarding of over-quota catches and ineffective methods to restrict effort (Froese and Quaas 2012; Kraak *et al.*, 2013) (Table 32).

Table 32 Stock status in UK waters of species targeted by bottom otter trawls (OTB)

Species	Stock	Fishing pressure (F_{MSY})	Spawning Stock Biomass (B_{MSY})	Status
Cod	North Sea and eastern English Channel	Above	Below	Unsustainable
	Celtic Sea and western English Channel	Above	Below	Unsustainable
Haddock	southern Celtic Seas and English Channel	Below	Above	Sustainable
	North Sea, West of Scotland, Skagerrak	Below	Above	Sustainable
Plaice	Eastern English Channel	Below	Above	Sustainable
	Western English Channel	Above	Above	Unsustainable
	Bristol Channel, Celtic Sea	Below	Above	Sustainable
	North Sea	Below	Above	Sustainable

2.2.9.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Moderate	Medium	Moderate	Medium

There is empirical evidence to show that bottom trawling, including OTB vessels, can affect predator-prey relationships (Collie *et al.*, 2017), through the removal of target and non-target species and abrasion on the seafloor.

Mixed fishery target species, such as plaice, have been found to be negatively affected in correlation with increased disturbance caused by trawling intensity. For example, Hiddink *et al.*, (2011) reported a reduced condition of plaice due to a reduced production of in faunal invertebrates, upon which plaice feed. Mortality amongst benthic invertebrates due to bottom-trawling is reported to range between 20 – 50% (Collie *et al.* 2000a; Kaiser *et al.* 2006). However, more generalist species such as dab (*Limanda limanda*) or piscivorous species such as whiting (*Merlangius merlangus*) were not affected by the reduced benthic biomass in the same heavily trawled areas. The disturbance caused by OTB vessels can further have an effect on fish feeding behaviour. For example, Collie *et al.*, (2017) review that fish feeding in disturbed areas are able to maintain stomach fullness in comparison to undisturbed areas, despite a reduced species composition. For example, when reviewing the stomach contents of 10 species before and after trawling, Collie *et al.*, (2017) reported that disturbed areas supported 1.6 times the normal number of fish and all fish present consumed 2.16 times the amount of that normally ingested.

In mixed-species fisheries because bottom trawls are size selective, large predator species have a higher catchability than smaller prey species (Brown and Trebilco 2014; Collie *et al.*, 2017), which can reduce the abundance of predator species, thereby enhancing the productivity of prey species.

2.2.9.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Strong	Medium

Fisheries using bottom trawls are the most widespread source of anthropogenic physical disturbance to UK seabed habitats (Foden *et al.*, 2011; Hiddink *et al.*, 2017). Of the components that make up an otter trawl that come into contact with the seabed (e.g., weights, sweeps), trawl doors have the most severe impact on the seabed (Eigaard *et al.*, 2016). Additionally, the cumulative effect of intense otter trawling is as important as gear weight and design in impacting the benthos (Ball *et al.,* 2000). Depending on the substrate type, trawl doors can dig trenches up to 35cm deep (Eigaard *et al.*, 2016), having both a surface and sub-surface impact. However, literature suggests that otter trawls are the least impactful in comparison to other bottom-trawling gears. For example, a study that collated all available data for experimental and comparative studies of trawling impacts on sedimentary habitats revealed that otter trawls caused the least depletion, removing 6% of biota per pass penetrating the seabed on average down to 2.4cm with a median recovery time post trawling of 1.9 and 6.4 years (Hiddink *et al.*, 2017).

Of the 10 métiers studied by Rijinsdorp *et al.*, (2020) in a trawling impact assessment in the North Sea, muddy habitats are shown to be impacted the most and coarse habitats the least. This is supported by Hiddink *et al.*, (2017), which suggests that the magnitude of impacts on seabed is strongly linked with gravel content of the sediment. Communities on gravel may be more sensitive to trawling due to a greater abundance of epi-fauna that are particularly vulnerable to trawling methods.

There are several methods that have shown to reduce the seabed impact of trawl doors. These include the use of trawl doors with a higher height to length ratio; the use of trawl doors with a lower show angle relative to the towing direction and a use of a shorter warp length relative to the fishing depth to achieve bottom contact (Valdmarsen *et al.*, 2007). Additional measures to protect sea floor integrity includes spatial restrictions to protect areas with benthic communities which are highly susceptible to fishing disturbance and physical damage from trawling activities. Area closures and nearshore zoning are implemented by IFCAs across England to protect species and seabed habitats of conservation importance. Examples include but are not limited to; Bottom Towed Fishing Gear Byelaw 2017 that covers Folkstone Pomerania MCZ, managed by the Kent and Essex IFCA; Mobile Fishing Permit Byelaw that covers Lyme Bay and Torbay SAC managed by Devon and Severn IFCA and Prohibition on the use of Mobile Fishing Gear in the English Section of the Berwickshire and North Northumberland Coast SAC managed by Northumberland IFCA.

2.2.9.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual

Major	Moderate	Medium	Moderate	Medium

Although a wide variety of marine litter and debris may impact marine taxa (Bergmann *et al.* 2015; Barbosa *et al.* 2019), the impacts of ghost-fishing[114] via ALDFG are undoubtedly the most serious (Allsopp *et al.* 2009). There are a range of causes for fishing gear from marine capture fisheries to be abandoned, lost or discarded unintentionally (Gilman *et al.* 2016). It is widely reported that gear may be lost due to a physical interaction between active and passive gears (gear conflict), and or, when active gear is snagged on the seafloor e.g., trawlers or dredgers (Gillman *et al.* 2016; Richardson *et al.* 2018).

The full impact of ALDFG on marine taxa within the UK, is difficult to ascertain as the majority of studies focus on beached and or floating ALDFG within coastal areas, with much less emphasis on underwater surveys (Ten Brink *et al.* 2009; Mouat *et al.* 2010; Allen *et al.* 2012).

There has been substantial effort to summarise the degree to which different types of fisheries produce ALDFG. Bottom trawl nets are one of the most often cited types of ALDFG in recent literature, however much of the focus is on gillnets; trammel nets and pots and traps (Gilman *et al.* 2016; Barboza *et al.* 2019; Lively and Good 2019; Richardson *et al.* 2019).

Gillman *et al.* (2016) states that authorities make limited use of the possible measures available to tackle issues of ALDFG e.g., gear marking, gear tracking and incentivised responsible disposable. This can be said for the UK where few management measures have been rolled out on a national scale.

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[114] The term ‘ghost fishing’ refers to abandoned, lost or discarded fishing gear in the marine environment that continues to ensnare and capture marine organisms without any economic benefit. Lost fishing gear, also known as ‘ghost gear’ can keep fishing for many decades, causing severe environmental damage to the marine ecosystem.

2.2.9.2.6 Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	High	N/A	High

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al.*, 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by fishing gears, especially when compared to the wider effects of bottom trawling on the marine environment.

In a study characterising the underwater noise levels in UK waters, recordings made in the southern North Sea suffered periodically from noise caused by colliding fishing gears deployed in close proximity of the recording device (Marchant *et al.*, 2016). Although the noise did not propagate far from the location, it was prominent in the data showing sustained periods of heightened noise. Daly and White (2021) reports noise emissions from both bottom trawlers and the gear itself, which are considered distinctly. Seabed sourced sound (i.e., from the interaction between bottom gear and the seabed) is reported to be of more potential harm to marine fauna, in particular resident and transient mammals, than noise created at the surface. This study further highlights that submarine canyons can focus or channel trawling noise to deeper waters suggesting the need for regulation and mitigation.

Given the lack of empirical evidence and considering the continuous interaction between trawling gear and the seabed it could be suggested that noise levels emitted from otter trawls are of potential harm to proximal marine fauna with a need for further research, potential regulation, and mitigation (Daly and White 2021).

2.2.9.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Almost certain	High	Moderate	High

The major negative impact of bottom otter trawling is related to the frequent discarding of undersized and non-target species. Bottom otter trawl fisheries alone contributed 2.4 million tonnes of discards globally, equating to over a quarter of the total (Perez Roda *et al.*, 2019; Gilman *et al.*, 2020). Specifically, in 2020 otter trawling contributed to 65% of cod discards caught in the Celtic Sea and western English Channel and 53% and 49% of plaice discards caught in the western English and Bristol Channel, Celtic Sea regions, respectively (ICES, 2021).

Mixed demersal fisheries target a plethora of species that, due to limitations on size selectivity, are often caught together. However, the quota issued for these species can often vary substantially. In the absence of quota for a particular species, that species can choke the fishery limiting their ability to continue fishing due to the regulations of the Landing Obligation (LO). This increases the risk of non-compliance through regulatory discarding in order to continue fishing practises and avoid consequential loss in revenue. For example, when investigating the fishing behaviour of a demersal trawler in the North Sea in response to the side-effects of the LO on mixed-fisheries, Mortensen *et al.*, (2018) identified saithe and cod as choke species. Analysis of catch and quota composition revealed temporal differences in when each species would choke the fishery and the subsequent losses in revenue that ranged between 43% - 87%. From an assessment of choke risk with the full implementation of the LO, the Celtic Sea Mixed Demersal Otter trawl fishery was identified as one of the highest risk fleets (CEFAS pers comm.)

In order to limit the capture of non-target species, selection devices can be employed. To reduce non-target fish sizes, the cod end is the most commonly used method. In recent years such size selectivity has been improved by the introduction of square mesh cod ends and selection devices like grids (Robert *et al.*, 2020).

2.2.9.2.8 Additional risk factor 2. Protected (ETP) species bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	N/A	Low

As part of the Cetacean Bycatch Observation Scheme (ME6044) conducted by Cefas, non-dedicated sampling was conducted under the English, Welsh and Northern Irish discard programme to meet requirements of the Data Collection Framework. Of the 466 demersal trawls conducted in 2017 and 571 in 2018, no ETP species (cetacean or seal bycatch) were reported. The absence of ETP species in this large sample size suggests that the risk of protected species bycatch through otter trawling is low. In regard to the scoring for mitigation for this descriptor, potential changes from mitigation are low and therefore the mitigation remains as “N/A” and the residual risk would remain as “Low”.

2.2.9.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Serious	Likely	High	Moderate	High

The minimum landing size and quota allocation for cod, haddock and plaice are detailed in Table 33. Non-compliance with these regulations poses a significant risk to the heath of the affected fish stocks by inhibiting stock replenishment.

Table 33 Minimum landing sizes and quota allocation for cod, haddock and plaice (2019)

Species	Stock	Minimum landing size	Adapted Quota (tonnes)
Cod	North Sea and eastern English Channel	35cm	1,911
	Celtic Sea and western English Channel		1,951
Haddock	Eastern English Channel	30cm	3,733
	Western English Channel		8,950
Plaice	Eastern English Channel	27cm	11,500
	Western English Channel		11,500
	Bristol Channel, Celtic Sea		1,716
	North Sea		104,350

The risk of non-compliance against these regulations amongst OTB and OTT vessels is high, due to documented evidence of prosecutions and knock-on effects to already unsustainably fished stocks. For example, in 2018 Ellie Adhmah (WD206) an Irish 25-metre otter trawler was charged with the incorrect operation of the electronic logbook and under recording of three quota species[115]. Further the Illustris, a 20-meter twin-rig otter trawler operating in the North Sea, was charged with logbook discrepancies in the weight of recorded cod, anglerfish, and dab[116]. The failure to record accurate data increases the risk of unrecorded catch, impacting the future sustainability of that stock.

2.2.9.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas

Consequence	Likelihood	Inherent	Mitigation	Residual
Serious	Likely	High	Moderate	High

A mosaic of bottom towed fishing gear area closures exists within the English inshore region, which are managed through the provision of IFCA Byelaws. Examples of which include but are not limited to; Bottom Towed Fishing Gear Byelaw 2017 that covers Folkstone Pomerania MCZ, managed by the Kent and Essex IFCA; Mobile Fishing Permit Byelaw that covers Lyme Bay and Torbay SAC managed by Devon and Severn IFCA and Prohibition on the use of Mobile Fishing Gear in the English Section of the Berwickshire and North Northumberland Coast SAC managed by Northumberland IFCA. Further, mesh size restrictions for otter trawls vary between 80 – 100mm codend and 90 - 120mm square mesh panel,

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[115] https://www.gov.uk/government/news/fishing-company-and-skipper-ordered-to-pay-37926-for-fisheries-offences

[116] https://www.gov.uk/government/news/trawler-owner-and-master-ordered-to-pay-35240-for-fisheries-offences

depending on the target fishery and region. Non-compliance with these regulations pose a significant threat to the target species and associated habitats impacted by the activity.

Recent incidences of non-compliance by OTT and OTB include the prosecution of Ellie Adhmah (WD206), an Irish 25-meter otter trawler, for undersized net offences operating in a biologically sensitive area within the Celtic Sea, posing threat to the reproductive capacity of the stock. Further, the Illustris, a 20-meter twin-rig otter trawler operating in the North Sea, was charged for excess meshes for the declared mesh size on both nets. Both pose serious knock-on effects to already unsustainably fished stocks and designated features within marine protected areas.

2.2.9.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Moderate	High

Essential fish habitat refers to waters and substrata necessary to fish for spawning, breeding, feeding, or growth to maturity. The risk from fishing activities depends in largely on the sensitivity of particular habitats to damage, as well as its rate of recovery. For example, habitats comprised of simpler composition (i.e., sand, or muddy sediments) are impacted to a lesser degree than those with a more complex three-dimensional structure and vertical profile (e.g., *Sabellaria* reef).

As discussed in previous sections, otter trawls and multi-rig otter trawls primarily target a mix of demersal species e.g., cod, haddock, and plaice. Spawning of cod occurs between January and April in central North Sea and eastern Irish and Celtic Sea pelagic waters (Ellis *et al.,* 2012). Juvenile cod (known as ‘codlings’) move towards the seabed to start schooling in shallow sublittoral waters, often with complex habitats such as seagrass beds, gravel areas, rocks and boulders. As a bottom-towed gear, the cod nursery grounds are at higher risk to the impacts of otter trawls than spawning grounds. The vertical profile and increased surface area allow otter trawling gear to easily become snagged or entangled, thus providing more opportunities for the habitat and juvenile species to be impacted, threatening the future sustainability of the stock. Key nursery grounds for cod, as identified by Ellis *et al.,* (2012), span the Eastern, North-Eastern, Northumberland and North-Western IFCA regions and therefore could be suggested as more vulnerable to the otter trawling.

Some spatial management is in place and further measures are being developed, such as a network of marine protected areas, to reduce the impact of this gear on vulnerable marine habitats. For example, in 2019, the Sussex IFCA introduced the

Nearshore Trawling Byelaw[117], prohibiting all towed gear along the Sussex coastline of between 1 and 4km from mean high water in order to protect nearshore essential fish habitats, covering an area of 304 square kilometres[118].

2.2.9.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Moderate	Medium	Moderate	Medium

The majority of wind farms in England are located in the offshore region. Exceptions to this, that are currently active or in operation include Blyth Demo Phase 1 (NIFCA), Teesside (NIFCA), Westermost Rough (NEIFCA), Humber Gateway (NEIFCA), Inner Dowsing and Lincs (EIFCA), Scromby Sands (EIFCA), London Array (KEIFCA), Thanet (KEIFCA), Kentish Flats (KEIFCA), Gunfleet Sands (KEIFCA), Rampion (KEIFCA), Burbo Bank (and Burbo Bank Extension) (NWIFCA), West of Duddon Sands (NWIFCA), Barrow (NWIFCA), Ormonde (NWIFCA) and Waldney 1, Waldney 2 and Waldney Extension 4 (NWIFCA). In addition to the loss of fishable area, a major issue posed to OTB and OTT vessels within the inshore region, is the occurrence of and potential snagging of sub-sea cables.

Currently, wind farm associated cables occupy approximately 20% of the English inshore region. Eastern IFCA has the highest percentage of cables at 10.8%. Other IFCA regions that have offshore wind cables present are North-Eastern (3.65%), North-Western (2.38%), Kent and Essex (1.64%), Northumberland (1.49%) and Sussex (0.06%). Devon and Severn, Cornwall, Isles of Scilly and Southern IFCA regions do not have any offshore wind farm cables present.

Mitigation measures applied to wind farm and construction and operation include the full involvement and engagement (Hooper *et al.*, 2015; Reilly *et al.*, 2015; Haggett *et al.*, 2020) of fishing industry representatives, for example through the use of Fishing Liaisons (Hagget *et al.*, 2020). However, there are mixed reports on their success, with poor relationships and inadequate communication between fishers and wind farm developers (Gray *et al.*, 2016).

2.2.10 Beam trawl (TBB) and Pair bottom trawl (PTB)

A beam trawl (Table 34) is a type of bottom trawl that is rigged to target flat fish on soft sand and muddy sea-beds. Beam trawls either have a series of tickler chains

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[117] Nearshore Trawling Byelaw 2019

[118] Sussex IFCA Nearshore Trawling Byelaw 2019

towed ahead of the mouth of the net designed to stimulate the fish out of the mud and over the footrope of the trawl (Figure **13**), a method used more commonly in the North Sea, or a stone mat designed to prevent large stones from entering the gear or causing harm to captured fish. The net opening is only approximately a metre above the sea-bed, which makes it ideal for targeting bottom-dwelling species e.g., plaice, sole, turbot and brill.

A pair trawl is a cone shaped net that is towed by two vessels simultaneously, one towing each side of the trawl and held open by the distance apart of the vessels, usually between 300 – 400 metres. Floats attached to the headline hold the net open in a vertical direction while the footrope is weighted to maintain contact with the seafloor (Figure 14). The design of the single trawl and pair bottom trawl does not differ greatly, apart from the pair trawl being larger and lacking trawl doors to keep the net open.

For this work, the risk scores for TBB and PTB have been assigned simultaneously due to similarities in gear design and method of fishing.

Table 34 Classification of beam trawl (TBB) and pair bottom trawl (PTB)

Métier	
Level 1	Fishing
Level 2	Trawls
Level 3	Bottom trawls
Level 4	Beam trawl (TBB) / Pair bottom trawl (PTB)

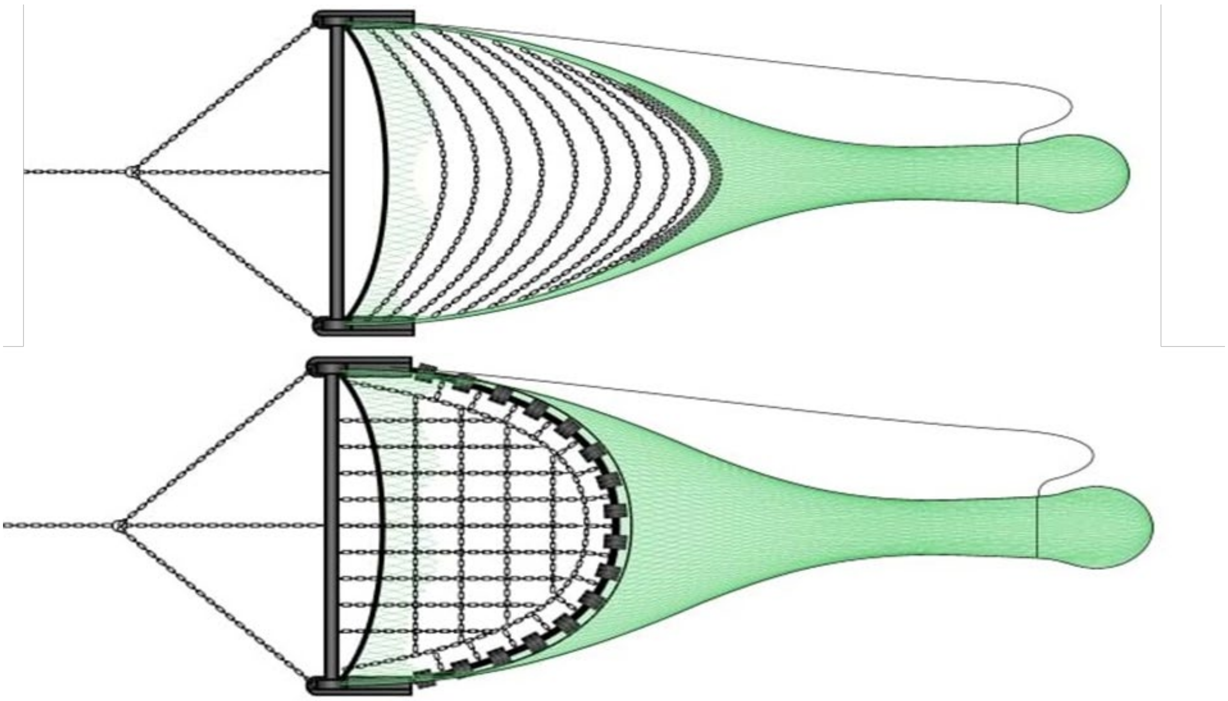

Figure 13 Beam trawl (TBB) (©Seafish. Reproduced with permission, Source: Seafish www.seafish.org)[119,120]

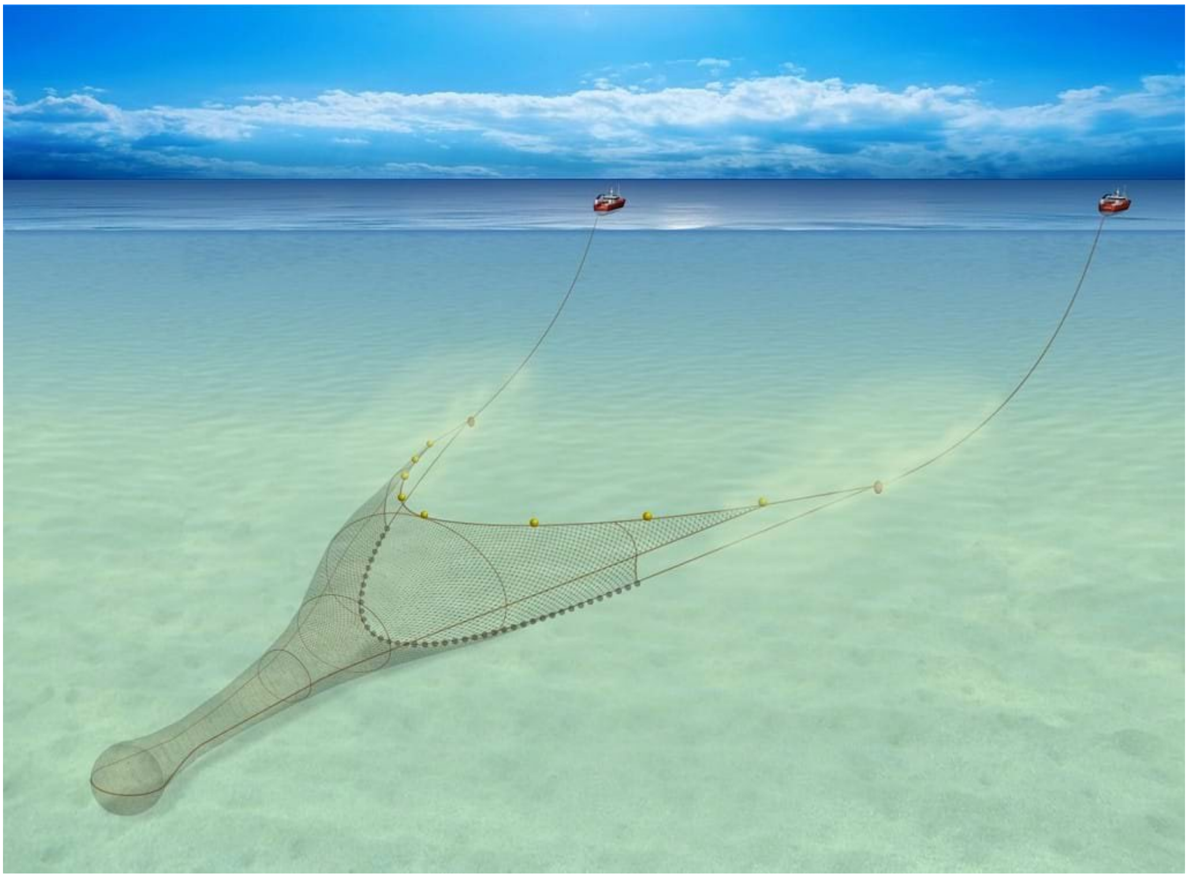

Figure 14 Pair bottom trawl (PTB) (©Seafish. Reproduced with permission: www.seafish.org)[121]

2.2.10.1 Distribution of vessels

Beam trawls (TBB) are the fifth most abundant métier, with a total of 388 vessels (Appendix 2). Of those, 237 are EU vessels, the majority of which Dutch (121) and Belgian (58) flagged operating in the shallow parts of the southern and central North Sea. Within England, over 10m TBB vessels are more common than under 10m and localised to the south-west (Cornwall and Devon and Severn IFCA) and south-east (Eastern IFCA) regions.

Pair-bottom trawls are far less abundant than TBB vessels, with a total of 27 vessels, all of which are UK registered and the majority operate out of Scottish ports.

2.2.10.2 Risk ratings

The most important species for beam trawlers are sole and plaice in terms of value and volume. Because a relatively small codend mesh size (80 mm) is used in beam trawls studies report significant quantities of fish below minimum size, resulting in high discard rates (Enever at al., 2008; Catchpole *et al.*, 2008; Reijden *et al.*, 2017; Schram *et al.*, 2020). A substantial amount of research in recent years has focused on gear – seabed interactions and the resultant environmental impacts (Eigaard *et al.*, 2017; Rijnsdorp *et al.*, 2018; Hiddink *et al.*, 2020; Rijnsdorp *et al.*, 2020).

2.2.10.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Moderate	High

It is well reported that beam trawling can impact biodiversity through the removal of target and non-target species and physical disruption of the seabed (Tillin *et al.*, 2006; Catchpole *et al.*, 2008; Depestele *et al.*, 2009; Cook *et al.*, 2013; Depestele *et al.*, 2015).

Beam trawling catches a variety of bottom-dwelling species (e.g., monkfish, lemon, and dover sole and European plaice). Over-exploitation of these stocks has a direct effect on biodiversity through the removal of biomass, inhibiting the reproductive capacity of the stock. For example, beam trawling can be attributed to 36% of sole landings in the eastern English Channel, where fishing pressure is currently above MSY, and stock spawning biomass is reported below MSY (ICES, 2021).

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[119] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/beam-trawl-open-gear/

[120] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/beam-trawl-chain-mat-gear/

[121] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/pair-trawl/#gear-classification

Beam trawling is not a well targeted fishery, with often poor selectivity and the potential to catch a wide variety of undersized and non-target species (e.g., crabs, starfish, and other shellfish). For example, a study investigating discarding in the Dutch beam trawl fishery in the North Sea reported 77% of the total catch made by commercial beam trawlers with 80mm mesh size was discarded, with species dominated by plaice and dab. Further, that less than 10% were estimated to survive due to severe damage caused by the trawl gear. Increasing the mesh size of the cod-end is the most common measure to reduce catches of juvenile and unwanted organisms. Different gear requirements are applicable to different target species and spatial areas, in accordance with UK and IFCA fishery regulations.

Beam trawling causes physical disruption of the seabed through contact of the gear components with the sediment and the resuspension of sediment into the water column. Penetration into the seabed can be up to 8cm, depending on beam trawl weight, towing speed, and sediment type (Depestele *et al.*, 2015). Contact with the seafloor can lead to high mortality of certain species (Cook *et al.*, 2013) and alterations to the functional composition of faunal benthic invertebrate communities (Tillin *et al.*, 2006). To minimise fishing disturbance and damage to seabed habitats and biota, spatial and effort restrictions are in place. The prohibition of bottom trawling on a spatial scale provides the most comprehensive protection of commercially important areas and/or areas of conservation interest and can also improve harvests by competing gears. Examples of area closures and nearshore zoning implemented by IFCAs across England include but are not limited to; Bottom Towed Fishing Gear Byelaw 2017 that covers Folkstone Pomerania MCZ, managed by the Kent and Essex IFCA; Mobile Fishing Permit Byelaw that covers Lyme Bay and Torbay SAC managed by Devon and Severn IFCA and Prohibition on the use of Mobile Fishing Gear in the English Section of the Berwickshire and North Northumberland Coast SAC managed by Northumberland IFCA.

2.2.10.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	Medium	Moderate	Medium

The major risk to the health of commercial fish populations targeted by beam trawlers is related to over-exploitation i.e., high levels of fishing pressure and the capture and frequently discarding of non-target sizes and species both of fish and non-fish species.

Fisheries that use TBB or PTB gear are designed to target flatfish such as Lemon sole (*Microstomus kitt*), Dover sole (*Solea solea*) and European plaice (*Pleuronectes platessa*). In general, the status of these stocks (Table 35) are healthy, based on 2021 ICES Advice on fishing opportunities, catch and effort. Exceptions to this include sole in the eastern English Channel, where fishing pressure is above F_{MSY}, and stock spawning biomass is below B_{MSY}. Further, sole stocks in the North Sea and Bristol Channel, Celtic Sea are over-exploited and outside of safe biological limits, demonstrated by fishing pressure above F^{MSY}. In these regions, beam trawlers contributed to 94% and 89% of port landings respectively and 100% of the discards in the Bristol Channel, Celtic Sea, equating to 106 tonnes in 2020.

The stocks are assessed annually by ICES, from which management controls are derived. Overall, control measures have been implemented within the range specified by scientific advice and contributed to a healthy increase in stock size. However, there is a residual risk of continued undocumented discarding when considering the effect of the implementation of the Landing Obligation.

Table 35 Stock status of species targeted by TBB and PTB vessels

Species	Stock	Fishing pressure (F_{MSY})	Spawning Stock Biomass (B_{MSY})	Status
Lemon sole	North Sea and eastern English Channel	Below	No reference point	Sustainable
Sole	Eastern English Channel	Above	Below	Unsustainable
	Western English Channel	Below	Above	Sustainable
	North Sea	Above	Above	Over-exploited
	Bristol Channel, Celtic Sea	Above	Above	Over-exploited
Plaice	Eastern English Channel	Below	Above	Sustainable
	Western English Channel	Above	Above	Unsustainable
	Bristol Channel, Celtic Sea	Below	Above	Sustainable
	North Sea	Below	Above	Sustainable

2.2.10.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	Medium	Moderate	Medium

Changes in the relative abundance of target and non-target species will affect interactions in several parts of a food web and may have an adverse effect on the food web status. For example, beam trawling has been linked to the creation of shortcuts in tropic relationships through the production of large amounts of dying discards and damaged benthos, enhancing secondary production of microbenthic per unit area between 6 – 13% (Groenewold and Fonds 2000).

Frequent trawling disturbance may further lead to the enhancement of smaller, more opportunistic benthic species, with faster life histories, due to their resilience to mortality imposed by trawling pressures. Further, these species may benefit from reduced competition or predation as populations of larger target species are depleted due to over-exploitation (Jennings *et al.*, 2001).

Ensuring normal abundance and diversity of the elements of marine food webs involves monitoring and assessment of tolls or indictors to inform management actions to control fishing activities. Commercial fish stocks are assessed annually by ICES. Resultant control measures of stocks targeted by TBB vessels have contributed to a healthy increase in stock size over the past decade.

2.2.10.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Moderate	High

Beam trawling has intense contact with the seafloor, which can impact the physical and biological characteristics of the seafloor through tow path and catch mortality (Depestele *et al.*, 2015).

A direct physical impact of the interaction of towed gear with the seafloor is the mobilisation of sediment in the tow path of the trawl gear (Depestele *et al.*, 2016; Rijnsdorp *et al.*, 2021). The quantity and distribution of sediment mobilized is related to the hydrodynamic drag of the gear components and the type of sediment over which they are trawled. Sedimentation has been shown to increase with length of beam trawl, for example Rijnsdorp *et al.*, (2021) reports a 9.2kg m^{-2} produced by a 12m beam and 4.2 kgm^{-2} by a 4.5m beam. Beam trawlers targeting flatfish fisheries, tend to operate over sand or muddy sediments.

Another impact of the tow path of the trawl gear is the removal of faunal benthic inveterate communities. Cook *et al.*, (2013) reports a significant reduction (90%) in the total number of epifaunal organisms following a single pass of a trawl; including anthozoans, hydrozoans, bivalves, echinoderms, and ascidians. This supports previous studies which show beam trawls to reduce deposit feeding macrofauna by 21% and cause a 68% decline in suspension feeders in sandy habitats (Collie *et al.,* 2000b). Further, in investigating the impacts on benthic invertebrate communities from beam trawling in four contracting regions of the North Sea, Tillin *et al.*, (2006) reports changes in the functional structure in three of the four areas sampled. Shifts towards short-lived, smaller species can occur in frequently fished areas due to faster recovery rates to fishing disturbance. Large scale shifts in the functional composition of benthic communities are likely to have effects on the functioning of costal ecosystems (Tillin *et al.*, 2006).

Several mitigation measures have been examined to reduce the described impact of beam trawling on the benthic environment. Gear modifications to minimise physical contact and penetration depth include: attaching varying sizes of rubber bobbins to create openings under the footrope to reduce unobserved mortality of benthic species (implemented in the Berring Sea and central Gulf of Alaska), a wing that skims just above the seabed to reduce penetrations and fuel consumption by 10%, benthos release panels and pulse trawls with electrodes that penetrate the seedbed less deeply, catching 40% less benthos compared to conventional trawls (McConnaughey *et al*.,2020). In the EU, only electric pulse trawling and benthos release panels have been reported to have a positive effect (Valdermarsen 2007; ICES 2020). While electric pulse fishing by UK or EU vessels did not take place within the English inshore regions, a ban on electric pulse fishing in UK waters was implemented post-Brexit on January 1st, 2021, due to concerns about the limited knowledge of the effects of electricity on the surrounding environment and biota. Additionally, the use of benthos release panels is only encouraged in beam trawl fisheries, not implemented e.g., vessels are exempt from discarding undersized plaice if gear is equipped with these panels[122].

As explained in 2.2.10.2.1 Descriptor 1, the implementation of spatial restrictions to legally protect sensitive habitats and some benthic communities is widely adopted by IFCAs.

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[122] Implementation of the landing obligation for the period 2021-2023

2.2.10.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Moderate	Medium	Moderate	Medium

Although a wide variety of marine litter and debris may impact marine taxa (Bergmann *et al.* 2015; Barbosa *et al.* 2019), the impacts of ghost-fishing[123] via ALDFG are undoubtedly the most serious (Allsopp *et al.* 2009).

There are a range of causes for fishing gear from marine capture fisheries to be abandoned, lost, or discarded unintentionally (Gilman *et al.* 2016). It is widely reported that gear may be lost due to a physical interaction between active and passive gears (gear conflict), and or, when active gear is snagged on the seafloor e.g., trawlers or dredgers (Gillman *et al.* 2016; Richardson *et al.* 2018).

The full impact of ALDFG on marine taxa within the UK, is difficult to ascertain as many studies focus on beached and or floating ALDFG within coastal areas, with much less emphasis on underwater surveys (Ten Brink *et al.* 2009; Mouat *et al.* 2010; Allen *et al.* 2012).

There has been substantial effort to summarise the degree to which different types of fisheries produce ALDFG. Bottom trawl nets are one of the most often cited types of ALDFG in recent literature, however much of the focus is on gillnets; trammel nets and pots and traps, (Gilman *et al.* 2016; Barboza *et al.* 2019; Lively and Good 2019; Richardson *et al.* 2019).

Gillman *et al.* (2016) states that authorities make limited use of the possible measures available to tackle issues of ALDFG e.g., gear marking, gear tracking and incentivised responsible disposable. This can be said for the UK where few management measures have been rolled out on a national scale.

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[123] The term ‘ghost fishing’ refers to abandoned, lost or discarded fishing gear in the marine environment that continues to ensnare and capture marine organisms without any economic benefit.

2.2.10.2.6 Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Likely	High	N/A	High

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al*., 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by fishing gears, especially when compared to the wider effects of bottom trawling on the marine environment.

In a study characterising the underwater noise levels in UK waters, recordings made in the southern North Sea suffered periodically from noise caused by colliding fishing gears deployed in proximity of the recording device (Marchant *et al*., 2016). Although the noise did not propagate far from the location, it was prominent in the data showing sustained periods of heightened noise. Daly and White (2021) reports noise emissions from both bottom trawlers and the gear itself, which are considered distinctly. Seabed sourced sound (i.e., from the interaction between bottom gear and the seabed) is reported to be of more potential harm to marine fauna, in particular resident and transient mammals, than noise created at the surface. This study further highlights that submarine canyons can focus or channel trawling noise to deeper waters suggesting the need for regulation and mitigation.

Given the lack of empirical evidence and considering the continuous interaction between trawling gear and the seabed it could be suggested that noise levels emitted from beam trawls are of potential harm to proximal marine fauna with a need for further research, potential regulation, and mitigation (Daly and White 2021).

2.2.10.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Almost certain	High	Moderate	High

Beam trawling is not a well targeted fishery, with often poor selectivity and the potential to catch a large amount and wide variety of non-target species (e.g., crabs, starfish, and other shellfish). A relatively small codend mesh size (80 mm) is used in beam trawls targeting flatfish which results in significant quantities of fish below minimum sizes being caught, resulting in high discard rates. For example, in 2020 beam trawling contributed to 100% of the Bristol Channel, Celtic Sea cod discards (106 tonnes).

Studies investigating discarding amongst English and Dutch beam trawl fisheries operating in the North Sea have reported the percentages of discarded fish (by weight) to range between 31 – 77% (Enever at al., 2008; Catchpole *et al*., 2008).

Due to damages caused by trawl gear, fish mortality rates imposed by tickler chain beam trawling are reported to range between 10-32 % in flatfish (Reijden *et al.*, 2017; Schram *et al.*, 2020). Of the bycatch species investigated in Schram *et al.*, (2020), direct mortality was lowest amongst ray species (2 – 8%).

The most serious risks of choke situations for the main commercial stocks are estimated to be with North Sea plaice in small-meshed beam trawl fisheries, due to the large number of small plaice caught in the sole targeted fisheries, operated primarily by the Netherlands and Belgium (Ulrich 2018).

Technical measures to reduce bycatch levels in beam trawl fisheries include the mandatory use of 180 mm mesh sizes in the entire upper half of the anterior part of the net. Further, more regionalised management initiatives have shown to reduce the discard rates. Project 50%, an innovative partnership between scientists and Devon beam trawlermen, reduced discards by 52% through gear modifications including larger mesh sizes, square meshes and escape panels allowing younger fish to escape. However, the implementation of the Landing Obligation still leaves risk for continued undocumented discarding.

2.2.10.2.8 Additional risk factor 2. Protected (ETP) species bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Unlikely	Medium	Moderate	Medium

Reported incidental catch of ETP species among beam trawlers within the English inshore region is minimal. As part of the non-dedicated sampling undertaken on board a variety of commercial beam trawlers operating across the southern North Sea, English Channel and Bristol Channel and southern Celtic Sea, no cetacean or seal bycatch was reported in the 901 hauls conducted, targeting a mixture of sole, anglerfish and megrim (Northridge *et al.*, 2018).

In analysing the data collected as part of at-sea observer programmes in English and Welsh waters between 2002 – 2016, Silva and Ellis (2019) highlight the need for increased observer coverage and data collection on prohibited species (discarded, dead or alive), especially areas and métiers where species are more likely to encountered.

2.2.10.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Serious	Likely	High	Moderate	High

The minimum landing size and quota allocation[124] for sole and plaice are detailed in Table 36. Non-compliance with these regulations poses a significant risk to the heath of the affected fish stocks by inhibiting stock replenishment.

Table 36 Minimum landing size and adapted quota for sole and plaice (2019)

Species	Stock	Minimum landing size	Adapted Quota (tonnes)
Sole	Eastern English Channel	24cm	2,886
	Western English Channel		1,373
	North Sea		14,286
	Bristol Channel, Celtic Sea		1,106
Plaice	Eastern English Channel	27cm	11,500
	Western English Channel		11,500
	Bristol Channel, Celtic Sea		1,716
	North Sea		104,350

Recent instances of non-compliance amongst TBB and PTB vessels includes the prosecution of the 38.75m beam trawler ‘Northern Joy’ for multiple breaches of the vessel’s license conditions including declaration of unauthorised catches of sea bass via electronic log-book with a value of £7,500[125]. In this particular instance, Northern Joy had no authorisation to catch bass, which is a particularly vulnerable species and is therefore subject to a separate authorisation process.

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[124] Section 2 of the UK Sea Fisheries Statistics 2019

[125] https://www.gov.uk/government/news/fishing-vessel-owner-and-skippers-ordered-to-pay-8877760-for-fisheries-offences

2.2.10.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas

Consequence	Likelihood	Inherent	Mitigation	Residual
Serious	Likely	High	Moderate	High

A mosaic of bottom towed fishing gear area closures exists within the English inshore region, which are managed through the provision of IFCA Byelaws. Examples of which, that overlap with beam trawling effort include; Marine Protected Areas Byelaw 2016 that covers The Wash and North Norfolk Coast SAC managed by Eastern IFCA, Closed Area (European Marine Sites) No. 2 that covers Lizard Point SAC managed by Cornwall IFCA and Mobile Fishing Permit Byelaw that covers Severn Estuary SAC managed by Devon and Severn IFCA. Further, codend restrictions for beam trawls are set at a minimum of 80mm and for fisheries targeting sole and mixed demersal species, vessels must have a headline panel with at least 180mm mesh in certain ICES areas. Non-compliance with these regulations pose a significant threat to the target species and designated habitats impacted by the activity.

Recent instances of non-compliance amongst TBB and PTB vessels includes the prosecution of the 38.75m beam trawler ‘Northern Joy’ for multiple breaches of the vessel’s license conditions including entry into seasonal closures at speeds consistent with fishing on ten occasions over a period of three months, putting the vulnerable species for which the seasonal closure is implemented at risk from overfishing[126].

2.2.10.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Moderate	Medium	Moderate	Medium

Essential fish habitat refers to waters and substrata necessary to fish for spawning, breeding, feeding, or growth to maturity. The risk from fishing activities depends in largely on the sensitivity of particular habitats to damage, as well as its rate of recovery.

Of the species primarily targeted by beam trawls and pair-bottom trawlers, sole usually spawn between April and June, where their eggs and larvae are pelagic. Spawning grounds are mainly in the shallow waters of the eastern Irish Sea, Cardigan Bay, Trevose Head, eastern English Channel and Greater Thames Estuary (Ellis *et al.,* 2012). Metamorphosed individuals (c. 15mm) settle in coastal areas,

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[126] https://www.gov.uk/government/news/fishing-vessel-owner-and-skippers-ordered-to-pay-8877760-for-fisheries-offences

which serve as nursery areas for approximately two years before reaching maturity (Post *et al.,* 2017). These areas are generally of simple composition e.g., sandy, or muddy substrata in shallow and sheltered, often estuarine, which are impacted to a lesser degree by beam trawling than those with a more complex three-dimensional structure and vertical profile. Identified Important nursery grounds include the Bristol Channel, parts of the English Channel and Greater Thames Estuary (Ellis *et al.,* 2012).

2.2.10.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Moderate	Medium	Moderate	Medium

The rapid developments in the offshore renewables sector in the UK pose numerous threats to local fishing communities. Although many wind farms in England are located in the offshore region. Exceptions to this, that are currently active or in operation include Blyth Demo Phase 1 (NIFCA), Teesside (NIFCA), Westermost Rough (NEIFCA), Humber Gateway (NEIFCA), Inner Dowsing and Lincs (EIFCA), Scromby Sands (EIFCA), London Array (KEIFCA), Thanet (KEIFCA), Kentish Flats (KEIFCA), Gunfleet Sands (KEIFCA), Rampion (KEIFCA), Burbo Bank (and Burbo Bank Extension) (NWIFCA), West of Duddon Sands (NWIFCA), Barrow (NWIFCA), Ormonde (NWIFCA) and Waldney 1, Waldney 2 and Waldney Extension 4 (NWIFCA). The deployment of these structures and any further renewable energy sites will lead to the alteration of access to the area of instillation (Alexander *et al.,* 2016). This loss of access will affect many users, most notably fishers employing mobile gear such as beam trawlers, where loss of access may lead to displacement and reduced catch per unit effort resulting in resource conflict.

In addition to the loss of fishable area, a major issue posed to OTB and OTT vessels within the inshore region, is the occurrence of and potential snagging of sub-sea cables. Currently, wind farm associated cables occupy approximately 20% of the English inshore region. Eastern IFCA has the highest percentage of cables at 10.8%. Other IFCA regions that have offshore wind cables present are North-Eastern (3.65%), North-Western (2.38%), Kent and Essex (1.64%), Northumberland (1.49%) and Sussex (0.06%). Devon and Severn, Cornwall, Isles of Scilly and Southern IFCA regions do not have any offshore wind farm cables present.

Mitigation measures applied to wind farm and construction and operation include the full involvement and engagement (Hooper *et al.*, 2015; Reilly *et al.*, 2015; Haggett *et al.*, 2020) of fishing industry representatives, for example through the use of Fishing Liaisons (Hagget *et al.*, 2020). However, there are mixed reports on their success, with poor relationships and inadequate communication between fishers and wind farm developers (Gray *et al.*, 2016). Further options to mitigate the causes of conflict and provide possible benefits to the fishing industry include what is termed within the literature as the ‘artificial reef effect’ and ‘exclusion zone effect’ (Avery 2014). The presence of the renewable infrastructure provides shelter and additional hard substrate, which may lead to an increase in food availability for commercial species e.g., infauna and benthic epifauna. It is even suggested that the increased surface area provided by sub-surface renewable infrastructure could provide co-use management opportunities for habitat forming aquaculture practises (Avery 2014).

2.2.11 Nephrops trawl (TBN)

Nephrops trawl (TBN) (Table 37) is a long winged low net with lightweight ground gear suited for towing over the soft-muddy areas (Figure 15), where target species Nephrops (*Nephrops norvegicus*) are typically found. Since Nephrops are protected from trawling while in their burrows, they are generally caught when they emerge to feed, which usually happens twice a day at dawn and dusk. They are commonly caught in mixed fisheries. In 2019, 34,100 tonnes of *N. norvegicus* were landed into the UK by UK and foreign vessels, representation of a value of £112.8 million making them the most commercially valuable species.

Table 37 Classification of TBN vessels

Métier	
Level 1	Fishing
Level 2	Trawls
Level 3	Bottom trawls
Level 4	Nephrops trawl (TBN)

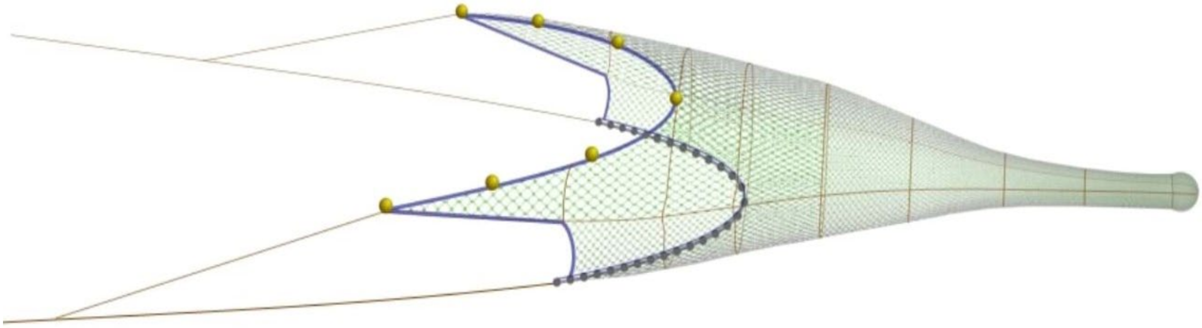

Figure 15 Nephrops trawl (Source: Seafish[127])

2.2.11.1 Distribution of vessels

Nephrop trawls (TBN) are the least abundant métier, with a total of 46 vessels. Of those, only two are EU vessels both Irish flagged. Within the UK, the majority (20) of TBN vessels are registered in Scotland, a larger proportion of which are over 10m. There is a total of eight TBN vessels registered in England, all of which are registered to ports on the eastern coastline within the Northumberland, North-Eastern and Kent and Essex IFCA regions (Appendix 2).

2.2.11.2 Risk ratings

The EU manages Nephrops fisheries collectively under the TAC scheme within the Common Fisheries Policy. Given the limited dispersal abilities of Nephrops, much of the literature on Nephrops fisheries is reported to the same geographic scale in which these fisheries' statistics are recorded i.e., by Functional Units (FU). Of these FUs there are two stocks which span the English inshore region; Farnes Deep (FU 6) and Irish Sea, East (FU 15).

Numerous studies and reviews have examined and reported on Nephrop fisheries in European waters (Ball *et al.*, 2000; Catchpole *et al.,* 2005; Catchpole *et al.*, 2006; Bailey *et al.*, 2012; Ungfors *et al.*, 2013), with many focusing on gear modifications (Catchpole *et al.*, 2006; Catchpole *et al.*, 2008) to mitigate the well reported bycatch and discard issue amongst these fisheries. In contrast to other bottom towed gears, very few studies focus on the benthic impact of Nephrop trawls specifically, rather referred to as otter trawls (Ball *et al.*, 2000).

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[127] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/demersal-trawl-nephrops-hopper-trawl/

2.2.11.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Moderate	Medium	Moderate	Medium

Nephrops inhabit branching burrows in predominantly shallow waters characterised by muddy sediments (Bailey *et al.*, 2012). A range of species may inhabit the same burrow as Nephrops including the echiuran worm *Maxmuelleria lankesteri*, the goby *Lesueurigobius friesii* and the thalassinidean *Jaxea nocturna* (Johnson *et al.*, 2013). The presence of suitable seabed habitat defines the distribution of the Nephrops and therefore ultimately the spatial extents of fishery. This presents potential effects on marine biodiversity through the removal of target and non-target species and physical damage and disturbance to the sea floor.

The removal of target species reduces the available harvestable biomass of Nephrop populations, which in turn can reduce reproductive capacity. According to ICES advice (2020), the fishing pressure reported in Farnes Deep (FU 6) is above F^{MSY}. However, stock size as been above the B^{MSY} for the previous three years, suggesting that the stock is currently within safe biological limits.

Nephrops fisheries also catch non-target species such as whiting (*Merlangius merlangus*), haddock (*Melanogrammus aeglefinus*) and cod (*Gadus morhua*), and numerous other commercial and non-commercial species (Cosgrove *et al.*, 2019), such as invertebrates (Bergmann and Bergmann 2001), of which much of the fish catch can be undersized and or experience mortality potentially impacting already threatened stocks. Many studies record also large amounts of invertebrate discards, specifically crustaceans (Bergmann *et al.*, 2002) and echinoderms (Bergmann and Bergmann 2001) including starfish *Asteria rubens* and brittlestar *Ophuira ophihura*, accounting for up to 83% of discards in the Clyde Sea Nephrops fishery. Mortality rates of these species were reported between 0 – 31%, with *A. rubens* showing lower mortality.

In a study comparing the long- and short-term consequences of a Nephrops trawl fishery on the benthos and environment of the Irish Sea, fauna reported at an inshore site showed a showed a decrease in numbers following experimental trawling, although very few were statistically significant (Ball *et al.*, 2000). It is suggested that fishing intensity influences the long-term negative trends in the benthos of Nephrop grounds rather than the direct passage of gear (Ball *et al.*, 2000). Decreases in the species abundance of these species would presumably lead to changes in habitat complexity and community structure.

2.2.11.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Unlikely	Medium	Moderate	Medium

The two stocks which span the English inshore region; Farnes Deep (FU 6) and Irish Sea, East (FU 15) are managed collectively by the EU under the TAC scheme, as part of the CFP. The Farnes Deep fishery extends from Teesside to the Scottish boarder. In the Irish Sea, Nephrops are exploited in the waters surrounding the Isle of Man.

According to ICES Advice 2020 on fishing opportunities, catch and effort (Table 38), the Farnes Deep fishery is over-exploited with fishing pressure above F^{MSY}; however, stock spawning biomass has been reported above B^{MSY} for the previous three years. In contract, the Irish Sea, East fishery is reported sustainable with fishing effort below F^{MSY} and spawning stock biomass above B^{MSY}.

Table 38 Stock status of Nephrops

Species	Stock	Fishing pressure (F_{MSY})	Spawning Stock Biomass (B_{MSY})	Status
Nephrops	Central North Sea, Farnes Deep	Above	Above	Over exploited
	Irish Sea, East	Below	Above	Sustainable

Regular stock assessments of Nephrops are conducted at functional unit level, a much finer scale than other species. Input (i.e., effort control, closed seasons, minimum mesh size) and output measures (i.e., TAC quota, MLS, catch composition) are all used for Nephrops fishery management in a variety of combinations across the functional units (Catchpole *et al.*, 2008).

2.2.11.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Moderate	Low

An increase in damaged and discarded fauna associated with trawling activity (Bergmann and Bergmann 2001; Tillin *et al.*, 2006) could increase the relative abundance of Nephrop populations, through the increased provision of prey available to the mobile scavengers (Johnson *et al.*, 2013). Further, through analysis of stomach contents, it is widely reported in the literature that Nephrops are primary preyed upon by cod. The high bycatch rates of cod (and other whitefish species) with Nephrops fishing gear are a concern for the management of Nephrops and bycaught species (Catchpole *et al.*, 2008), as their continual decline may further contribute to a reduced predation pressure on Nephrops stocks.

2.2.11.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Moderate	Medium	Moderate	Medium

Nephrops fisheries are focused on core areas characterised by muddy substrates with specific silt and clay content; a sediment-type necessary for burrowing communities (Ungfors *et al.*, 2013). Often, this habitat and, therefore fishery occur in deeper waters than for other commercial crustacean fisheries in Europe, such as brown crab (*Cancer pagurus*) and European lobster (*Homarus gammarus*).

Fisheries using bottom trawls are the most widespread source of anthropogenic physical disturbance to UK seabed habitats (Foden *et al.*, 2011; Hiddink *et al.*, 2017). Of the components that make up a nephrop trawl, that come into contact with the seabed (e.g., weights, sweeps), trawl doors have the most severe impact on the seabed (Eigaard *et al.*, 2016). Trawl doors can dig trenches up to 35cm deep (Eigaard *et al.*, 2016), having both a surface and sub-surface impact. However, the literature suggests that this configuration of gear is the least impactful in comparison to other bottom-trawling gears. Further, in soft mud communities, a large proportion of the fauna lives in burrows up to 2m deep, below the penetration depth of nephrop trawlers (Ball *et al.*, 2000). Lifting the trawl door off the bottom would result in less physical contact and was shown by He *et al.*, (2004) to be effective in reducing fuel use without reducing the capture efficiency of the gear in shrimp fisheries. Similar modifications could be explored for the Nephrops fishery.

In a study comparing the long- and short-term consequences of a Nephrops trawl fishery on the benthos and environment of the Irish Sea, fauna reported at an inshore site showed a decrease in numbers following experimental trawling, although very few were statistically significant (Ball *et al.*, 2000). In fact, the frequency of polychaetes increased in response to trawling by 16 – 457%, depending on the species, which play an important role in maintaining the structure and oxygenation of muddy sediment habitats.

In preparation for the North Sea Advisory Committee Long Term Management Plan for the North Sea Nephrops fisheries[128], a report by Newcastle University was submitted to the Marine Management Organisation (MMO) outlining potential management options and conservation measures (Bailey *et al.*, 2012). During the

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[128] NSAC Long Term Management Plan for the North Sea Nephrops Fisheries

stakeholder consultation, Scottish skippers said measures had already been taken by the Scottish industry to improve gear selectivity; allowing escape of undersize whitefish through netting panels with larger meshes and through metal and plastic grids. Known as a Scottish 'flip flap' trawl, this highly selective gear was designed to facilitate the escape of cod, in accordance with the Cod Recovery Plan. Additionally, Scotland has banned Scottish vessels using multi-trawl gears in the North Sea, which also extends to British vessels in Scottish waters. In England, the Days at Sea Scheme 2011/12 Cod Recovery Zone scheme was published by the MMO in 2011 which incentivised vessels to use more selective gear, e.g., square mesh panel, to reduce cod bycatch and gain extra days at sea.

Within the management plan, the proposed ecological instruments to reduce damage to vulnerable organisms and to the seabed include: 1) Identifying and implementing Marine Protected Areas in consultation with fishers; 2) Restricting the range of gears that can be used in vulnerable areas (including creel only areas); 3) Promoting the development of environmentally friendly fishing practices, for example gears with less intrusive bottom contact, larger meshes and better selectivity profiles; 4) Improving data recording systems to identify capture and damage to endangered, threatened and protected species or habitats and 5) Safe and speedy return to the sea of endangered and threatened species. A research and monitoring programme will also be established to evaluate the progress and outcomes of the management plan.

2.2.11.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Unlikely	Medium	Moderate	Medium

Although a wide variety of marine litter and debris may impact marine taxa (Bergmann *et al.* 2015; Barbosa *et al.* 2019), the impacts of ghost-fishing[129] via ALDFG are undoubtedly the most serious (Allsopp *et al.* 2009). There are a range of causes for fishing gear from marine capture fisheries to be abandoned, lost or discarded unintentionally (Gilman *et al.* 2016). It is widely reported that gear may be lost due to a physical interaction between active and passive gears (gear conflict), and or, when active gear is snagged on the seafloor e.g., trawlers or dredgers (Gillman *et al.* 2016; Richardson *et al.* 2018).

The full impact of ALDFG on marine taxa within the UK, is difficult to ascertain as most studies focus on beached and or floating ALDFG within coastal areas, with

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[129] The term 'ghost fishing' refers to abandoned, lost or discarded fishing gear in the marine environment that continues to ensnare and capture marine organisms without any economic benefit.

much less emphasis on underwater surveys (Ten Brink *et al.* 2009; Mouat *et al.* 2010; Allen *et al.* 2012).

There has been substantial effort to summarise the degree to which different types of fisheries produce ALDFG. Bottom trawl nets are one of the most often cited types of ALDFG in recent literature, however much of the focus is on gillnets; trammel nets and pots and traps, (Gilman *et al.* 2016; Barboza *et al.* 2019; Lively and Good 2019; Richardson *et al.* 2019).

Gillman *et al.* (2016) states that authorities make limited use of the possible measures available to tackle issues of ALDFG e.g., gear marking, gear tracking and incentivised responsible disposable. This can be said for the UK where few management measures have been rolled out on a national scale.

2.2.11.2.6 Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Moderate	Medium	N/A	Medium

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al.*, 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by fishing gears, especially when compared to the wider effects of bottom trawling on the marine environment.

In a study characterising the underwater noise levels in UK waters, recordings made in the southern North Sea suffered periodically from noise caused by colliding fishing gears deployed in proximity of the recording device (Marchant *et al.*, 2016). Although the noise did not propagate far from the location, it was prominent in the data showing sustained periods of heightened noise. Daly and White (2021) reports noise emissions from both bottom trawlers and the gear itself, which are considered distinctly. Seabed sourced sound (i.e., from the interaction between bottom gear and the seabed) is reported to be of more potential harm to marine fauna, in particular resident and transient mammals, than noise created at the surface. This study further highlights that submarine canyons can focus or channel trawling noise to deeper waters suggesting the need for regulation and mitigation.

Given the lack of empirical evidence and considering the continuous interaction between trawling gear and the seabed it could be suggested that noise levels emitted from Nephrop trawls are of potential harm to proximal marine fauna with a need for further research, potential regulation, and mitigation (Daly and White 2021).

2.2.11.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Moderate	Moderate	Moderate	Medium

Due to the co-location of nephrops and whitefish on muddy substrates and small cod end mesh sizes employed, nephrop trawls consequently have large quantities of commercial fisheries bycatch e.g., whiting (Merlangius merlangus), haddock (Melanogrammus aeglefinus) and cod (Gadus morhua) (Catchpole and Revill 2008), which is quite often below minimum conservation size and or discarded dead. Recent observations (2020) in the Irish Sea, East fishery have shown overall discards by numbers to be 12% of total catch.

Measures to reduce bycatch and discards of whitefish in nephrop fisheries have been the subject of much research over the years, resulting in technical measures which improve selectivity (Catchpole and Revill 2008). These include selection grids which physically filter the catch, shown to reduce the bycatch of commercially sized fish by 80-100% and undersized fish by 30 – 65% (by weight) (Ulmestrand and Valentinsson 2003); separator and guiding panels which is inserted at an appropriate height inside the trawl terminating in two discrete cod ends with varying mesh sizes. One, a larger mesh size to retain white fish, and a smaller mesh size for retaining nephrops and other potential target species.

In a study comparing compare the survival of discarded *Nephrops* across three distinct northern European trawl fisheries, the size range of *Nephrops* caught at Farnes Deep was 20–55 mm carapace length, with a dominant mode at 28 mm (Fox *et al.*, 2020) which is 3 mm above minimum landing size. The percentage of discard Nephrops in this study with observed injuries ranged between 23 – 67% of species examined in each haul. The most observed injuries included loss or damage to one of both chelae, puncture, and crush wounds to the thorax or abdomen and damaged rostra. However, no immediate mortality was observed.

2.2.11.2.8 Additional risk factor 2. Protected (ETP) species bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Rare	Moderate	Strong	Low

As part of the Cetacean Bycatch Observation Scheme (ME6044) conducted by Cefas, non-dedicated sampling was conducted under the English and Welsh DCF programme, 50 hauls were conducted by Nephrops trawls targeting Nephrops. Within which no bycatch of dolphins, porpoise, seal, or seabird were recorded (Northridge *et al.,* 2011).

2.2.11.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Moderate	Medium	Moderate	Medium

The minimum landing size for Nephrops is 25mm carapace length. Catching juvenile species can deplete future reproductive stocks. Despite the lack of publicly available evidence of non-compliance against minimum landing size and misreporting of quota species, Nephrops fisheries are at an elevated risk of non-compliance with the Landing Obligation due to the level of bycatch and stock status of gadoid species, especially cod. Therefore, vessels targeting Nephrops could experience reduced fishing opportunities through chocking (Cosgrove et al., 2019).

2.2.11.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Rare	Low	Moderate	Low

A mosaic of bottom towed fishing gear area closures exists within the English inshore region, which are managed through the provision of IFCA Byelaws. An example of which that overlaps spatially with Farnes Deep Nephrops fishery (FU 6) is the ‘Prohibition on the use of Mobile Fishing Gear in the English Section of the Berwickshire and North Northumberland Coast SAC’ covering an area of 586.79km^2, managed by Northumberland IFCA. This covers the Berwickshire and North Northumberland Coast SAC; Northumberland SPA; Berwick to St Mary's MCZ. Further, standard gear sizes employed in this fishery include a 90mm codend (using single twine of 5mm) and one of either a 120mm square mesh panel or sorting grid with maximum bar spacing of 35mm.

Non-compliance with these regulations pose a significant threat to the target and non-target species and the designated habitats impacted by the activity. There is no publicly available evidence of non-compliance against area restrictions amongst domestic and foreign Nephrop trawlers.

2.2.11.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Moderate	Medium	Moderate	Medium

Essential fish habitat refers to waters and substrata necessary to fish for spawning, breeding, feeding, or growth to maturity. The risk from fishing activities depends largely on the sensitivity of particular habitats to damage, as well as its rate of recovery.

The distribution of essential habitat utilised by *Nephrops* is determined by the spatial extent of suitable muddy substrates; a sediment-type necessary for burrowing communities (Ungfors *et al.*, 2013). Especially for females carrying fertilised eggs on their abdomen that tend to remain in their burrows for period of between eight and nine months. Nephrops have an annual reproductive cycle, where sexually mature individuals moult towards the end of spring. Although small planktonic Nephrops larvae are transported by the currents, they do not have a high dispersal potential and it is believed that there is very little exchange of adults between FUs (Bailey *et al.*, 2013) and adult Nephrops show no evidence of migration. Key nursery grounds for Nephrops therefore overlap with the FUs discussed within this scope of work (Ellis *et al.,* 2012), of which not all is protected by bottom-towed closures of designed as protected habitats.

2.2.11.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Unlikely	Medium	Moderate	Medium

The majority of wind farms in the UK are located in the offshore region. Exceptions to this, that are currently active or in operation and span the relevant Nephrop fisheries FUs include Blyth Demo Phase 1 (NIFCA), Teesside (NIFCA), Burbo Bank (and Burbo Bank Extension) (NWIFCA), West of Duddon Sands (NWIFCA), Barrow (NWIFCA), Ormonde (NWIFCA) and Waldney 1, Waldney 2 and Waldney Extension 4 (NWIFCA). In addition to the loss of fishable area, an issue posed to TBN vessels within the inshore region, is the occurrence of and potential snagging of sub-sea cables.

Currently, wind farm associated cables occupy approximately 20% of the English inshore region; specifically, 2.38% of the North-Western and 1.49% of the Northumberland IFCA regions.

Mitigation measures applied to wind farm and construction and operation include the full involvement and engagement (Hooper *et al.*, 2015; Reilly *et al.*, 2015; Haggett *et al.*, 2020) of fishing industry representatives, for example through the use of Fishing Liaisons (Hagget *et al.*, 2020). However, there are mixed reports on their success, with poor relationships and inadequate communication between fishers and wind farm developers (Gray *et al.*, 2016).

2.2.12 Mid-water otter trawl (OTM) / Mid-water pair trawl (PTM)

Mid-water otter trawl (OTM) (Table 39) is a type of pelagic trawl that is spread horizontally in the water column by a set of pelagic trawl doors (Figure 16). The net opening is maintained by weights and bridles between the net and trawl doors. Mid-water otter trawls can be up to 200m wide and 150m deep. The larger mesh size in the mouth of the trawl serves to herd shoaling species into the trawl. Generally seen as a species-specific gear, the codend mesh size can be altered suit the target species. Target species in England include primarily sardines (*Sardina pilchardus*), herring (*Clupea harengus*) and horse mackerel (*Trachurus trachurus*). A mid-water pair trawl (PTM) and mid-water otter trawl are similar in design but differ in that the mid-water pair trawl is towed between two vessels, rather than one (Figure 16). Due to the similarities in design and interaction with the marine environment, OTM and PTM have been aggregated and scored simultaneously for the purpose of this work. Where discrete references to each métier are made, this will be distinguished within the presented evidence.

Table 39 Classification of midwater otter trawl (OTM) and mid-water pair trawl (PTM)

Métier	
Level 1	Fishing
Level 2	Trawls
Level 3	Pelagic trawls
Level 4	Midwater otter trawl (OTM) / Mid-water pair trawl (PTM)

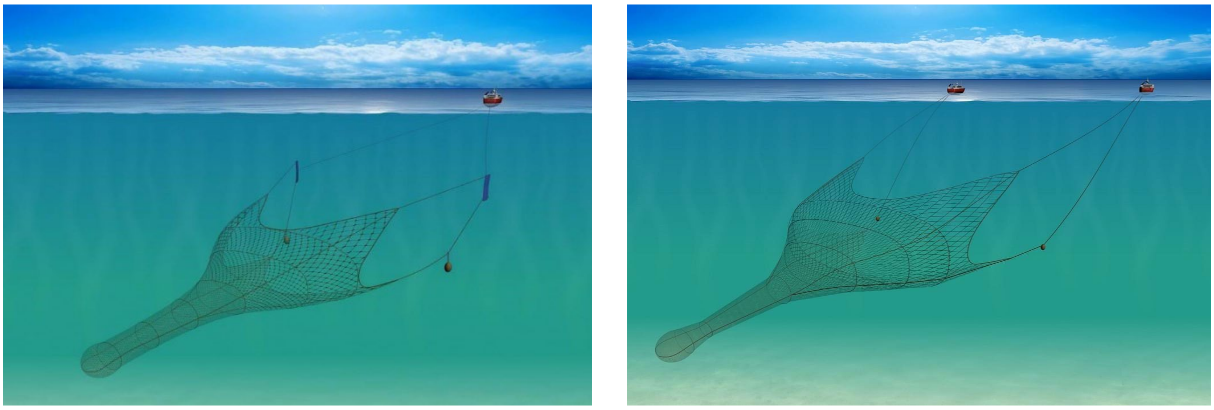

Figure 16 Mid-water otter trawl (OTM) and mid-water pair trawl (PTM) (©Seafish. Reproduced with permission: www.seafish.org)[130,131]

2.2.12.1 Distribution of vessels

There are a total of 147 mid-water otter trawlers (OTM) potentially operating across the English inshore region (Appendix 2). Of those, 110 are EU vessels, most which Irish flagged (65), and 35 are UK vessels. Within the UK, Scottish over 10m vessels are the most abundant known to target mackerel in the Channel and northern parts of the Celtic Seas, with very few OTM vessels registered to English ports.

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[130] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/pelagic-trawl/

[131] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/pelagic-pair-trawl/

Mid-water pair trawls (OTT) are far less abundant than OTM vessels, with a total of 29 vessels. Of those 23 are EU vessels, with all but one French flagged and the Irish. In the UK, there are six PTM vessels.

2.2.12.2 Risk ratings

Given the pelagic nature of the gear, and therefore minimal contact with the seafloor, much of the literature reporting on pelagic trawling focuses on the bycatch associations with the gear (Pierce *et al.,* 2002; Bonanomi et al., 2018), most notably the association of pair trawlers with dolphin bycatch (de Boer *et al.,* 2012).

2.2.12.2.1 Descriptor 1. Biodiversity is maintained

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Unlikely	Medium	Moderate	Medium

Mid-water otter trawls are nets towed by a fishing vessel within the water column (i.e., between the surface and seabed). The result is that, by design, these gears rarely interact with the seabed, with impacts to the benthic environment considered negligible[132] (Rosen *et al.* 2012). This means that OTM vessels directly impact biodiversity in two main ways (i) the removal of target species and (ii) the removal of non-target species. However, target pelagic species do not typically aggregate in great numbers in coastal waters, so fishing for these species generally takes place offshore (Defra, 2020).

OTM generally targets small pelagic shoaling species (Rosen et al 2012), primarily sardines (*Sardina pilchardus*), herring (*Clupea harengus*) and horse mackerel (*Trachurus trachurus*) around England (MMO, 2020). Species such as these are all highly productive, fast maturing species with high annual recruitment, making them less susceptible to over-fishing than more slow growing species (Burgess et al 2013).

Pelagic trawls are generally highly selective in operation, with typically low bycatch and discard rates (Reed *et al.,* 2017). This means that generally their consequence on non-target species is low. However, around parts of England, the winter inshore migration of certain cetacean species (e.g., short-beaked common dolphins (*Delphinus delphis*)) can result in high density dolphin aggregations in areas of high fishing pressure from gears including OTM (de Boer *et al.,* 2012). This can lead to bycatch a mortality event that have been linked to the localised decline in common dolphin populations (de Boer *et al.,* 2012).

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[132] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/pelagic-trawl/

There are only seven registered OTM and three PTM vessels in England (*Appendix 2*), so it is considered that the probability of the risk interaction occurring within a one-year period is low (i.e., unlikely).

2.2.12.2.2 Descriptor 3. The populations of commercially exploited fish and shellfish are healthy

Consequence	Likelihood	Inherent	Mitigation	Residual
Serious	Likely	High	Moderate	High

Scores assigned under this descriptor are reflective of the three pelagic species with the highest landings into England by UK vessels 2019[133]; sardine, herring, and horse mackerel.

According to ICES Advice 2020 and 2021 on fishing opportunities, catch and effort, the North Sea, Irish Sea, and the eastern English Channel herring stocks are reported to be sustainably fished (i.e., below F_{MSY}) and of good reproductive capacity (i.e., above spawning stock biomass (B_{MSY})), based on ICES MSY or Management Plan approach.

Similar advice revealed that all sardine and horse mackerel stocks are unsustainably fished, or the data are not available to make a conclusive assessment. However, ‘other passive gears’ (which contained pelagic trawls) contributed <1% (by weight) of all species landed into the UK, by-UK vessels in 2019, and only around 1% of all pelagic species landed in the UK, by UK and foreign vessels, also 2019. Therefore, it could be suggested that the status of stocks below is a minor and unlikely reflection of risk posed by pelagic trawls. Herring and horse mackerel are both quota managed species, but sardines are not (**Table 40**).

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[133] https://www.gov.uk/government/statistics/uk-sea-fisheries-annual-statistics-report-2019

Table 40 Stock status for sardine, herring, and horse mackerel

Species	Stock	Fishing pressure (F_{MSY})	Spawning Stock Biomass (B_{MSY})	Status
Sardine	The Celtic Sea, Irish Sea and the English Channel[134]	Unknown	Unidentified	Unknown
Herring	North Sea, and the eastern English Channel[135]	Below	Above	Sustainable
	Irish Sea[136]	Below	Above	Sustainable
Horse mackerel	The Celtic Sea, Irish Sea and the western English Channel[137]	Above	Below	Unsustainable
	Southern and central North Sea, eastern English Channel[138]	Unknown	Unidentified	Unknown

2.2.12.2.3 Descriptor 4. Elements of marine food webs ensure long-term abundance and reproduction

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Unlikely	Medium	Moderate	Medium

The nature of OTM means that these fisheries have a negligible impact on seabed habitats and are also considered generally ‘clean’ fisheries, characterised by little bycatch. Therefore, the main way that OTM fishing will degrade elements of the food web is through the direct removal of the target species.

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[134] ICES. 2019. Sardine (Sardina pilchardus) in Subarea 7 (southern Celtic Seas and the English Channel). ICES Advice on fishing opportunities, catch, and effort

[135] ICES. 2020a. Herring (Clupea harengus) in Subarea 4 and divisions 3.a and 7.d, autumn spawners (North Sea, Skagerrak and Kattegat, eastern English Channel). ICES Advice on fishing opportunities, catch, and effort

[136] ICES. 2021. Herring (Clupea harengus) in Division 7.a North of 52°30’N (Irish Sea). ICES Advice on fishing opportunities, catch, and effort.

[137] ICES. 2020b. Horse mackerel (Trachurus trachurus) in Subarea 8 and divisions 2.a, 4.a, 5.b, 6.a, 7.a–c, and 7.e–k (the Northeast Atlantic). ICES Advice on fishing opportunities, catch, and effort.

[138] ICES. 2019. Horse mackerel (Trachurus trachurus) in divisions 3.a, 4.b–c, and 7.d (Skagerrak and Kattegat, southern and central North Sea, eastern English Channel). ICES Advice on fishing opportunities, catch, and effort

Small to medium-sized pelagic species (e.g., sardines and herring) are known as 'forage fish'. This group occupies a critical role in marine ecosystems by transferring the energy in plankton to predators in higher trophic levels (Essingtona *et al.* 2015). Forage fish, therefore, are a vital link in the food chain and a food source for lots marine predators including seabirds, other fish species and marine mammals (Pikitch *et al.* 2014). Overfishing of these fishes can have far reaching consequences on surrounding ecosystems, through the direct removal of elements of food webs that ensure the long-term abundance and reproduction of many species that rely on them.

However, 'other passive gears' (which contained pelagic trawls) contributed <1% (by weight) of all species landed into the UK, by UK vessels in 2019, and only around 1% of all pelagic species landed in the UK by UK and foreign vessels, also 2019. Therefore, it could be suggested that the effect of pelagic trawls is minor in comparison to other fishing methods that target the same species.

2.2.12.2.4 Descriptor 6. Sea floor integrity ensures functioning of the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

The pelagic nature of OTM means that these fisheries have a negligible impact on seabed habitats.

2.2.12.2.5 Descriptor 10. Marine litter does not cause harm

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Moderate	Medium	Moderate	Medium

The nature of OTM means that these fisheries have a negligible interaction with the seabed. This means that there is little opportunity for OTM nets to become entangled, snagged or broken and these nets are rarely lost at sea, and are not among the gear types most often cited in recent literature as major components of Abandoned, Lost and otherwise Discarded Fishing Gear (ALDFG) (Gilman *et al.* 2016; Barboza *et al.* 2019; Richardson *et al.* 2018).

Gear may be lost due to a physical interaction between active gear (e.g., OTM) and passive gears (e.g., gillnets or pots and traps). For example, such gear conflicts can occur when passive gear is towed from its original setting, and potentially damaged in the process, by the action of trawlers or dredgers (Richardson *et al.* 2018). However, OTM tends to occur mainly on deeper offshore water, where these types of gear interactions are less likely to occur.

As proposed by Macfadyen *et al.*, (2009[2]), interventions can be broadly divided between measures that prevent (avoiding the occurrence of ALDFG in the environment); mitigate (reducing the impact of ALDFG in the environment) and remediate (removing ALDFG from the environment).

2.2.12.2.6 Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	N/A	Low

Anthropogenic sources of underwater noise have ramifications for marine species e.g., fish, invertebrates (Weilgart 2018) cetaceans (Nowack *et al.*, 2007). Well studied sources of underwater noise include shipping, pile driving (Weilgart 2018) and geophysical seismic surveys (Popper at al., 2005; Godley 2016). However, there is a distinct paucity of information within the literature on the impact of underwater noise created by trawling, when compared to the wider effects of trawling on the marine environment.

However, Daly and White (2021) report noise emissions from both bottom trawlers and the gear itself, which are considered distinctly. Seabed sourced sound (i.e., from the interaction between bottom gear and the seabed) is reported to be of more potential harm to marine fauna, in particular resident and transient mammals, than noise created at the surface. This type of sound will be negligible for OTM and PTM as there is little to no gear seabed interaction. A study by Peña et al (2011), however, showed that the "*sound pressure spectrum of radiated underwater sound from "Brennholm" [a pelagic trawler] showed a higher (ca. 30 dB) than recommended levels by the ICES CRR 209, at vessel speeds of 9, 11 and 12 knots*".

In regard to the scoring for mitigation for this descriptor, potential changes from mitigation are negligible and therefore the mitigation is scored as "N/A" and the residual risk remains as "Low".

2.2.12.2.7 Additional risk factor 1. Commercial fish bycatch

Consequence	Likelihood	Inherent	Mitigation	Residual
Minor	Unlikely	Low	Strong	Low

OTM and PTM are very species specific in operation as the large mesh at the mouth of the trawl which will only herd shoaling species into the trawl, allowing other free-swimming fish to escape. Depending on the size of the trawl, the individual meshes can be anything between 5 m up to 50 m in length[139]. Shoaling fish, such as sardines, herring, and mackerel, will move as one as the trawl begins to enclose around the fish, trapping them in the smaller mesh size at the codend. The design of the trawl therefore capitalises on the behaviour of shoaling fish and therefore there is a low risk to non-shoaling fish species.

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[139] https://www.seafish.org/responsible-sourcing/fishing-gear-database/gear/pelagic-pair-trawl/

Nevertheless, there is a risk of catching other shoaling fish. While there is little evidence of this occurring in the UK, in the US Atlantic herring (*Clupea harengus*) and mackerel (*Scomber scombrus*) fishery, bycatch of river herring (alewife, *Alosa pseudoharengus*, and blueback herring, *Alosa aestivalis)* is causing ecological concern for their population status due to their co-occurrence in spatial distribution with Atlantic herring and mackerel (TurnerRiver herring were under consideration for listing under the US Endangered Species Act in 2019, albeit was not warranted[140], and regulatory management measures (e.g., temporal-spatial closures and catch limits) and improved fleet communication strategies (e.g., "move-on rules") are in place to mitigate river herring bycatch (Cournane *et al*., 2013).

Additionally, specific fishing grounds are targeted based on the skipper's knowledge in knowing where the species will be during their annual migration route, as well as using echo sounder and sonar screens to locate the shoaling fish. The height of the trawl in the water column is controlled by the speed of the vessel and amount of trawl warp shot which can be monitored using electronic sensors on the headline to ensure the correct position of the trawl to catch the shoaling fish.

2.2.12.2.8 Additional risk factor 2. Protected (ETP) species bycatch

Consequence	**Likelihood**	**Inherent**	**Mitigation**	**Residual**
Major	Likely	High	Strong	Medium

Bycatch during fishing operations poses a serious threat to the survival and decline of ETP species. Where there is a spatial overlap in pelagic fisheries and areas of high prey density, bycatch is likely to occur as some cetaceans may enter the trawl chasing the shoals of pelagic fish.

Acoustic pingers have been developed for pelagic trawls to deter cetaceans coming close to the trawl. In the UK, a study investigated the use of pingers in the bass pair trawl fishery. Previous observations suggest bycatch is very high, with mean bycatch rates of around 1 short-beaked common dolphin (*Delphinus delphis*) per tow, (Northridge *et al.,* 2011). Estimates of dolphin bycatch in the south-west bass pair trawl fishery have been made annually since 2001 for the winter season (**Table 41**). Since 2007, the use of pingers has resulted in a decline in observed bycatch in UK pair trawls. This is supported by trails in French trawlers indicating a 70% reduction in common dolphin bycatch (Morizur *et al.,* 2008). Additionally, the closure of the pair trawl fishery for bass in 2017 would further decrease cetacean bycatch in UK waters.

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[140] https://www.federalregister.gov/documents/2019/06/19/2019-12908/endangered-and-threatened-wildlife-and-plants-endangered-species-act-listing-determination-for

Table 41 Common dolphin bycatch in the southwest bass pair trawl fishery (Northridge *et al*., 2011)

** LCL (lower confidence level), UCL (upper confidence level)

Winter Season		Point Estimate or Census	LCL	UCL
2000 to	**2001**	190	172	265
2001 to	**2002**	38	23	84
2002 to	**2003**	115	88	202
2003 to	**2004**	439	379	512
2004 to	**2005**	139	139	146
2005 to	**2006**	84	84	85
2006 to	**2007**	70	55	117
2007 to	**2008**	0	0	0
2008 to	**2009**	2	2	2
2009 to	**20010**	28		

2.2.12.2.9 Additional risk factor 3. Non-compliance against minimum landing size and quota species (e.g., misreporting)

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Rare	Low	Moderate	Low

2.2.12.2.10 Additional risk factor 4. Non-compliance against area restrictions e.g., gear type / marine protected areas

Consequence	Likelihood	Inherent	Mitigation	Residual
Major	Likely	High	Moderate	High

Recent instances of non-compliance amongst OTM and PTM vessels include the prosecution of the Dutch trawler ‘Frank Bonefass’ (SCH-72) in 2015 for illegally retaining 632,166kgs of mackerel deemed to be caught in a mackerel box closure situated in the southern Celtic Sea[141]. Fishing vessels seeking to fish in this area are required to provide a minimum of 24 hours’ notice prior to entering the area and to inform the MMO of the total quantities of mackerel on-board prior to entering. Vessels equipped with regulated fishing gears are limited to catches made up of not more than 15% mackerel.

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[141] https://www.gov.uk/government/news/master-and-owner-ordered-to-pay-over-102000-for-illegal-mackerel-catch

Further, in May 2019 the Irish flagged mid-water trawler 'Ocean Venture II' (S121) was prosecuted for operating in a hake recovery zone and square mesh panel area threatening the protection of juvenile fish[142]. Earlier this year, Greenpeace reported the Glorieuse Immaculee (a 23m French flagged pair trawler) to be fishing in Bassurella Sandbank SAC[143], which are designated for the presence of sandbanks which are slightly covered by seawater all the time.

2.2.12.2.11 Additional risk factor 5. Essential fish habitat

Consequence	Likelihood	Inherent	Mitigation	Residual
Insignificant	Rare	Low	N/A	Low

The pelagic nature of OTM means that these fisheries have a negligible impact on seabed habitats.

2.2.12.2.12 Additional risk factor 6. Displacement of fishing activity due to presence of offshore wind farm

Consequence	Likelihood	Inherent	Mitigation	Residual
Moderate	Moderate	Medium	Moderate	Medium

The rapid developments in the offshore renewables sector in the UK pose numerous threats to local fishing communities. Although the majority of wind farms in England are located in the offshore region. Exceptions to this, that are currently active or in operation, include Blyth Demo Phase 1 (NIFCA), Teesside (NIFCA), Westermost Rough (NEIFCA), Humber Gateway (NEIFCA), Inner Dowsing and Lincs (EIFCA), Scromby Sands (EIFCA), London Array (KEIFCA), Thanet (KEIFCA), Kentish Flats (KEIFCA), Gunfleet Sands (KEIFCA), Rampion (KEIFCA), Burbo Bank (and Burbo Bank Extension) (NWIFCA), West of Duddon Sands (NWIFCA), Barrow (NWIFCA), Ormonde (NWIFCA) and Waldney 1, Waldney 2 and Waldney Extension 4 (NWIFCA). The deployment of these structures and any further renewable energy sites will lead to the alteration of access to the area of instillation (Alexander *et al.,* 2016). This loss of access will affect many users, most notably fishers employing mobile gear such as mid-water otter trawlers, where loss of access may lead to displacement and reduced catch per unit effort resulting in resource conflict.

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[142] https://fiskerforum.com/irish-skipper-and-owner-fined-by-uk-court/

[143] https://www.express.co.uk/news/uk/1463086/brexit-fishing-news-trio-french-ships-caught-uk-waters-illegal-dangerous-greenpeace-mpas

Mitigation measures applied to wind farm and construction and operation include the full involvement and engagement (Hooper *et al.*, 2015; Reilly *et al.*, 2015; Haggett *et al.*, 2020) of fishing industry representatives, for example through the use of Fishing Liaisons (Hagget *et al.*, 2020). However, there are mixed reports on their success, with poor relationships and inadequate communication between fishers and wind farm developers (Gray *et al.*, 2016). Further options to mitigate the causes of conflict and provide possible benefits to the fishing industry include what is termed within the literature as the ‘artificial reef effect’ and ‘exclusion zone effect’ (Avery 2014). The presence of the renewable infrastructure provides shelter and additional hard substrate, which may lead to an increase in food availability for commercial species e.g., infauna and benthic epifauna. It is even suggested that the increased surface area provided by sub-surface renewable infrastructure could provide co-use management opportunities for habitat forming aquaculture practises (Avery 2014).

3. Objective 2: Framework of Remote Electronic Monitoring

The below sections document the Methods, Results, Recommendations and Framework produced in the delivery of Objective 2: Framework of Remote Electronic Monitoring.

3.1 Methodology

The following sections provide a detailed description of the methods undertaken in the delivery of this study. There were eight key tasks to completing Objective 2:

1. A systematic literature review of the global practices of REM;
2. An in-depth review of available REM technologies and their application;
3. Survey engagement of REM vendors and their products;
4. Survey engagement of English fisheries management organisations, policy-makers and regulators with respect to their REM requirements and objectives for inshore fisheries;
5. Identification and design of the most appropriate REM systems for English fisheries, by applicability to the fishing fleet and fulfilment of the stakeholder requirements;
6. Determination of the monitoring, analysis, and management requirements for implementing REM nationally;
7. Determination of the implementing cost of rolling out REM nationally; and,
8. Development of a modular risk-based matrix for the delivery of REM to English fisheries.

3.1.1 Literature review – REM global experiences and good practices

As part of the review and analysis of existing REM technological solutions, pilot trials and operational systems implemented by other countries, showcasing good practice examples, recommendations, potential risks, dependencies etc. were evaluated for integration into the analysis. These international case studies were cross examined for applicability where fleet operations mirror those of the English fisheries (inshore and offshore) where the methods of implementation and experiences exhibit cross-sector transferability to the English fishing sector. Experience drawn from this task was consolidated to provide Natural England with a series of the most appropriate models for the effective implementation of REM solutions on the inshore fishing fleets.

Questions addressed in the literature review:

1) What REM programmes are taking place around the world (and in the UK/Europe specifically – looking at cross transferability to the English fisheries)?
2) What fisheries / gear types do these REM programmes take place?
3) What REM technologies are used in these fisheries / on these vessels – do they give specific examples of the REM design (illustrations?), the number and type of technology (cameras/sensors), companies involved?
4) What good practice examples or experiences are shared in these reports which we may draw from (in terms of running REM programmes and in managing the fisheries)?
5) What is the most appropriate model for running REM programmes? An audit or census approach to monitoring and analysis.
6) Are there any given costs for these REM technologies or in the running of these programmes?
7) What is the most appropriate level of observer and/or REM coverage, and analysis used in fisheries globally? And, what defines why this coverage is needed?

3.1.2 Literature review – REM technologies, application and production

A global literature review was conducted to collect information on REM / EM programmes, identifying vendors within the EM community and the technologies they produce. The vendors and products were initially reviewed and assessed for suitability against the scope of the project. These were then compiled into a contact list for the intended purpose of distributing a detailed survey collating product specific information.

3.1.3 REM Vendor survey

The vendors listed Table 42 below, were approached to provide further information on their products; covering, design, capabilities, functionality, costs, and application. These vendors were first engaged via email to outline the task we are undertaking and why we are contacting them. Then followed up with the information requested in the form of an excel template.

Table 42 Breakdown of REM / EM Vendors (companies) contacted during the survey

Company / Vendor	Contact	Responded – Documents provided.
Anchor Lab	info@anchorlab.net	Y
Archipelago Marine Research / Marine Instruments	info@archipelago.ca	Y
Cvision.ai	https://www.cvisionai.com/#contact	Y
FINNZ	info@finnz.com	Y
Hookpod	https://www.hookpod.com/en/contact/#contact	Y
Integrated Monitoring	info@integratedmonitoring.net	Y
SafetyNet Technologies	enquiries@sntech.co.uk	Y
Satlink / Digital Observer Services	info@digitalobserver.org info@satlink.es	Y
Sea Scope	grant@seascopefisheries.co.uk	Y
St. Andrews University	Mark James - maj8@st-andrews.ac.uk	Y
Succorfish	enquiries@succorfish.com sales@succorfish.com	Y
Teem Fish / SnapIT	info@teem.fish info@snapit.group	Y
Thalos	contact@thalos.fr	Y
AST Marine Sciences LTD	info@ast-msl.com	N
Deckhand	lange@deckhandlogbook.com	N
DTU Aqua	aqua@aquc.dtu.dk	N
Echomaster Marine	sales@echomastermarine.co.uk	N
Fishtek Marine	info@fishtek-consulting.co.uk	N
Flywire	sales@flywirecameras.com	N
Harbour Light Software	support@harborlightsoftware.com	N
SaltWater Inc	info@saltwaterinc.com	N

3.1.3.1 Survey design

The Vendor’s survey was designed around three main themes: company and product details; defining product capabilities and costs; product application globally. These three themes were addressed in the following tables split across different tabs. The text has been rotated across the below Tables: **Table 43** Vendor Survey - Tab 1 – Company and EM product details, **Table 44** Vendor Survey - Tab 2 – Product capabilities and costs and **Table 45** Vendor Survey - Tab 3 – Product application to clearly display question headers.

Table 43 Vendor Survey - Tab 1 – Company and EM product details

			Technologies manufactured or sold (please tick the below)											Product Features (please tick the below)									
Company Name	Company Description	Company Experience	Cameras	Hydraulic Sensors	Independent GPS / AIS / VMS	RFID	Weight scales (inshore and offshore)	In-gear / below-surface technologies	Bycatch mitigation devices	Electronic Reporting / Logbook	Control Box / Hard drive	Video display / Monitor	Other? Specify.	Inshore capable?	Offshore capable?	Capable of Independent or	Secure hard drive (encrypted /	Onboard processing / AI capability?	Remote data transmission enabled?	Analytical review software?	Compatible with other technologies?	Remote cloud based storage?	End user AI capable?

Table 44 Vendor Survey - Tab 2 – Product capabilities and costs

					Capabilities. Please provide text in the cells below describing your product.					Costs (GB £'s) please indicate these below where applicable.											
															Transmission and communication						
Company Name	Product and description	Is the product commercially available now?	Is this a standalone product or part of an integrated EM system?	Can this product be integrated with other technologies made by other suppliers?	Internal Storage Capacity (external Storage) / Data compression	Number of Cameras and/or sensors that may be connected	Security / Encryption / Ruggedised / Tamperproof / Backups	Transmission method / communication / Reporting / Remote access	Additional features (e.g., AI capable, cloud-based storage, biological data collection capable (i.e., Length-Weight measurements), Data collection protocols)	Unit	Installation	Maintenance (over a year)	Licencing (over a year)	Tech Support (over a year)	(Please indicate the cost)	(Please indicate the units -i.e., per report, ping, data (gb/mb)	Software (over a year)	Please indicate if you offer commercial discount for bulk purchase)	Does this product meet the EFCA minimum standard requirements?	Do you include cost recovery options with your product (i.e. technology buy-back options for vessels)	Additional comments

Table 45 Vendor Survey - Tab 3 – Product application

		Métier. Please provide information on which fisheries and gear types of your products have been used.																					
		Level 3	Dredge	Trap	Nets					Rods and Lines		Longlines		Bottom trawls					Pelagic trawl				
Company	Product and description	Level 4	Boat dredge (DRB)	Pots and traps (FPO)	Nets	Gillnets (GN)	Drift net (GND)	Set gillnet (GNS)	Trammel net (GTR)	Hand and pole lines (LHP)	Hooks and lines (LX)	Longlines (LL)	Set longlines (LLS)	Trawl	Bottom otter trawl (OTB)	Multi-rig otter trawl (OTT)	Beam trawl (TBB)	Nephrops trawl (TBN)	Midwater otter trawl (OTM)	Other	National / Federal Designations held (if any).	Fishery (Location)	Reference to reports or published materials (if any)

3.1.3.2 Evaluating technologies

REM technologies identified through the engagement with vendors were synthesised into a master list, standardised, where possible; and evaluated against the European Fisheries Control Agency (EFCA) technical standards for REM (EFCA, 2019). We caveat, that the EFCA technical standards are overly stringent, and all REM systems will fall short on at least one category. Taking this into consideration, the majority of the EFCA standards do form a useful benchmark to evaluate the REM systems against and provide a uniform standard to work from. It should be noted, that the EFCA standards are attempting to be all encompassing across a wide variety of fisheries (i.e., the entire EU flagged fleet). As such, for example, it contains requirements that would be relevant to large offshore factory vessels but would have no relevance to the English inshore fleet.

3.1.3.3 Costings

REM technologies identified through the engagement with vendors were synthesised into a master list, standardised, where possible; and evaluated into like-for-like and comparable system designs. All costs given were quoted in sterling as requested in the survey distribution.

Many costs given were not comparable, nor necessarily like-for-like, this is due to the bespoke nature of many of the operational projects. Additionally, many of the costs did not provide an itemised nor cost-specific breakdown. REM vendors use several different business models when providing costings. Some will use a per vessel per year rate for licencing of software and review services, others will use a per fleet model for software. Others are moving towards a model of providing services for a monthly fee though this is primarily for mature REM programmes.

Where this occurred, clarity was sought from the vendors. Where applicable, itemised costs not available in the returned information were averaged and standardised, the wider recent literature on REM technologies and costings were also consulted to provide as useable and realistic estimates as possible for an entire REM programme.

3.1.3.4 Shortlisting / recommending technologies

Once standardised and categorised, technologies considered most applicable to the designs and stakeholder monitoring requirements of REM were shortlisted and matched against the requirements of the fleet. The complete short list is provided as an annex to this document and given in full, with product specifications to Natural England.

3.1.4 Stakeholder engagement survey

A web-based stakeholder survey, targeting English fisheries managers, policy makers and regulators, was constructed using the LimeSurvey[144] software and hosted on internal secure MRAG web servers. This survey was designed to address a number of questions relating to English fisheries monitoring priorities, risks, concerns and requirements. The survey ran for a four-week period (with extensions of two weeks made for specific stakeholders) to maximise the number and quality of responses possible within the timeframe of the project.

3.1.4.1 Survey design

The following questions were designed around capturing fisheries managers', regulators', and policy makers' priorities on applying REM to managing English fisheries. This survey identified some of the monitoring and regulatory objectives of implementing a national REM programme, encapsulating;

- What is the primary function and intended application of REM?
- Who will REM primarily benefit?
- What type of information and data are sought from implementing REM in English fisheries?
- What anecdotal experiences and concerns in how REM is applied to specific fisheries may help inform the modular framework for REM implementation?
- What are the preferred technologies to be applied across each fishing métier? and
- What are the national monitoring, analysis and reporting requirements across the métiers?

As identified in Section 2.1, Objective 1, 15 métiers of interest (i.e., métiers with >40 vessels (<>10m) registered to English ports, were the primary focus of framing the questions on fishery management and application of REM technologies addressed in this survey. For reference these were: (Beam trawl (TBB), Boat dredge (DRB) - all dredge gears, Bottom otter trawl (OTB), Drift net (GND), Gillnets (not elsewhere included) (GN), Hand and pole lines (LHP), Hooks and lines (not elsewhere included) (LX), Longlines (not elsewhere included) (LL), Midwater otter trawl (OTM), Multi-rig otter trawl (OTT), Nephrops trawl (TBN), Pots and traps (FPO), Set gillnet (GNS), Set longlines (LLS), and Trammel net (GTR)).

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[144] https://www.limesurvey.org/

A complete list of questions is given in Appendix 4.

3.1.4.2 Communication

The survey was shared via a website link to the list of stakeholders agreed with Natural England. These covered the relevant contacts or key organisations within a select group of governmental and non-governmental fisheries managers, regulators, and policy makers. Sixteen complete responses were received across twelve organisations giving us a fairly representative sample to work from across all levels of English fisheries management (Table 46 Stakeholders engaged in the REM survey.). As part of the survey design, stakeholders were requested to submit one response per organisation, however, a small number submitted multiple responses from experts in different departments, with differing sets of priorities and opinions.

Table 46 Stakeholders engaged in the REM survey

Organisation		Response received.
DEFRA		Yes
DAERA		No
NatureScot		No
MMO		Yes
CEFAS		Yes
IFCAs	Isles of Scilly	No
	Cornwall	Yes
	Devon and Severn	Yes
	Southern	Yes
	Sussex	No
	Kent and Essex	Yes
	Eastern	No
	Northern Eastern	Yes
	Northumberland	Yes
	North-Western	No
WWF		Yes
JNCC		Yes
Natural Resources Wales		Yes

3.1.4.3 Response management

The responses returned by stakeholders were managed within the LimeSurvey platform. All responses were catalogued and allocated a unique identifier to maintain data integrity. The level of responses was monitored to allow targeted follow ups during the consultation period. Responses that completed the whole survey are identified separately from any incomplete or partial responses so that only the fully completed surveys were exported for analysis.

3.1.4.4 Analysing responses

The list of complete responses was downloaded from the MySQL database that holds the data for the LimeSurvey software. Patterns and trends of interest identified in the evaluation of the responses and graphics were regenerated in R for improved clarity and visual representation.

Limited quantitative information and data availability on the additional risk factors (*outlined in Section 2.2, Objective 1*) had been highlighted as a concern when addressing discarding practices, protected species bycatch, misreporting and non-compliance. For this reason, anecdotal data capture was included within the survey methods, to strengthen the Objective 1 risk analysis. These were queried to identify the words and themes that occurred most frequently among the stakeholder responses. Where given, these responses were used to generate a word cloud, identifying the most pressing concerns and issues among stakeholders. Using R studio, the implementing team generated word clouds to obtain a value/weighting for concerns highlighted or raised multiple times (i.e., the number of times misreporting/non-compliance/a particular fleet or métier of concern are mentioned in the survey). This provides a comparable result to address the information captured through the literature review and were used to verify the outcomes of the risk assessment.

Several matrices laying out the monitoring and technology requirements were produced from the stakeholder responses. These were then used to inform the design and structure of the proposed REM systems in the modular framework and approach to the REM management plan. Given the wide range of products of different technical capability available from REM vendors the stakeholder responses were critical in informing the following aspects of the analysis.

- Scoring system used in scoring the different control boxes in terms of best suitability to the English inshore fleet,
- Determining the optimum number of cameras and sensor inputs to meet the required monitoring objectives,
- The optimum technical capability required, and
- The optimum forms of connectivity and data transmission.

3.1.4.5 Incorporating stakeholder responses into the modular framework, establishing monitoring requirements and REM management plan.

All stakeholder responses were consolidated into a single output for the analysis and reporting. Aggregated data were used to map and report on the responses collectively, draw together a series of themes underpinning the requirements of REM and used to inform our decision making on recommending REM Systems, producing data collection designs, determining analysis effort and programme management requirements. Stakeholder responses are reported on in Section 3.2.5.

3.1.5 REM technologies applicability review

It is important to understand how REM components may contribute to mitigating the risks of fishing métiers on the wider marine environment; specifically, we looked to determine how REM can be used for meeting regulatory objectives, promoting, and ensuring compliance with the regulations and supporting data capture for all species, but of greater interest for strengthening biological data collection, data on data-limited stocks and documenting protected species interactions. As such the identified REM technologies were evaluated against the available literature, operational experiences, results of pilots and REM suppliers and manufacturers product specifications in order to determine their effectiveness in supporting English fisheries management.

Technologies at the level required to support the objectives listed above are generally readily available, therefore, these were analysed in accordance with the working modality of each fishing métier as a means to target specific fleets with the most appropriate REM technology. Integrated approaches applying different technology types, systems and designs were considered in order to achieve the priority objectives and functions of REM as identified by stakeholders.

The specific criteria that the technology capabilities were reviewed against were data storage, attachment capacity i.e., cameras and sensors, processing, and transmission capabilities Table 47. The optimum desired capability was determined from the requirements of the inshore fleet and the stakeholder responses. Scoring criteria were developed in order to give an overall traffic light grading system but with grading within each colour also to accurately reflect the capability of the different boxes relative to the requirements (Table 47).

Table 47 Scoring criteria for control boxes

Ranking	Score	Internal Storage	# Camera & Attachment	Connectivity	AI/Machine Learning
High	**8**	1-2 TB or bespoke	4 cameras & 4 sensors, or more, or bespoke	Wi-Fi, cellular & satellite capable	Onshore & at sea options
Medium	**7**	1.5-2	4 cameras and 3 sensors available	Missing satellite option	Onshore option & at sea in development
Low	**6**	1 -1.5	3 cameras and 3 sensors available	Missing one more option	Onshore option, no plans for at sea
High	**5**	2-4TB	Less than 3 cameras and sensors	Missing a key capability - Wi-Fi	Onshore in development & at sea in development
Medium	**4**	4-6TB or 500GB-1TB	Bespoke cameras, no sensors	Missing a key capability – cellular	Onshore in development only
Low	**3**	6-8TB or 250 - 500GB	Low number of cameras, no sensors	Missing key capabilities - Wi-Fi & cellular	At sea in development only
High	**2**	over 8TB	Single camera	Non specified remote option or physical swap	None, but development in the pipeline
Medium	**1**	Under 250GB	Single sensor	Satellite or physical swap	No information provided
Low	**0**	No internal storage	No cameras or sensors	Physical swaps only	None

3.1.5.1 REM Designs

Three REM designs were produced for each métier based on the technologies currently commercially available or at a high stage of development identified by each of the vendors and information extracted from the global literature. These designs were framed around the themes of low cost-minimal critical data gathering; a cost-effective data gathering using select technologies and a balanced approach to yield critical data at a justified cost; and maximising data gathering where applicable and reasonable. These three themes were used to determine the number of technologies applied to each fishing métier for vessels above and below 10m in length.

Once designed, these were crosschecked against the stakeholder requirements for English fisheries management, as reported in Section 3.2.5 and reviewed against the risks identified in Objective 1 Section 2.2 to ensure the REM designs and data gathering approach were sufficiently robust and comprehensive i.e., understanding the diverse sets of risks identified under Objective 1 for each gear type and ensuring that any REM design would be able to mitigate or reduce one or more of the risks. Each design was incorporated into the split-matrix framework and scored on the capability of the REM system against meeting the stakeholder needs and addressing the highest risk concerns for each fishing métier. The most appropriate of the three themed designs for each fishing métier were selected and put forward for recommendation in the modular framework. In order to remain impartial, no specific vendor’s products were assigned to the three designs for each métier. Instead, the potential benefits to monitoring for the fleet were addressed, although at this stage stakeholder engagement with fishers has not taken place and a shortlist of the most applicable REM technologies were identified.

3.1.5.2 Determining the monitoring and analysis requirements

The monitoring and data analysis requirements were synthesised from the stakeholder responses. These were then used to produce the design that would meet national data collection objectives whilst also being proportional to the level of risk presented for each métier, as identified in Objective 1, Section 2.2. These were then applied as a percentage value to the total fishing time across each métier in the fleet.

Fishing time was calculated from 2017 fishing effort data, courtesy of Poseidon Aquatic Resource Management & AVS Developments Ltd in pursuance of the development of the Fishing Impact Decision Information Toolkit. The documented number of days for each vessel category was multiplied by the specified number of active fishing hours per day for each vessel <>10m. This provided a total “data capture time” value for each métier, if using an audit approach, all fishing effort would be documented. This time value could then be used to determine the total quantity of data generated by each métier annually (<>10m), the level of data storage each métier would require, the quantity of data needed to be transferred, the quantity of data that needed to be reviewed for each métier, and the cost in analysing, managing, and reporting on that data captured for each métier.

3.1.5.3 Determining the cost of implementing REM nationally

Implementing any REM programme will generate a number of direct and indirect costs. Ranging from the initial investment in the purchasing of hardware, to the annual maintenance and running of the equipment and data collection mechanisms, separately to managing the equipment: storage, transfer, auditing, and analysis of the data, through to the management and reporting of the project. In addition to this, indirect costs will be generated in verification and / or auditing REM technologies, training for review staff and technicians. Depending upon the level of ownership of the entire system required by regulators in the long-term, there may be a requirement for investment in infrastructure to support implementation. The type of infrastructure required could include but is not necessarily limited to servers for data storage, platforms for uploading the data, bespoke software for managing and analysing the data and software for making the data available to end-users. Each of these have been covered to some extent in the report, with costs attributed to these synthesised through expert experience in running a REM programme, reviewing the available information in the global literature, and evaluating the information provided by vendors and stakeholders. Where possible, these costs were quantified as an annual value and incorporated into the design of the modular framework. Costs were not quantified for the infrastructure requirements for implementing a REM programme nationally, as this would form the basis of a much larger and comprehensive project. The costs and benefits identified through such a study would be heavily dependent upon the level of ownership required by regulators and the scale of an actual roll-out.

Table 48 provides a breakdown of some of the costs involved in running a REM programme with indicative long-term infrastructure costs included. All costs shown below except for long-term infrastructure have been scoped with the modular framework. See Section 7.3 for further information on long-term infrastructure.

Table 48 breakdown of costs involved in implementing a REM programme

One off equipment costs	Programme set up costs
Purchasing/leasing the equipment.	Management, including labour, coordination, documentation, and reporting.
Installation.	Staff training costs.
	Software customisation (where applicable).
	AI customisation (where applicable).
Annually reoccurring equipment costs	**Annual programme costs**
Maintenance and servicing.	Coordination and reporting.
Data transmission.	Analysis – analyst time to review REM data outputs over a year, quantified as an annual salary.
Data storage.	Review software licencing.
Hardware licencing (where applicable by vendor).	Technical support (as required).
Certification – auditing and certification that REM systems have been installed in accordance with the VMP.	Training (as required).
Long Term Infrastructure	

Hardware – large data servers, computer, and processing capability.	Software – analysis software, user portals, cloud-based storage.
Wi-Fi terminals.	AI and machine learning development.

3.1.5.3.1 REM equipment

Equipment costs were primarily derived from the vendors survey responses and given as an average value for comparable units. Where this information was not comparable, or has not been provided by the vendors, additional information was sought from the global literature on implementing REM programmes. A selection of key papers utilised here were the EFCA (2019), Course (2015), Course (2017), Course, Pierre, and Howell (2020) WWF international (2020), Pasco (2021) Michelin *et al.,* (2018).

3.1.5.3.2 Annually reoccurring costs

Annually reoccurring costs were derived from the vendors responses, the available literature on implementing a REM programme, and determined by the volume of data generated for each métier.

These costs can be broken down into three categories: costs associated with the REM hardware, costs associated with the data and costs associated with managing the programme.

3.1.5.3.3 Hardware associated costs

Hardware associated costs were taken directly from engagement with the vendors. This covered: information on the maintenance and services requirements of the REM equipment; their system for providing technical support and on average, what this entails (time and cost) to provide; and the costs for licencing the equipment for a period of one year. This cost was then validated against the available literature, such as the EFCA (2019) technical standard document, and the Course (2017) report detailing annual costs associated with hardware.

3.1.5.3.4 Data associated costs

Data associated costs were primarily determined from the calculation of data generated per métier. Once the volume of data was determined, the most appropriate transmission methodology was identified along with subsequent cost to move this volume of data. Vendors did provide some information on the cost to move data via cellular and satellite networks, but the responses were so variable, it was not possible to draw together a standard. Some information on this topic was available in the literature, but as discussed later in the report, the most appropriate methodology by stakeholder request and project feasibility, would be through a cellular mobile phone network. Therefore, costs were determined based on the average price for a high or unlimited data sim card for each vessel in the analysis fleet.

In addition, the data volume was used to determine the amount of time it would take an analyst to complete the review of the proportion of data set by the monitoring requirements. Assuming that on average, an analyst can work at a 1:4 ratio of analytical to recorded time, the value generated for total data collected was divided by four. The resulting value for total analytical time by métier was then multiplied by £14/hour – on the assumption that an analyst, will on average, be salaried at approximately £25,000 a year, working 35 hours a week, over 1,820 hours a year. This gave a total annual cost to review the data collected across the analysis fleet.

Determining the cost of analysis software was taken directly from the vendors and corroborated against the literature. Most vendors offered some form of analytical software and services to support and run alongside implementation of their REM hardware. Each of these had a variable cost structure base on the type of “package” or service being provided in the contract. Therefore, these were not directly comparable in most cases. Some vendors offered analysis software on a vessel-by-vessel basis, and others offered an integrated “fleet” tier package irrespective of the number of vessels used on. These instead were costed on the number and type of computer licences sold and were by far the most economical option. These values are calculated in the modular framework and included in the cost analysis (Section 6.3).

Not directly linked to the data associated costs in implementing REM, but for comparison, costs were given the equivalent cost of running an observer programme, utilising data courtesy of Poseidon Aquatic Resource Management & AVS Developments Ltd in pursuance of the development of the Fishing Impact Decision Information Toolkit and a reasonable achievable proportion of monitoring effort offset against that. This produced a value for the minimum monitoring time required by an observer per vessel and per métier. This value was divided by 12, assuming most observers nationally will be doing an average of 12-hour day trips, determining the number of observation “days” or “trips” required. The cost for an observer per day was based on a standard fee of £115, and salaried at a value of

£20,700, assuming the observer will complete a minimum of 180 sea days a year. These costs were displayed together, as we would propose a holistic approach to fisheries monitoring, utilising both fisheries observer and REM, to focus on the strengths and efficiencies of each, maximising the benefits and information gains to data collection and fisheries management. The justifications for these are provided in Section 6.1.

3.1.5.3.5 Management

Coordination, management and reporting are all key components of running any observation or monitoring programme, and generally can be quantified against the proportion of monitoring time.i.e.,, for an observer programme, management time will be calculated based on the observer sea days a year, and for a REM programme, the analytical time can be used, but as this is usually determined as a proportion of the fishing effort, so too can the management component. As such, this is the approach we have followed for this study. A percentage value was assigned to coordination, management and reporting based on the fishing effort. This was determined by the estimated quantity of time it would take to manage a REM programme simultaneously alongside the deployment of fisheries observers, this would encapsulate time for the coordination of both programmes, reporting obligations for each and the overall time required to ensure these are running as intended. These values were given as a number of hours per métier and multiplied against an “average” managers salary of £35,000 working 35 hours a week, over 1820 hours a year.

3.1.5.3.6 Infrastructure

The costs for the infrastructure required to run alongside a national REM programme are not given in the report. These infrastructure needs have been highlighted throughout the report, as a requirement to support implementation, but fell outside of the scope of the project to provide a cost for them. Below is a non-exhaustive list of some of the infrastructure needs:

- Hardware
  - Workstations (computers/monitors) for analysts to complete the data review;
  - Large data servers (cloud based or otherwise) to host the significant volume of data collected annually;
  - Computing and processing capability to run the analytical tools, rapidly disseminate data, host portals for data to be uploaded on to produce dashboards for staff to work from; and
    Portside infrastructure, such as Wi-Fi terminals to allow vessels to remotely connect, backup and store data.

- Software is required to:
  - Setup and ensure maintenance of data upload portals;

- Ensure data availability and security for fisheries, stakeholders, and end-users; and
- Include development of artificial intelligence and machine learning tools.

The level of infrastructure development required is dependent upon the degree of direct ownership required by regulators in the long term and what aspects will be contracted to the private sector, either directly to REM vendors or indirectly, such as the use of existing cellular networks rather than the construction of dedicated Wi-Fi towers.

3.1.6 Modular framework assessment and design

The modular framework design was structured to provide a quantifiable approach to rolling out REM across all English fisheries in our analysis fleet of 2,185 vessels.

This was done by providing a métier-by-métier breakdown for each IFCA region (based on where the vessels are registered), prioritising the most high risk métiers in relation to the descriptors identified in Objective 1, Section 2.2, and scoring this against the level of monitoring required (determined by the stakeholder inputs and the calculated minimum observation effort per vessel) and the achievable impact of the recommended REM design determined by data collection technologies and costs of rolling this out, i.e., the selection of technologies best able to meet the monitoring requirements set by the respective stakeholders and provide effective mitigation against impacts identified in relation to the various descriptors.

The level of monitoring and the achievable impact of the REM design were evaluated by a process of expert judgement of the evidence provided for monitoring and scored 10 for low, 20 for medium and 30 for high. These were then added to the risk score provided in Objective 1, Section 2.2 to give an overall value, ranking the priority for implementation – identifying the vessels or groups of vessels where REM will likely have the highest impact against achieving the monitoring objectives and helping to progress toward Good Environmental Status in English waters. Once ranked, the overall score was ordered by the number of vessels per region to determine which regions will generate the largest impact.

Figure 17 below provides a stepwise breakdown of the construction of the modular framework and a template structure for the modular framework has been given in Table 49.

Modular Framework Construction

Step 1: Objective 1 Vessel Classification

Vessels were classified under Objective 1 to determine the distribution and number of vessels (<>10m) by métier within each IFCA region. This generated a fleet of 2,185 vessels across the targeted 15 métiers.

Step 2: Objective 1 Risk Assessment

This risk assessment conducted during Objective 1 provided a risk score which fed into the matrix as a numerical value indicating the level of risk for each métier.

Step 3: Determining the monitoring requirement

The monitoring requirement was determined using a combination of resources. Firstly, the data gathering, monitoring and analysis requirements were determined through the stakeholder responses to the survey based on questions surrounding risk and fishing impacts across the métiers. Secondly, the global literature review synthesized information on the minimum data capture, monitoring and analysis requirement to generate statistically robust data on fisheries management objectives, and rarity of a specific event taking place. Lastly, recommendations for the minimum review were put forward based on cost, what is realistically achievable across the fishery and expert opinion in running fisheries observation programmes. This percentage value for each métier was multiplied by a value for fishing effort across the year to determine the minimum analysis time required.

The Monitoring requirement was determined by the number of hours of observation and review time required per vessel for each métier and scored a value of 10 (low), 20 (Medium) and High (30). <20 per vessel = Low; 20-40 per vessel = Medium; >40 per vessel = High.

Step 4: Determining the impact of REM system designs

The achievable impact of REM was determined through the evaluation of the recommended REM system design against the monitoring objectives determined through stakeholder responses.

Three system designs were based around the following: A - Maximum data collection; B - Cost-efficient data collection; and, C - Minimum data collection.

These were each evaluated against the data collection requirements and scored a value of 10 (low), 20 (Medium) and High (30).

Step 5: Overall Score determination

Vessel groups (arranged by IFCA region) were ordered according to the cumulative score of Risk, monitoring requirement and REM impact. Highest scoring groups were prioritized as these were seen to have the most substantial impact on achieving good environmental status in English fisheries.

Figure 17 stepwise breakdown of the construction of the modular framework

Table 49 Modular Framework Template

Ranking given, Order of implementation.	Fishing Vessel Métier		Region	Recommended REM System Design Option A - Maximum data collection Option B - Cost-efficient data	Assessment Criteria for the role out of the Modular Framework							
	Level 3	Level 4			Number of Vessels in the métier	Residual Risk Analysis Score (Score from OBJECTIVE 1)	Level of monitoring required and cost implications	Impact of REM achievable	Financial Cost to implement REM per vessel per year (given as £)	Total cost to implement across the selected vessels.	Additional justification (if required)	Overall Score
1	e.g., Métier A	e.g., Métier A	Kent and Essex	Option A - Maximum data collection	150	27	30	30	£15,000	£225	High risk, High monitoring, and High Impact	87
2	e.g., Métier B	e.g., Métier B	Devon & Severn	Option B - Cost-efficient data collection	200	29	20	20	£12,000	£258	High risk, Medium Monitoring, greater cost	69
10	e.g. Metier J	e.g., Métier J	Sussex	Option C - Minimum data collection	300	8	10	30	£5,000	£300	Low risk, low monitoring, high impact	48

Each métier underwent a separate evaluation to identify the most applicable REM technologies, in terms of the impact that can be achieved through monitoring and data gathered for vessels <>10m. Impacts were determined by the monitoring capability of the three low-cost, cost-efficient, and maximum data collection designs. These were then evaluated for the potential data gathering opportunities of each design against the monitoring and reporting requirements determined through the stakeholder engagement and scored 10 for low, 20 for medium and 30 for high. Each combination of technologies was given an itemised cost and tallied to determine the overall purchasing cost as outlined in Table 50 below.

The cost of installation, determined from the vendors responses, and available literature was included within the purchasing cost. As explained later in the report, the typical lifespan of a REM system is five years (Course, 2015; Course *et al.,* 2020). Therefore, as one-off costs, installation and equipment purchasing were divided by five, to provide an average annual value for the lifespan of the product. This annual value was added to the annual costs of maintenance, licencing, data transfer, analysis software and technical support; as outlined later in the report; to determine an annual cost per technology design, per vessel.

Table 50 Split Matrix template

Fishing Vessel Métier		Monitoring Objectives				
Level 3	Level 4	REM Technologies	Impact of REM	Justification	Cost implications	Cost per vessel per year (Given as £)
e.g., Métier A	e.g., Métier A	3 Cameras + weight-measurement board + GPS + Hydraulic Sensors + Mitigation Devices	30	The addition of further cameras enables greater clarity on fishing practices, capture discarding and including the use of weight-measurement boards / conveyor enables biological data collection.	Moderate increase in the cost of camera installation and maintenance. Marginal increase in biological data collection costs. Significant data storage and transmission costs.	£15,000
		Camera + GPS + Hydraulic Sensors + Mitigation Devices	20	Addition of a single camera to the minimum data collected below. This enables the additional layer of data gathered to support species ID and bycatch landed by the vessel. Greater reporting frequency.	Marginal increase in cost to include the installation of a single camera and associated data storage. Significant data transmission costs.	£10,000
		GPS + Hydraulic Sensors + Mitigation Devices	10	Minimum data collected – able to report fishing effort in real time to provide a quantifiable impact of fishing by days in a given area across the fleet. Able to report fishing behaviour within restricted areas.	Cost of unit, installation, maintenance, and reporting / transmission.	£5,000

3.2 Results

3.2.1 Good practice examples

We have identified good practice examples of REM use around the world and where these may be the best available in their specific situation, they may not be the best in all situations. Therefore, we purposefully use the phrase “good practice” to identify those examples that may be of use in the current situation for the inshore fleet.

In the UK for instance, trials using REM with CCTV on board vessels have been performed in Scotland and England since 2009, on different fleet segments and fisheries (i.e., offshore otter trawl fisheries, refrigerated sea water pelagic trawl fisheries and shellfish potting fisheries). The results from all these trials were very promising, and REM has been shown to be able to fully monitor fishing activity and crew behaviour regarding a discard ban.

In 2012, the Marine Management Organisation (MMO) conducted a Catch Quota Project, trialling REM in commercial English fisheries (North Sea trawl and net fisheries, and South-West beam trawl fishery). Fishermen participating in the trial were selected on a voluntary basis, with the incentive of receiving an additional quota equivalent to 75% of the estimated discard rate. Fishing activities were recorded through REM and 10% of the data collected were randomly selected for review. If the information contained in a vessel’s logbook did not match the REM data, the activity of the vessel could be inspected more thoroughly. This methodology is like the one used in British Columbia’s hook, line and trap groundfish fisheries. The results showed that the discard rate of several species decreased significantly when comparing the trial with the average discard rate of 2011 in the UK, and that the extra quota distributed, encouraged fishermen to fish more selectively to maximise their profit (e.g., by using nets with bigger meshes).

Following on from this project, the MMO initiated two other REM trials in 2014 (North Sea Cod Catch Quota Trials) and 2015 (South-West Beam Trawl Catch Quota Trials). Both studies confirmed that REM was an efficient tool in monitoring discards, and flexible enough to be used in many diverse fisheries. The final reports of these two projects are publicly accessible online (MMO, 2014; MMO, 2015).

In 2008, Denmark was the first European country to undertake trials on REM with CCTV cameras on board vessels. These tests were performed on the Danish demersal trawl fleet (Ulrich *et al*., 2015), where REM was shown to perform very well. Accidental bycatch control through REM and associated cameras was also shown to be efficient, as compared to data provided by fishermen. Danish studies concluded that using REM with cameras was approximately 6.7 times cheaper than using observers. More recently, DTU Aqua has been conducting studies on the application of gear cameras on bottom trawlers to monitor interactions between fishing gear and protected and vulnerable habitats and species, e.g., sediment displacement and geotechnical impact on the seabed; with a focus on precision fishing, through the development of technological decision-making tools for better control of the catch, e.g., real-time cameras mounted on trawls as well as adjustable trawl doors.

In 2014, the Redersvereniging voor de Zeevisserij (RVZ), in collaboration with REM vendor Archipelago Marine Research Ltd., conducted a pilot study on the use of REM data to confirm full retention of catch on board a freezer trawl vessel (F/V Jan Maria) (Pelagic Freezer-Trawler Association, 2016). One of the main goals of the project was to develop a methodology for monitoring catch and fishing activities on freezer trawlers through REM. Eight cameras were used, six on the wet deck, and two in the factory. REM was shown to be an efficient tool to control large amounts of fishing activities in a cost-efficient way. Nevertheless, it was noted that some discarding had been performed outside of the cameras' control points. It was suggested that sensors could be used to detect such activities. As a conclusion, this study highlighted that fishery characteristics and monitoring needs are linked with technology capabilities, regulatory framework, incentive systems, and programme operational requirements. Hence, defining the data that are needed for management purposes is essential.

3.2.1.1 Global experiences

Australia: an integrated REM system was introduced in several fisheries by the Australian Fisheries Management Authority (AFMA) as a replacement for at-sea observers from 1 July 2015. Under the current program, AFMA uses the integrated REM system to validate fisher-reported logbook information with an audit target of 10% of sets (defined here as the haul of catch from a single set) from each vessel and 100% of all gillnet-sets for protected species interactions in the Australian Sea Lion Management Zones. The 100% monitoring rate of this fishery is to confirm the veracity of the mandatory self-reporting of all interactions by fishers. This audit includes an analysis of catch composition, discards, and interactions with protected species. Audits are conducted by specialised video reviewers onshore following the completion of trips (Emery *et al.*, 2019).

Canada: Catches in the groundfish hook and line fishery in British Columbian Canada's west coast have been monitored since 2006 with an interrelated suite of technical components. These include, but are not limited to, full (100%) independent dockside monitoring, full video capture of fishing events and vessel monitoring at sea, 10% partial review of the video imagery from each trip, and full coverage of fisher logbooks. REM imagery from a 10% random sample of fishing events were reviewed and compared with the logbook records of counts for the same quota species onshore following completion of the trip. This showed that it could meet the operational and management requirements of the fishery. This fishery operates in a mixed fishery area with other choke species present which are also subject to quota. Operationally, test scores were consistently high, with values of 9 or 10 being achieved in 80% of the comparisons between REM and fisher reported data, with a score of 10 indicating a difference of less than two individuals. More importantly, the catch estimates (including discards) were sufficiently precise and unbiased for management and operational needs. Compared with the census, the audit approach is less costly. The former would cost at least 50% more. The audit system was also more robust and flexible, as well as being more intuitive and transparent to the harvesters (Stanley *et al*., 2011).

3.2.1.2 International case studies most applicable to English fisheries

The following international examples detailed in Table 51 were identified as approaches that would be applicable to English fisheries.

Table 51 International REM case studies

Gear type	Target species	Country/ region	REM technology used	Literature and further information
Boat dredge	Scallop	Scotland	Cameras showing number of dredges used, GPS, winch movement detection	Scottish Government (2020) Part of the Future Fisheries Management Strategy in Scotland (2020). Funding available to encourage EM installation prior to becoming mandatory.
Pots and traps	Crabs	Canada	GPS, Cameras, hydraulic sensor, RFID tags and scanners.	Sensors trigger cameras during gear set and hauling. RFID tags and scanners are used to identify individual pots being deployed and retrieved. Department of Fisheries and Oceans Canada (2021)
Gillnets	Elasmobranchs	Peru	Solar panel charged cameras	Bartholomew *et al*. (2018) Detect and quantify target catches & identifying genera.

Gear type	**Target species**	**Country/ region**	**REM technology used**	**Literature and further information**
	Gummy sharks	Australia	3 or more cameras, hydraulic gear sensor, drum sensor, GPS, satellite comms & control centre.	Australian Fisheries Management Authority (2020) Sensors trigger cameras during gear set and hauling. Data stored on hard drive; location transmitted for real time monitoring.
	Mixed	France	Cameras, hydraulic sensors and systems for data storage	Bay of Biscay, monitoring marine mammal bycatch and enforcement of the landing obligation.
Trammel net	Rig shark, elephant fish and school sharks	New Zealand	Cameras, GPS, Hydraulic and drum-rotation sensors	Pria *et al.* (2014) EM used to document captures of protected species, specifically Hector's dolphins. EM system recorded location data. Camera's turned-on during setting and hauling. EM had a 97% catch detection rate.
Hooks and lines	Groundfish	Canada	Two (plus) cameras, GPS, winch sensor, hydraulic pressure sensor for fishing gear	Strauss (2013) Audit based. 10% randomly audited to track catch and discards.
Longlines (Pelagic/ demersal)	Patagonian Toothfish	Southern Ocean	Two (plus) Cameras, hydraulic sensors.	REM data used to demonstrate good fishing practises and aid traceability
Trawl (Pelagic/ demersal)	Cod	North Sea	Closed circuit CCTV (up to 8 cameras), GPS, hydraulic pressure sensor, winch sensor.	Ulrich et al. (2015) Looking at accidental bycatch control. MMO (2016) North Sea Cod Fully Documented Fisheries trials. North Sea, 2008, pilot project, followed by further trials on EU landing obligation (2015). Assessing levels of cod discards and efficacy of acquiring length data from CCTV cameras. Audit method with 6.6% of data audited.

3.2.2 What is the most appropriate model for running REM programmes?

Monitoring rates for fisheries that currently carry REM systems can vary widely and this depends on the objective of the programme. Footage is either used to census all or review a proportion (which can then be extrapolated or raised), of fishing effort to estimate catch composition and/or to audit a proportion of fishing effort to verify fishing logbooks. In cases where the audit approach is used 10% monitoring of fishing operations has generally been considered adequate to pass an audit for verifying fisher reported data (Mangi *et al*., 2015). The census approach, where 100% of fishing effort is monitored, is generally used for programmes where the focus is on interactions with seabirds and marine mammals. The approach taken has varied depending upon a number of factors, primarily the overall monitoring objectives but also such factors as whether the programme is a pilot or a full rollout in a particular fishery. Whether a programme is voluntary or mandatory also significantly affects the coverage.

Given that REM is a relatively new technology there are not that many areas where it has been used as a monitoring tool across an entire fleet or fishery for a significant amount of time rather it is being deployed as part of a pilot, with voluntary participation of a small number of vessels, for a particular fishery (Michelin *et al*., 2018).

Canada, and subsequently the USA and Australia have been the pioneering countries in REM and as such these are where mature mandatory REM programmes exist with the audit model employed in all of these cases as described in Good practice examples Section 3.2.1.

3.2.3 Cost overview

Many costs given were not comparable, nor necessarily like-for-like. Additionally, many of the costs didn’t provide an itemised nor cost-specific breakdown. There are a number of reasons why this occurred, and these can be broken down into the following categories:

Hardware: Items like control boxes could generally be compared, though capabilities vary widely. Similarly, the price of an individual cameras can be compared though the capability of different vendors’ system for the number of cameras connectable varies widely. The addition of sensors and radio-frequency identification (RFID) scanners further complicate the situation as, again, the variety and quantity of sensors that can be connected may vary widely. With regard to the application of different sensors, these will vary depending upon the data that are being collected, a generic sensor maybe able to be connected or there may be a need to have very specialised functionality.

Software including licensing: Software and licensing broadly fell to two categories. Vessel specific, giving a cost and breakdown of the requirements on a per vessel basis, or server and user licence based targeted at the number of machines or people requiring use of the analysis software. Again, the cost did somewhat depend on the complete package of services being provided, but it was possible to decern to cost structures based on these categories.

Technical Support: Technical support is difficult to quantify without knowing more about the products servicing needs, and whether this support was applicable only to the hardware, trouble-shooting software, or in supporting the analysis software. Costs for these were largely incomparable, charged by the number of hours, days or a number integrated within a wider service package. Therefore, assumptions had to be made to standardise potential cost to the framework based on a value that had been given. For reference, we elected for 15 hours technical support, equivalent to two full days of staff time, per vessel over the course of the year.

Data transmission: Data transmission costs were quoted for both satellite and cellular coverage, but not consistently. There was very little standardisation to draw from to enable these to be comparable. Some vendors quoted by a fixed number of gigabytes, others quoted the cost over a period of a year (assuming a fixed amount of data transmission), others provided a bespoke package covering unlimited 1 minute position reports, weather updates, social media allowance – clearly geared toward vessels that operate on the high seas, and for a sizable per vessel cost.

Essentially, due to the very large number of variables that must be accounted for to generate a costing for a REM programme it is extremely difficult to generate a full estimate taking in to account all parameters at this scale accurately. Furthermore, it should be noted that almost all vendors indicated that during the build up to operating a new REM programme there is generally a high degree of consultation between the REM vendor and the client on these variables that will determine the final cost. Two of the largest of these factors are the objectives and volume of review along with the volume and frequency of data transmission.

It should be noted that all bar two vendors indicated that bulk discounts and / or lease options were possible depending upon the scale or nature of the programme involved.

3.2.4 Vendors Survey

Despite information being collected in a standardised format, the responses returned were highly variable, with many products not directly comparable. No two REM systems offered truly like-for-like comparability across the data collected. The REM hardware showed significant variation in the setup, design, capabilities and functionality between vendors, products, and their intended market. For instance, certain vendors and products were clearly targeted at high seas industrial purse seiners and were not applicable to the fishing fleets likely to operate in the English inshore. A degree of cherry picking was required to identify the vendors and products most applicable to the English inshore fishing fleets and draw comparisons from them.

The vendors showed the greatest degree of variation in the financial and business models to supplying technologies and in the provision of their REM services, i.e., bulk purchase discount, discount for multi-product purchase (inclusion of software and hardware, licensing, and hardware), integrated licences, integrated maintenance and technical support, cost recovery and leasing options. Therefore, drawing direct comparisons across all vendors was impossible. Where this was encountered, similar products were compared, and where itemised values given, these were used. The global literature was used to provide some degree of standardisation and supplement areas which were light in detail.

As part of the evaluation, all technologies were broken down into their individual component types (control box, camera, sensors, E-logbook, review software, etc.) and assessed for functionality and applicability. Control boxes presented the most variability across the technologies, these were categorised into four-unit types initially to start developing the REM designs against the potential requirements of the English inshore fleet, and then later analysed in more detail using a bespoke scoring methodology.

The four initial specifications identified were: high functionality (8+ cameras and external data inputs), medium functionality (4-8 cameras and external data inputs), low functionality (1-4 cameras and external data inputs). An additional category was included for two products which included sensor data input but no camera functionality. On a preliminary assessment against the fishery, it was determined that the high functionality control boxes and systems had far greater powered technology than what would be required, and consequently significantly more costly for the intended requirements of the English inshore fisheries, being targeted to distant water heavily industrial fishing fleets. The medium and low functionality REM systems were most applicable to what is sought to be achieved through the deployment of REM in English inshore and offshore fisheries and were middle of the range and low cost. There is some purpose and scope for low functionality without cameras, which were the cheapest option, on considerably low risk fleets, and fleets where the monitoring requirement isn’t conditioned on real-time verification of fishing activities using video footage.

The REM products provided by vendors were generally not itemised and were either quoted as the cost and capability of a full REM design, based on a prescribed number of cameras and inputs, or given as the control box alone. Overall, all REM designs are only as capable as the control box installed. This determines the functionality, the number of data inputs, the volume of data stored, the information processing, transmission, and connectivity functionalities. Section 4.1.1, provides a breakdown of REM Vendors (companies) and the control boxes they produce, the most applicable to English fisheries were assessed using a bespoke scoring methodology developed to determine applicability to this study.

3.2.5 REM Stakeholder Survey

The analysis of the stakeholder survey responses generated some predictable and consistent results on the application of REM in English fisheries from the perspective of fisheries managers and regulators. Most stakeholders that responded provided a consolidated response to the survey. A small number of stakeholders submitted multiple responses. These were completed by different departments within the organisation and conveyed a different set of opinions, therefore, the responses were not combined. This may have unfairly biased the results where some stakeholders may have wished to express several opinions but had consolidated their response before submitting the survey. However, given the general consistency of responses across all stakeholders, this is thought not to be the case. Some opinions did diverge between stakeholders, but in general they ran along several recurring themes.

These themes are as follows:

1. Determining vessel position, time and duration of fishing effort is the highest priority. Emphasis has been put on the requirement for position and activity reporting to take place in near real-time.
2. Maximising biological data collection and determining catch composition are secondary concerns to effort reporting.
3. Maximising data collection and monitoring effort is a priority focus for high risk métiers i.e.,
    a. Determining the impact on the benthic environment by bottom towed gear types; and
    b. Determining the impact of gillnets and trawls on bycatch (protected species).
4. Balancing costs against capabilities is a running theme. Cellular data exchange is a priority over other methods across all gears. Monitoring and data collection requirements are higher for high benthic impact and high bycatch gear types. Minimal data collection for low-risk gears like hooks and lines.
5. Greater weighting was given to the importance of REM data security in the design - by this we mean, for inshore vessels (<10m) remote data storage (data security through backups); uninterruptable power supply (to ensure data gathering is consistent); were the highest scoring requirements, followed by live reporting functionality. For larger vessels (>10m), live reporting fell behind remote data storage, sufficient internal storage (assuming vessels will operate for longer periods outside of cellular range); ruggedisation and encryption (to ensure control boxes cannot be damaged or tampered with); and uninterruptable power supply.

3.2.5.1 Question 4 responses: Importance of descriptors to determine fishing impact in the UK marine environment

Within the stakeholder responses, there was a clear emphasis on the importance of Descriptor 3 and Descriptor 1 to determine the fishing impact of different gear types in the UK marine environment, and (Figure 18). Changes in the stock status of commercial fish populations would provide a clear indication on how fishing pressure is impacting target stocks, as well as the removal of non-target species which will affect the biodiversity of the local area. This was followed by the recognition of Descriptor 4 and Descriptor 6 to reveal the long-term impacts of fishing activity on the wider ecosystem. Descriptor 10 and Descriptor 11 generated the least interest in stakeholder responses and consequently was ranked the lowest importance. To some extent, this was to be expected, as logically, greater weighting would be given to Descriptors 1 and 3, owing to the very directs impact of fishing pressures against these two descriptors.

Figure 18 below provides a breakdown of each of the six core descriptors, giving stakeholders the opportunity to rank these 1-6 for importance. These were ordered by ranking given on the X axis and the number of times occurrences for each ranking on the Y axis.

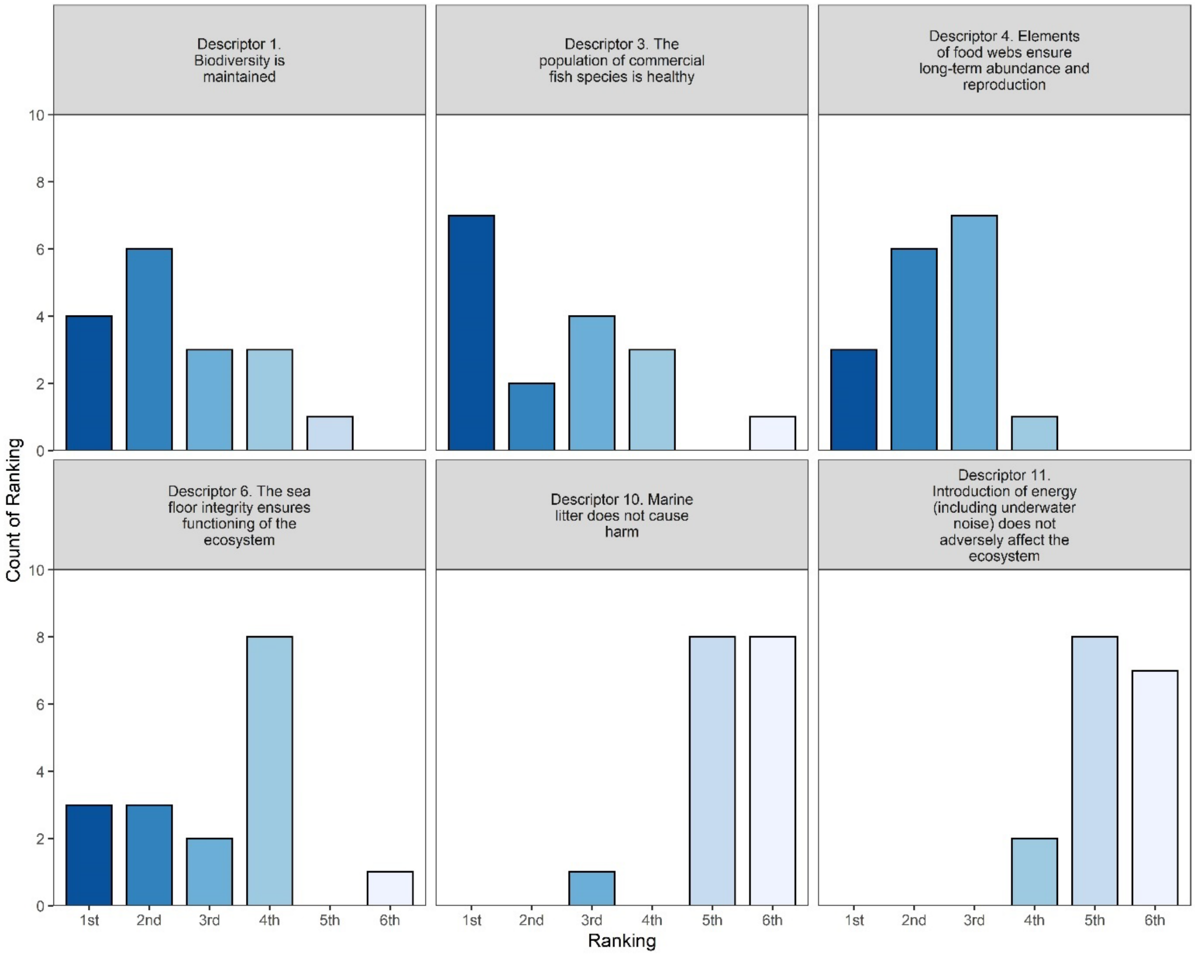

Figure 18 Stakeholder responses to Question 4 on the importance of descriptors to determine fishing impact in the UK marine environment

3.2.5.2 Question 5 responses: The most important use of REM technology within the fishing industry

Determining where vessels operate was considered a high priority for stakeholders, particularly the regional and national regulatory authorities where compliance with fishing regulations is a primary concern (Figure 19). Additionally, maximising data value and the collection of biological data to inform sustainable stock management, as well as identifying (video identification) catch composition, were deemed essential uses of REM technology to ensure appropriate management and conservation measures are in place, such as gear modifications to exclude undersized or bycatch species which can be observed in the catch composition. This links back to Q4 response highlighting the importance of healthy commercial fish populations and sustained biodiversity as indicators to fishing impacts.

Figure 19 below provides a breakdown of each of the 6 uses of REM within the fishing industry, giving stakeholders the opportunity to rank these 1-6 for importance. These were ordered by the number of times each ranking occurred.

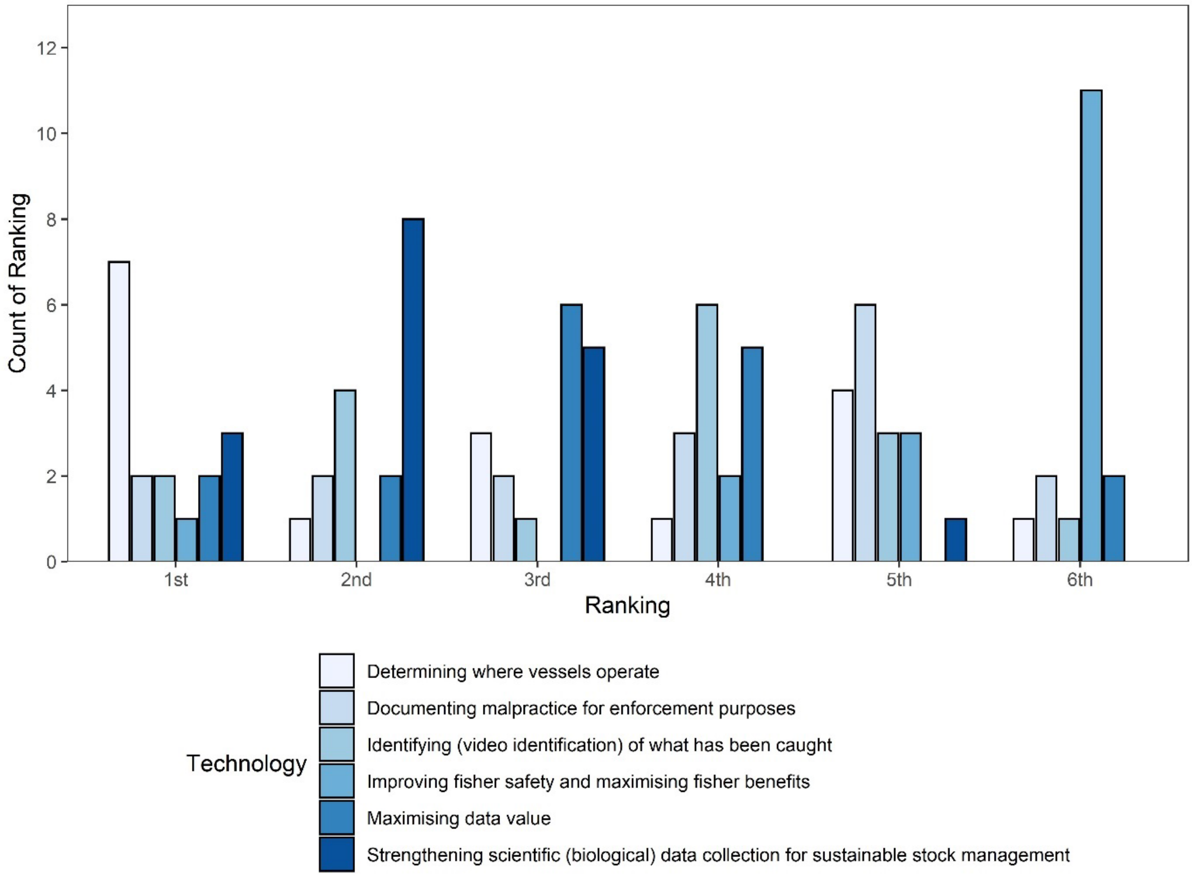

Figure 19 Stakeholder responses to Question 5 on the most important use of REM technology within the fishing industry

The use of REM technology to document malpractice for enforcement purposes was evenly spread throughout the responses yet ranked 5th overall. However, within IFCAs where compliance is clearly their focus, this was ranked a much higher priority. REM technologies would therefore better equip IFCAs to combat non-compliance against illegal, unreported, and unregulated (IUU) fishing within those particular regions.

Improving fisher safety and maximising fisher benefits was not regarded as a high priority for REM by most responses, apart from Natural Resource Wales which ranked it as the most important use of REM technology. This is to be expected due to the scientific context of GES descriptors and risk of fishing activity to the marine environment (which is the focus of this work). It is thought that the responses given do not mean that fisher safety is of low importance, just that respondents in the most part do not see REM as the primary solution to fisher safety and other unrelated activities and policies would drive improvements to safety at sea.

3.2.5.3 Question 6 responses: What are the most important factors for determining the risk posed by fishing activity?

When asked to rank the importance of different factors in determining the level of risk posed by fishing activity against achieving GES in English waters, the stakeholders responded reasonably consistently; assessing the vulnerability of marine habitats and fishing grounds; and assessing the impact of fishing practices on stocks; jointly ranked the highest. However, collectively over the first and second ranking, assessing the impact of the different fishing gear types to the marine environment scored higher overall (Figure 20). This response aligns with the thinking and methodology delivered in Objective 1, confirming the development process used for the methodology.

This was followed by assessing métier by number and size of vessel to determine the overall impact of the fishing fleet and any differences in size (i.e., inshore <10 m vessels and offshore > 10 m vessels) which would affect fishing effort due to the amount of gear use and catch landed.

Monitoring the impact of fishing practices (i.e., bycatch and discards) on stocks was considered an important factor as this would have implications on how fishing activity was affecting the status of commercial fish populations and abundance of non-target species.

Assessing the impact of English fishing vessels operating in the English inshore (inside the 12nm territorial sea) was considered a lower priority compared with other factors yet would still be valuable as a high number of under 10m vessels operate in the inshore region, as well as over 10 m vessels deploying mobile gear. Maximising data collection on the English fleet will help inform national and regional management to sustain locally important fisheries and conserve priority habitats and features.

There was a consensus that assessing the impact of devolved nation and foreign fleets operating in the English inshore (sub 12nm area) was the least important factor as stakeholders were not concerned by who was fishing, rather they were interested in those vessels' impact on the marine environment.

Figure 20 below provides a breakdown of the six key factors in determining the risk presented by fishing pressures, giving stakeholders the opportunity to rank these 1-6 for importance. These were ordered by ranking given on the X axis and the number of times occurrences for each ranking on the Y axis.

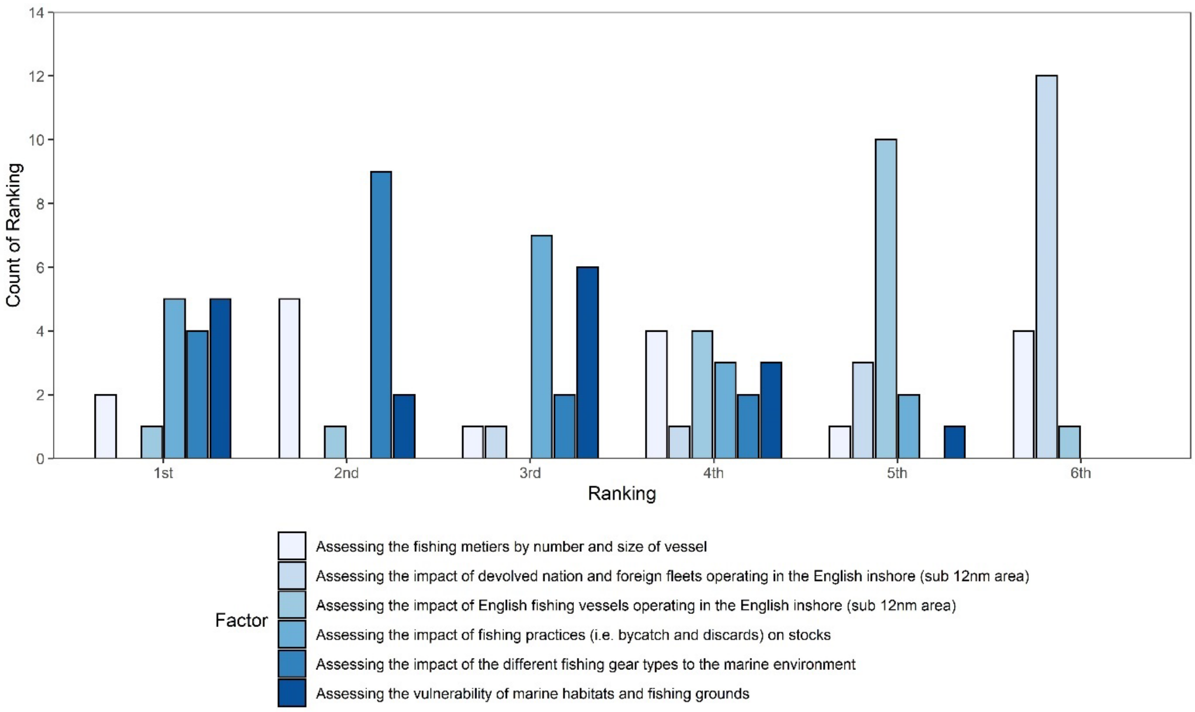

Figure 20 Stakeholder responses to Question 6 on the most important factors in determining the risk posed by fishing activity

3.2.5.4 Question 7 responses: Application of REM

Stakeholder preference for the application of REM was centred on maximising benefits to fisheries managers, enforcement and regulators and maximising scientific data collection (Figure 21). Complimentary to each other, the use of REM to inform and/or enforce fishery management was a top priority for every stakeholder. By providing constant coverage on the vessel positioning, time and duration of fishing effort, enforcement officers have more ability to monitor fisheries in their district and have access to tangible evidence to prosecute and fine vessel owners in the event of any misconduct. Additionally, maximising scientific data collection will not only address and fill knowledge gaps on data limited stocks, but also increase data confidence to advise stock management of commercial fish species targeted by vessels in English waters.

In contrast, the application of REM to maximise fisher benefits and minimise impact to fishermen was deemed a lesser priority. Indicating that from the stakeholder perception, REM is very much a tool to be used for fisheries management. However, short of a hard-line approach to REM roll out nationally where every vessel is mandated to carry REM and maintain the equipment to fulfil management objectives, greater concern will need to be given to working alongside the fishers, in order to achieve successful implementation. Fisheries managers should look to incorporate fisher benefits within their long-term goals. Such an approach could include fleet wide digitalisation, giving fishers access to their own portfolios and data, leading fishing effort with pre-catch information to increase efficiency and reduce fisher costs increasing catch allowances through better managed stocks and rewarding compliance, resulting in a fairer and more productive fishing industry.

Figure 21 below provides a breakdown of the four applications of REM, giving stakeholders the opportunity to score these 1-5 for importance. These were ordered by application on the X axis and the number of times occurrences for each score given on the Y axis.

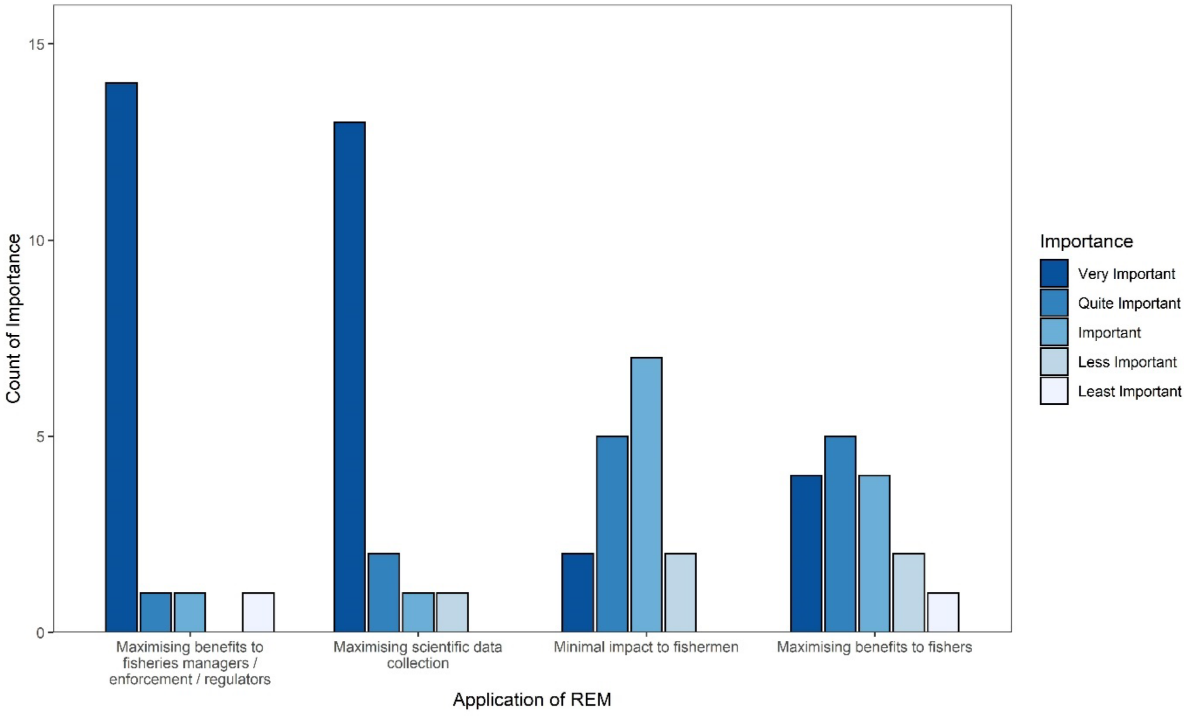

Figure 21 Stakeholder responses to Question 7 on the application of REM

3.2.5.5 Question 8 responses: Other stipulations with respect to REM application

Additional considerations of REM technology mentioned in stakeholder responses included the design, implementation, access and use of data. One response stated, "*For REM to be implemented successfully, it needs to be accepted by the industry*". Therefore, a co-design of data collection and step-change approach to phase in the use of systems is likely to enhance cooperation and compliance. However, the prioritisation of gear sensors and cameras onboard vessels was mentioned by several stakeholders to benefit management approaches e.g., the Landing Obligation, deliver better compliance due to increased observation of operators' behaviour and could identify invasive non-native species (INNS).

Other uses of REM implementation focused on position recording for temporal and spatial management of fisheries to ensure compliance with restrictions (i.e., access to MPAs) on different gear types or temporal closures of areas which are spawning/nursery grounds for key commercial species. One response stated: "*The main benefit of REM would be iVMS to monitor the local fleet for enforcement purposes, particularly for spatial management measures such as MPAs with byelaws i.e., no bottom towed gear zones, and for vessels that fish both inside and outside the district where different legislation applies"*.

Access to this information would provide evidence of any reported misconduct or non-compliance with management measures such as within MPAs and allow local IFCAs to prosecute skippers and vessel owners more efficiently. However, data security, compatibility with other existing systems and operational costs were flagged as important considerations to ensure the smooth-running and appropriate use of data by relevant authorities, as well as anonymity of data if publicly available.

Furthermore, the collected data would be crucial to underpin scientific advice to set realistic quotas and management measures, as well as modernise stock management for non-quota species such as whelks.

3.2.5.6 Question 10 responses: Anecdotal responses to strengthen the risk-assessment.

Many stakeholder responses highlighted the benefit of using REM technology to improve current vessel monitoring methods. At present, vessels under 12m are not obligated to install VMS which excludes many fishing vessels and fishing effort from surveillance in English fisheries (although this is now being addressed through the MMO's planned roll out of iVMS on all <12m vessels by the end of 2022) (MMO, 2021). In response to this, the IFCAs in particular emphasised the importance of the impact REM can have toward compliance and documenting fishing activity with 6nm of the coast. This will greatly enhance the ability for regional IFCAs to monitor fishing activity within inshore areas and provide a better understanding of the scale, location, and seasonality of fishing effort in English waters.

Furthermore, REM should be used to address issues of non-compliance within the fleet. Such as, an example given of concerns over scallop dredgers operating illegally in the North Eastern IFCA; or the extensive breaches of bass regulations occurring across the Kent and Essex IFCA district - it was reported that fishers have manipulated and circumnavigated the regulations in order to retain more bass than they should, and is therefore a high priority concern to be addressed through REM. Additionally, different fishing regulations apply within different marine boundaries (i.e. IFCA districts or statutory marine limits).

Without the technology to locate fishing activity on board the <12m vessels, fishers can abuse some fishery management measures, with limited means for validation of the catch. One such concern that was raised was the ability to circumvent the minimum conservation reference size (MCRS), by claiming catch was taken from outside the managed zone. This was a significant concern for the whelk fishery in Kent and Essex IFCA district, which has implemented a tightly regulated permit fishery within the six nautical mile limit (pot limit of 300, MCRS of 53mm shell length, escape gaps in pots for juvenile whelks etc). Beyond 6 miles, however, the MCRS is set at national restrictions of 45mm.

The lack of surveillance means enforcement officers cannot validate undersized landings from the inshore region when reported as caught outside of the 6nm managed zone. Non-compliance against byelaw regulations therefore puts the inshore fishery at risk and is unfair on the compliant fishers. Mandatory position reporting onboard all vessels will address these types of issues and protect local fisheries from unsustainable and unfair exploitation. Vessel monitoring would also assist with spatial restrictions such as protecting designated MPAs as one stakeholder stated, "*conventional 'at sea' monitoring is generally only good as a deterrent in the immediate vicinity of the vessel".*

REM also has the capability to increase data collection on a number of different issues such as documenting bycatch events, particularly in gillnet fisheries; determining the impact of fishing on choke species, monitoring discarding practices; documenting illegal modification/attachment of nets; the loss and under reporting of fishing gear; and validation of gear conflicts between vessels. Additionally, data can be gathered on misreporting of catches by species to determine area and discard rates, which presents a high risk of overfishing if top up quotas are allocated to vessels to meet catch limits. Similarly, REM can be used to validate misreporting / undeclared catches which when practiced can exacerbate overfishing of fish stocks. For example, one stakeholder mentioned anecdotal reports of supertrawlers targeting pelagic species, circumventing fishing restrictions by grinding illegal catches into fishmeal.

3.2.5.7 Question 12 responses: REM technologies for each métier (under 10 m vessels)

For the under 10m vessels, position reporting was clearly a top priority for all stakeholders and should be applied for all fishing métiers (Figure 22). Currently, VMS is only required on fishing vessels 12m and over in length. Extending this to the under 12m fleet would improve data gathering and understanding of all licensed vessel activity in English waters. This would allow for real-time spatial management of fisheries as it provides constant coverage and monitoring of fishing location and activity, supporting resource-limited enforcement bodies in managing fishing effort within restricted areas.

There was consensus throughout the stakeholder responses that technologies such as above and below surface data capture - gear sensors and cameras should be installed on mobile gears, namely beam trawl (TBB), boat dredge (DRB), bottom otter trawl (OTB), midwater otter trawl (OTM), multi-rig otter trawl (OTT) and nephrops trawl (TBN). Here, the use of hydraulic sensors would enable the skipper to monitor when the gear is in the water and, if applicable, on the bottom of the seabed. In-water gear sensors would also collect data, for instance, monitoring catch composition and determining impacts of mobile gears on the surrounding environment, which could contribute to meeting management objectives. Work implementing underwater technologies (i.e., net cameras) is currently being undertaken by Aberdeen University to develop a “Smart Trawl” which essentially uses a camera to monitor the catch composition and if choke species are identified it could trigger a “gate” in the net to open and release unwanted catch. Smart net technologies are being developed across a number of different institutes and organisations globally.

Furthermore, the use of cameras to monitor onboard activity, such as validating winch activity during gear deployment and recovery; and, specifically for catch identification, would provide constant observation, and help combat issues with compliance. Such an application would include monitoring the use of prohibited gear types, and the misreporting of gears, or undeclared catches. In addition, the application of cameras could strengthen bycatch monitoring and reporting helping strengthen mitigative techniques and gather data on the success of gear modifications aimed at reducing incidental capture of protected and non-target species. Here, one stakeholder recommended the placement of a camera on the side of the vessel looking down on the point of hauling for gillnetters, “*in order to capture drop-outs of harbour porpoise which is known to occur”.*

Bycatch mitigation technology sensors (electronically linked pingers, and streamer line tension meters as examples of these technologies in use or development) were recommended for use on all types of gillnets (drift net (GND), gillnet (GN), set gillnet (GNS) and trammel nets (GTR)), due to the known bycatch risk documented for gillnet fleets. On all types of trawl gear bycatch mitigation technology sensors were a lesser priority, with hand and pole lines (LHP) being of least concern.

The stakeholders showed less of an appetite for the application of RFID tags, receiving less than half the responses. However, within the responses received priority of application was given for static gears such as pots and traps (FPO) and all gillnets gear types, as would be expected of the application of RFID tags in the industry. RFID tags are best used to monitor and validate data collected on fishing effort when applied alongside hydraulic sensors. They work best with vessels where the gear is deployed from a single point on the vessel (i.e., pots and traps, gillnets, and longlines all deploy and haul gear in a sequential fashion from fixed points on the vessel). Tagging pots and creels for instance would give a record of the exact number of pots entering the water. While this information would give a very high resolution of data it would also come at a very high cost, considering tags range from £1.5-2.5 each – for a creeler setting hundreds of pots, this would become very expensive to implement nationally.

The real strength in RFID application would be to tag the buoys, recording the exact time the first and last buoy enters the water. Such an application could then be used as a marker to draw a REM analysts' attention to when fishing takes place and can document the fishing effort and soak time. This information can also be attached with position reports, enabling real time validation of fishing activity for fisheries managers. Applying RFID tags in this fashion is entirely repeatable for gillnets and longliners. RFID tags can also be used by regulatory authorities to control the number of pots per vessel by issuing a certain number of physical tags bearing a license or permit number. This helps to cap the fishing effort of certain gear types.

Lastly, issuing weight scales to collect biological data was deemed to be applicable for all gear types, but viewed as a lesser priority across the under 10m fleet. The thinking behind this is probably down to the practicalities of installing weight scales on the limited deck space on an under 10m vessel.

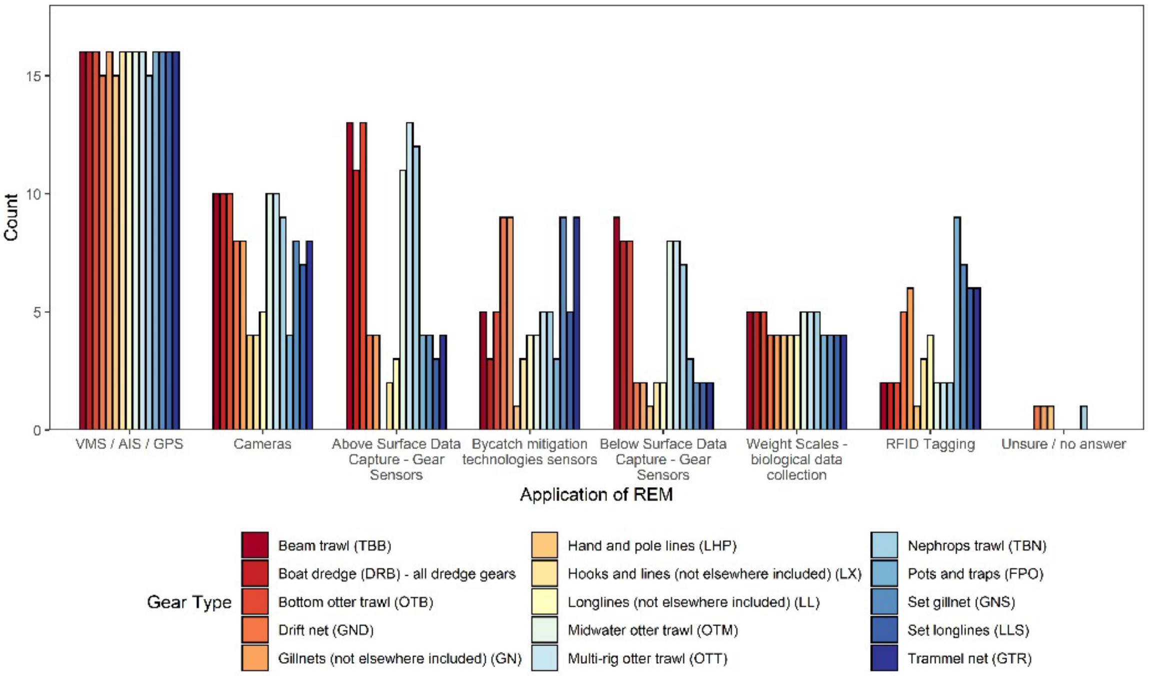

Figure 22 Stakeholder responses to Question 12 on REM technologies for each métier (under 10 m vessels).

3.2.5.8 Question 13 responses: REM technology capabilities (under 10 m vessels)

It is important to note the extent of REM technology capabilities is also very much dependent on vessel size which may limit the available space for REM hardware. Practicalities across different vessels and gear types may require a bespoke approach to the REM hardware deployed.

Within the stakeholder responses, there was general agreement that the main focus of REM's technology capability should be on the setup and design of REM for all gear types onboard under 10m vessels. Remote data storage, uninterruptable power supply and ruggedised, secure and encrypted, were all listed as important capabilities to ensure the efficient, secure, and reliable use of REM technology (Figure 23). In the stakeholder comments, the requirement for an effective ping rate was highlighted to provide reasonable understanding of the location and speed of vessels, which may indicate active fishing activity. This can also be supported by cameras.

During the implementation of REM, live reporting capabilities, remote access to cameras/control box and sufficient internal storage capacity for days/weeks should be prioritised for mobile gears which are likely to be out at sea for longer periods of time without regular checks. This would enable live observation of onboard fishing activity and increase monitoring capabilities for IFCA enforcement officers.

Stakeholders believed REM should be independent of vessel systems, particularly mobile gears, and support AI/machine learning software across all gears. In future, the development of AI may offer a huge scope to operate as a key tool in species recognition. Nevertheless, onboard space and absence of vessel cabin may create practicality issues to install full REM technology for under 10m vessels.

Across all the gear types, trawls and dredges were the highest priority most frequently, followed by gillnets, pots and traps and longlines. It should be noted that all capabilities were recommended by more than half of the stakeholder, rising to over two thirds where there was strong preference.

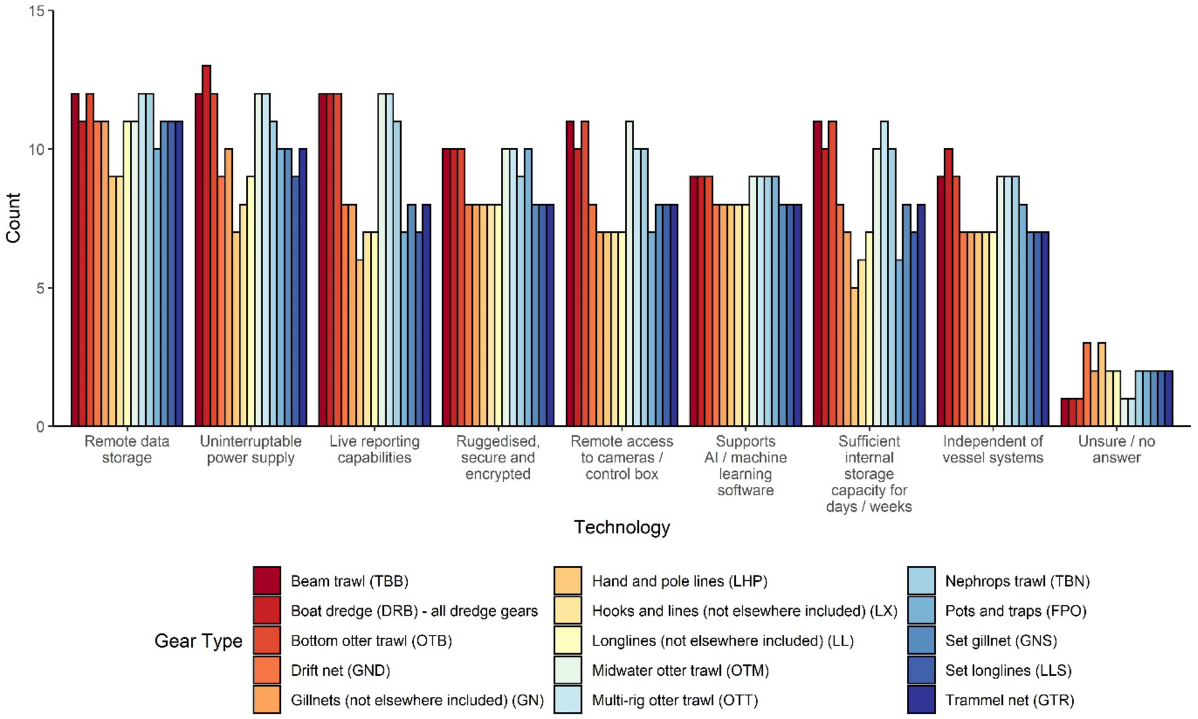

Figure 23 Stakeholder response to Question 13 on REM technology capabilities

3.2.5.9 Question 15 responses: REM technologies for each métier (over 10 m vessels)

Equivalent to the requirements for under 10 m vessels, position reporting was the highest priority unilaterally across all gear types (Figure 24).

The implementation of cameras onboard over 10 m vessels towing mobile gear was deemed a higher priority compared to under 10 m vessels, although application of cameras did receive a greater response overall.

Above and below surface data capture – gear sensors, bycatch mitigation techniques and RFID tagging all broadly showed a similar pattern for vessels under and over 10m. The use of weighing scales for biological data collection was considered of greater importance for the over 10 m across all gears. Again, space availability was likely a contributing factor to the thinking behind this.

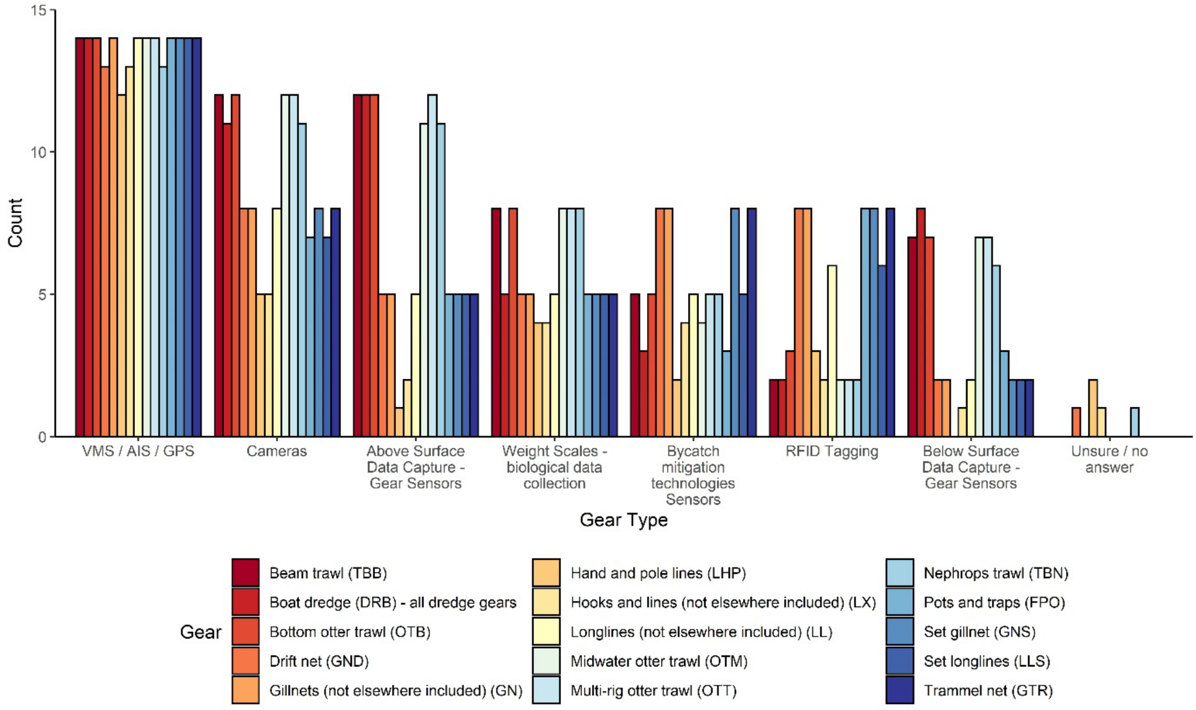

Figure 24 Stakeholder response to Question 15 on REM technologies for each métier (over 10 m vessels)

3.2.5.10 Question 16 responses: REM technology capabilities (over 10 m vessels)

For the over 10 m vessels, stakeholder responses were similar to the under 10 m vessels in that the main emphasis was on the REM setup (Figure 25). These factors were high priorities for all gears except hand and pole lines (LHP) and hooks and lines (LX) which generally accrued fewer responses. The thinking behind this is that this métier is less impactful than other higher risk gear types.

Remote data storage and sufficient internal storage capacity saw the greatest increase in responses between the <>10m fleet. It is likely that vessels >10m in length will have to operate for extended periods away from port, potentially for days at a time, therefore, the REM system should have sufficient internal storage to capture this data. As before, ruggedised, secure and encryption was a high priority in order to ensure that the data are protected and tamper proof.

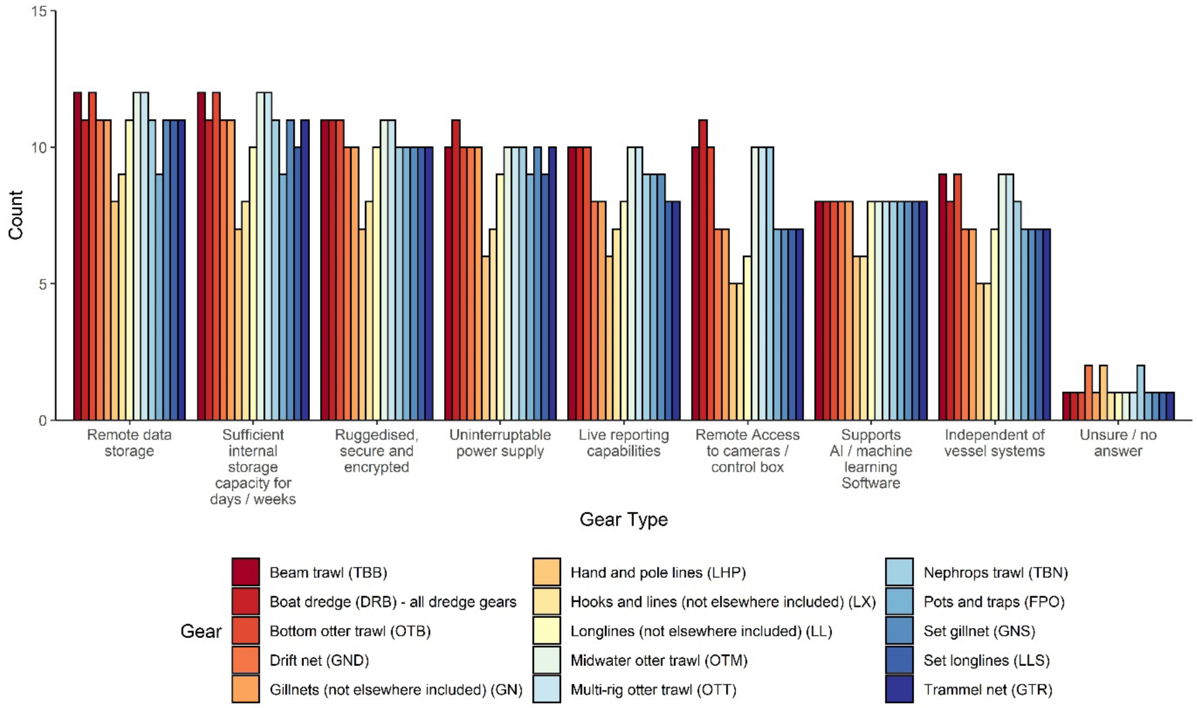

Figure 25 Stakeholder responses to Question 16 on REM technology capabilities (over 10 m vessels)

3.2.5.11 Question 17 responses: Additional information/comments

The use of REM technologies will differ depending on the fisheries management objectives and the data to be captured e.g., minimising discards requiring video verification or monitoring vessels fishing in MPAs requiring position and activity reports. The bare minimum of information collected (and most requested), is data on where a vessel is fishing, for which there is currently limited data for <12m vessels. This will in most cases only require the use of the REM GPS and integrated sensor data to indicate when gear is deployed and hauled.

Cameras would provide valuable data for identifying and monitoring catches, specifically within catches of protected or choke species.

The stakeholders surveyed suggested that cameras should be implemented on all vessels, however, one stakeholder pointed out if costs became an issue, then they could be excluded from the lowest risk gear types. Other applications of cameras can include the capture information on gear selectivity which will inform gear modifications, including the design and management.

When considering mitigation measures for different gear types, one strategy for pots and traps (FPO) is to limit the interactions of cetaceans with the lines and adjoining strings. One stakeholder explained the current estimates of entanglement of minke whales and humpbacks in the Scottish creel fishery is 30 and 5, respectively, every year. Suggested mitigation strategies include leaded line and rope less technologies which, to date, have shown to been successful during informal trials (Ryan *et al*., 2020).

3.2.5.12 Question 18 responses: Best type of connection in the English inshore fisheries

There are a number of mechanisms for transferring data from ship to shore. Most commonly we will see cellular (mobile networks) used for inshore fisheries and satellite for offshore and high seas fisheries. These will typically report only position and activity data while operating at sea. Once back to port, the most conventionally implemented method of bulk data transfer is through hard drive exchange, where one loaded hard drive sent to the fisheries managers for processing and a blank is fitted in its place. When surveyed for the most appropriate method of transferring REM data in English fisheries, especially with a focus on the inshore, cellular/4G was scored the highest most frequently (Figure 26). Satellite uplink came second, indicating that there is a preference for this functionality to be included, but it falls behind cellular as a default option. This is unsurprising as satellite can be prohibitively costly but does offer redundancy to live reporting when outside of a cellular network. For in port options, Wi-Fi was favoured slightly over hard drive exchange, but there were mixed opinions on both. It should be noted that cellular networks do offer the capability to upload significant volumes of data. In the past this would have been prohibitively expensive, favouring port Wi Fi or hard drive exchange methods of data transfer. However, as documented later in the report, the costs of unlimited data sims are becoming cheaper all the time, making this a viable option to consider for position reporting as well as bulk data transfer.

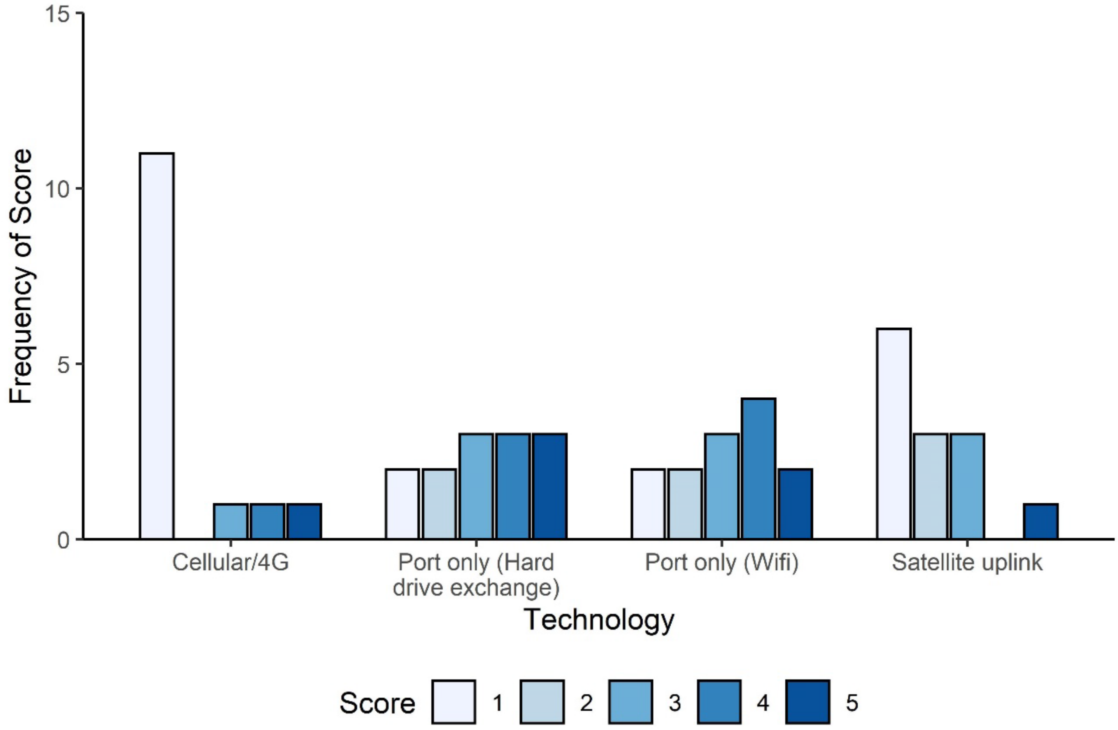

Figure 26 Stakeholder responses on the type of connection that works best in the English inshore fisheries

3.2.5.13 Question 19 responses: Additional information/comments and alternative methods of connection

Whilst satellite uplink was a popular second choice of data transfer, due to reliability and access to live data, stakeholder feedback shows concerns over the cost of this method. Inshore vessels are often in range of 4G, or can periodically move to be within range, making this the more popular and cost- effective option. This method is not perfect, however, due to unreliability of connection to 4G networks around the country.

In port data transmission does not allow for live data review but does enable large amounts of data to be collected for future analysis. Transfer via a hard drive is the best method in cases of larger transfers where costs need to be kept down, or where the infrastructure to automatically transfer data is limited. The drawback raised here is that this involves the coordination of staff and vessel crew for the collection and replacement of these hard drives, in addition to the manual upload, processing and wiping of data required. This may not always be possible or practical, while additionally driving a significant indirect cost to data transfer.

A suggested option was a combination of methods to allow for live tracking at sea, where possible when the vessel is within coverage, with data stored on board and transferred using an in-port method on return. Security and data protection concerns were raised regarding using Wi-Fi in port. Aside from this there were no other comments on the use of Wi-Fi for data transfer, and it appears to be preferred over the exchange of hard drives as it avoids the need for human coordination.

The method used will largely come down to the needs of the programme in place, and the budget given. Where live data analysis is not required, or where the systems behind live reporting are not in place, in port methods of data transfer or transfer while connected to cellular/4G networks can help to keep costs down. Satellite uplink is repeatedly mentioned as a preferred option if cost were not an issue.

3.2.5.14 Question 20 responses: Reporting mechanisms

When surveyed on the preference for reporting requirements of English fisheries, the stakeholders largely scored fishing activity (start-end markers), position reporting pings and alerts when fishing within a geofenced area as the most important (Figure 27). Catch reporting, such as species identification and quantification reports were also rated highly, closely followed by protected species bycatch reporting. Reporting discarding activity was rated as generally important, although not so consistently by all stakeholders. Bycatch mitigation reporting had mixed responses but was overall rated as the least important reporting mechanism polled. This trend largely reinforces the thinking behind the responses for the equipment requirements and capability submitted by the stakeholders.

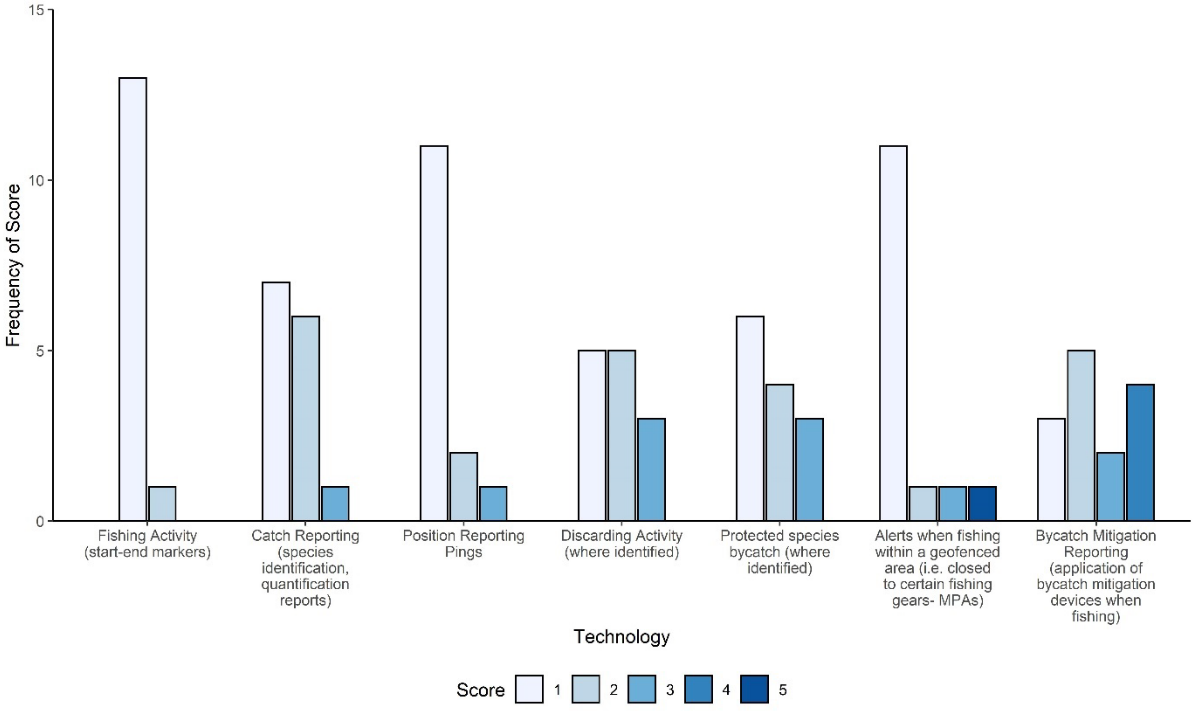

Figure 27 Stakeholder responses on importance of reporting mechanisms

3.2.5.15 Question 21 responses: Additional information / comments on reporting mechanisms.

The position of fishing activity transmitted through frequent location pings, paired with knowledge of start and end times, was deemed as very useful information by all stakeholders, but has been noted as being fulfilled by traditional VMS for >12m vessels. Alerts for fishing in protected areas were remarked as a useful tool within position reporting. One stakeholder indicated that all of the reporting requirements are being used / would be used, but their applicability varied across each fishery, and the monitoring requirements of these. Another remarked that reporting methods need to focus on what is achievable in the given situation and capability for the given fleet and budget – many vessels are small and don't have the extra capacity or funds for the new gear.

3.2.5.16 Question 22 responses: Most cost-effective position reporting frequency

The majority of stakeholders selected the 3mins position reporting frequency, although expressed that cost estimates are needed to make this decision, and evidence from scientific studies should be used to judge what is needed in a given situation. Some organisations have a specific position on this, such as the IFCA groups who requested 3-minute positional reporting to give the accuracy suited to their needs; where others have indicated that position reporting should be dependent on the vessel gear type and activity at that time. For instance, position reports need not be as frequent when steaming and not deploying or retrieving gear from the water. Likewise, some gear types operate on a slow linear track, fishing over a large area would require less frequent reporting intervals (i.e., trawlers towing at 3 knots).

3.2.5.17 Question 23 responses: Risk associated with various métiers

When asked to rank the level of risk associated with each métiers (for both vessels <10 m and >10 m in length), there was general agreement regarding towed mobile gears to be very high risk and static gear to be lower risk (Figure 28). The primary gears of concern were boat dredge (DRB), beam trawl (TBB), multi-rig otter trawl (OTT), bottom otter trawl (OTB) and nephrops trawl (TBN). These stakeholder responses were fairly predictable given their highly efficient and, to an extent, destructive fishing methods, posing a high risk to seabed integrity, benthic bycatch, biodiversity and overall sustainability of the fishery.

On the other side of the spectrum, hand, and pole lines (LHP) and hooks and lines (LX) were considered to be low/very low risk due to their negligible impacts on the seabed. Pots and traps (FPO) were also viewed as low risk, mainly by IFCA and Government advisory bodies, albeit Kent and Essex IFCA ranked FPO as high risk.

All types of gillnets were ranked as high risk, with 20% of stakeholders scoring drift nets (GND) as very high risk. This may be largely due to the widespread fishing effort of gillnets in English waters and their attributed risks of catching undersized and non-target species as bycatch and high potential for “ghost fishing” if nets are abandoned, lost, or discarded in the marine environment.

Overall, the stakeholder responses align with the main findings of Objective 1.

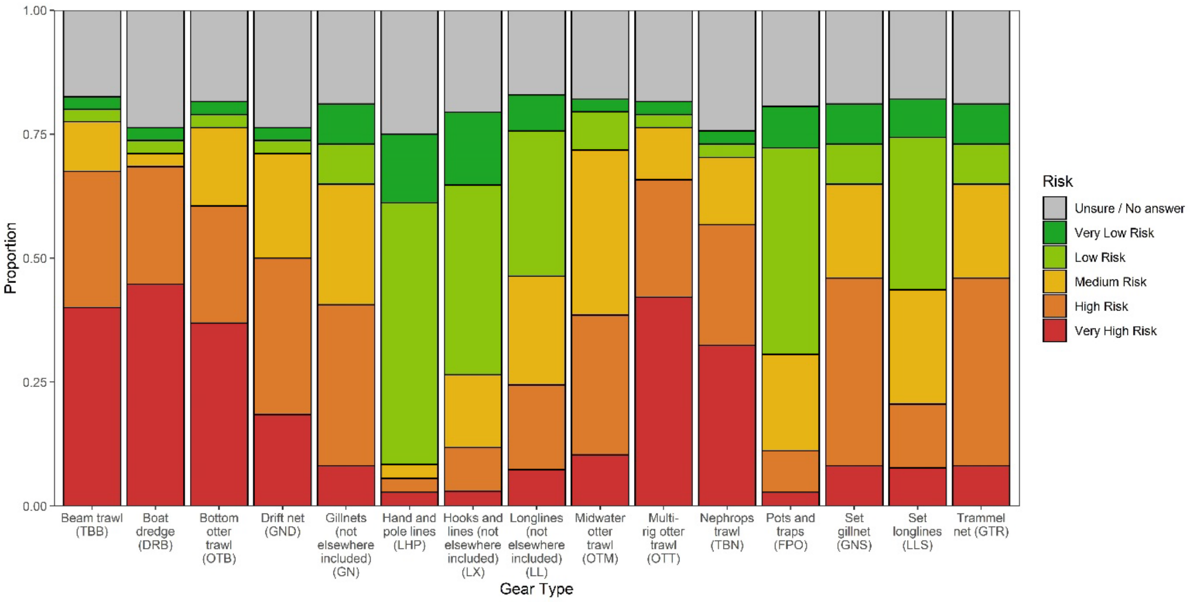

Figure 28 Stakeholder responses to risks associated with various métiers

3.2.5.18 Question 24 responses: The monitoring requirement associated to level of risk

When considering the level of monitoring required, one stakeholder commented that two questions should be asked: 1) What is scientifically appropriate (representative of target fleet to raise to the power of whole fleet)? and 2) What is the risk of that vessel (compliance history) + risk of that fishery + risk of that gear type?

Overall, within the stakeholder responses, there was a clear emphasis for 100% monitoring of vessels identified as being very high risk (Figure 29, Table 52). This indicated the application of REM technology onboard these vessels are a top priority for fisheries managers and regulators to meet data collection and analysis requirements. Similarly, 100% monitoring was also indicated for high-risk vessels, yet most responses proposed 50% or greater as an appropriate level of monitoring coverage.

Many stakeholders opted for medium risk vessels to receive 20 % monitoring while low risk and very low risk should be monitored for 10% and 5%, respectively.

The upward trajectory in percentage levels of monitoring for vessels with increasing risks on the marine environment was a likely outcome from the stakeholder responses and highlights the necessity to have full coverage of the fishing operations conducted by very high risk and high-risk vessels. Interestingly, all vessels of varying risks received at least one vote to have 100% coverage onboard however, for certain gears such as hand and pole lines (LHP) this is unlikely to require all the REM technology capabilities on offer.

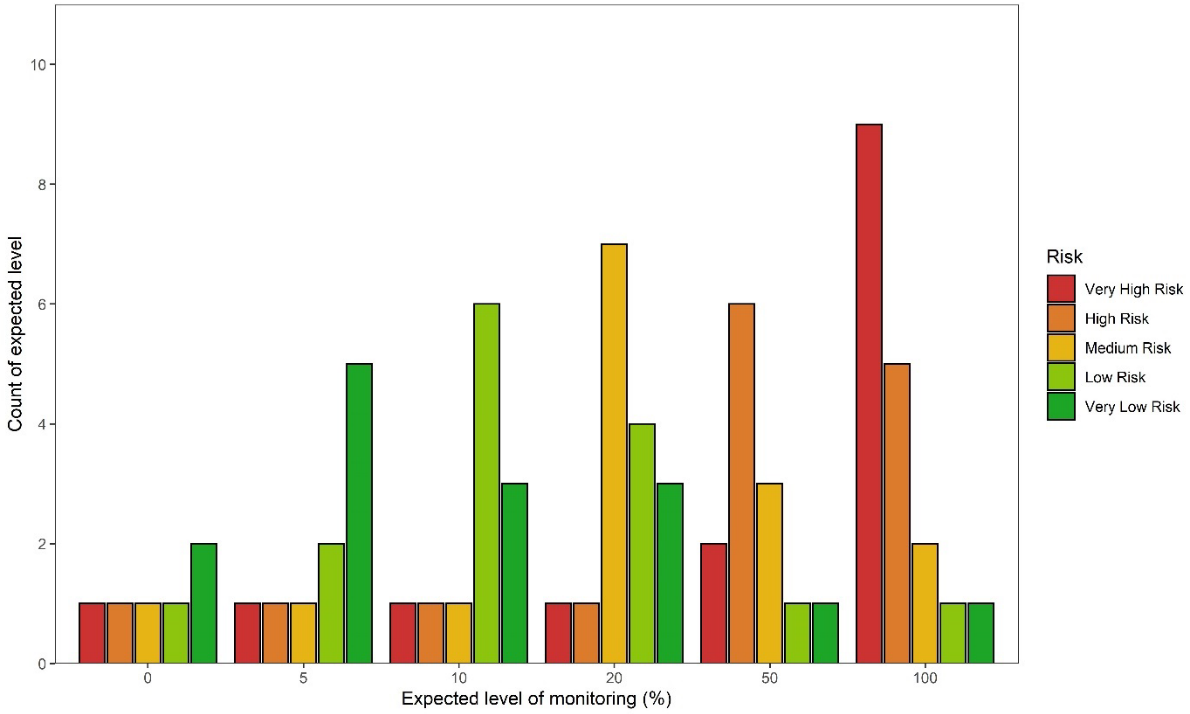

Figure 29 Stakeholder responses mapping the percentage of monitoring and analysis against the identified level of risk

Table 52 Stakeholder responses mapping the percentage of monitoring and analysis against the identified level of risk

% Level of data analysis required.	Very Low Risk	Low Risk	Medium Risk	High Risk	Very High Risk
0	2	1	1	1	1
5	5	2	1	1	1
10	3	6	1	1	1
20	3	4	7	1	1
50	1	1	3	6	2
100	1	1	2	5	9

3.2.5.19 Question 25 responses: REM technology to improve data gathering

The use of REM technology to improve data gathering on different categories was scored from 1 = very important to 5 = least important (Figure 30). In general, the top priorities for REM are to monitor compliance, assess fishing impact on stock populations and to spatially analyse fishing effort on a daily basis. The collection and collation of this data in a secure, yet accessible evidence base to authorised users (i.e., fishery managers) will help inform scientific stock assessments and fisheries management, as well as tackle non-compliance, contributing to the fair and sustainable management of fishing activities.

Fishing impacts on the ecosystem and trophic structure, as well as endangered, threatened or protected (ETP) species had equal weighting and were considered areas where REM would be important/very important to improve data collection. Cameras on board vessels could be used to assess the levels of non-target and ETP species bycatch in fishing gear, as well as attached to the gear to visualise the direct impact on the seabed and document how ETP species interact with the gear. However, it is important to note the data on ETP species may be limited to the rare nature of capture events. Nevertheless, the analysis of data may help understand and mitigate bycatch fatalities and give an indication to any cascading effects from the removal of certain species on the trophic structure and wider ecosystem.

The application of REM technology to improve data gathering on AI and machine learning received mixed responses from the stakeholders, with four responses considering it to be very important while one stakeholder viewed it as the least important use of REM technology. Overall, enhancing data collection on benthic habitat verification was treated as the lowest priority for REM technology.

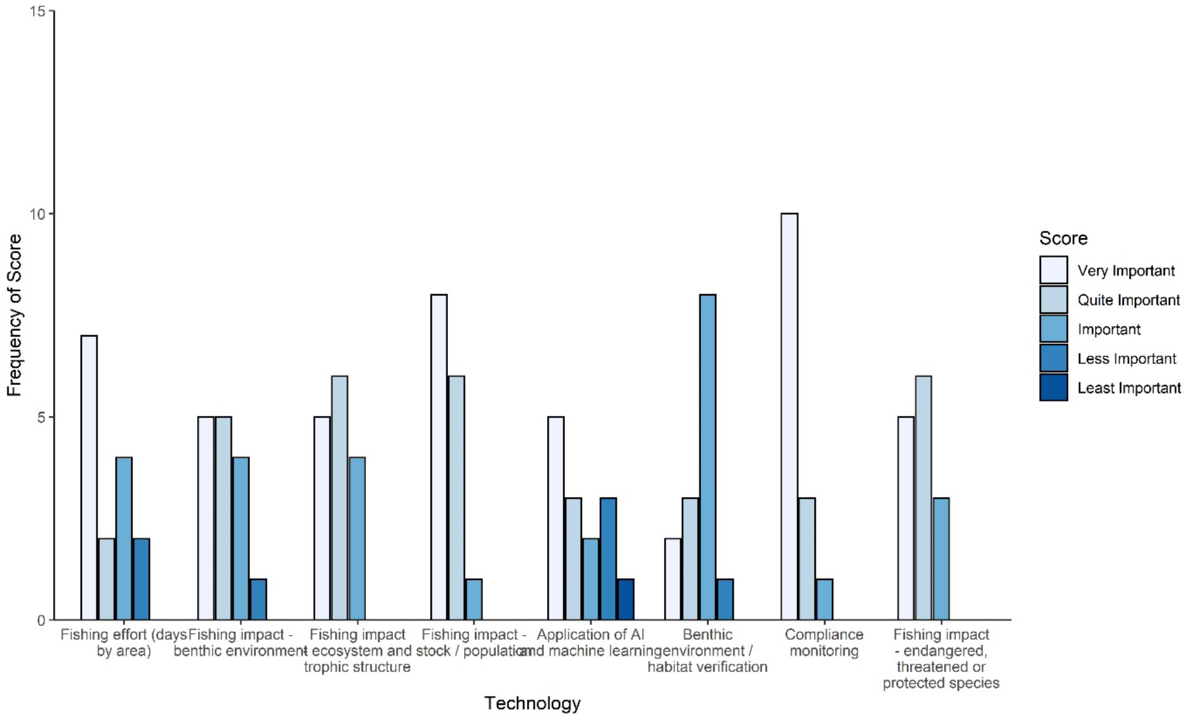

Figure 30 Stakeholder responses to how REM can improve data gathering

3.2.5.20 Question 26 responses: Alternative methods of connection

One stakeholder highlighted an issue with Question 24, emphasising the need for 100% coverage of fishing activity in terms of position, course, and speed data but additional technologies such as cameras would not benefit fishery management on all gears as it would only be possible to review a small percentage of video data. However, another stakeholder argued the amount of video coverage to review will differ depending on the management objectives of the fishing activity. Additionally, for discarding purposes, 10% of video footage can be scanned to indicate discarding behaviour and irregularities which will trigger 100% scanning of the data. For bycatch monitoring, fast scans can be completed quickly, and any bycatch event would be easily picked up, especially if the operator is asked to log it.

Using REM to improve understanding and verification of benthic communities/ecosystems would require enhanced ID skills and one stakeholder mentioned it could be completed by other means. Additionally, impacts to benthic habitats may not be well evidenced by REM and the footage would need to be cross-referenced with previous data collected on the seabed. One stakeholder highlighted underwater cameras monitoring fishing activity would likely have decreased visibility from disturbed sediment and wouldn’t be able to foresee adverse impacts on the seabed making it too late to do anything. Nevertheless, capturing this data may still provide some useful information.

3.2.5.21 Question 27 responses: Catch documentation requirements

When asked to indicate which of the following catch documentation requirements stakeholders would like to see achieved through REM (scored from 1= very important to 5= least important), the majority listed species identification, specifically identifying catch using cameras, as very important (Figure 31). Additionally, collecting information on the weight of catch (kg/tonnes) was also considered to be very important, followed by biological data, e.g., length and weight of catch, and number of individuals caught.

Collecting biological data on the sex of fish caught was considered the least important catch documentation requirement of REM.

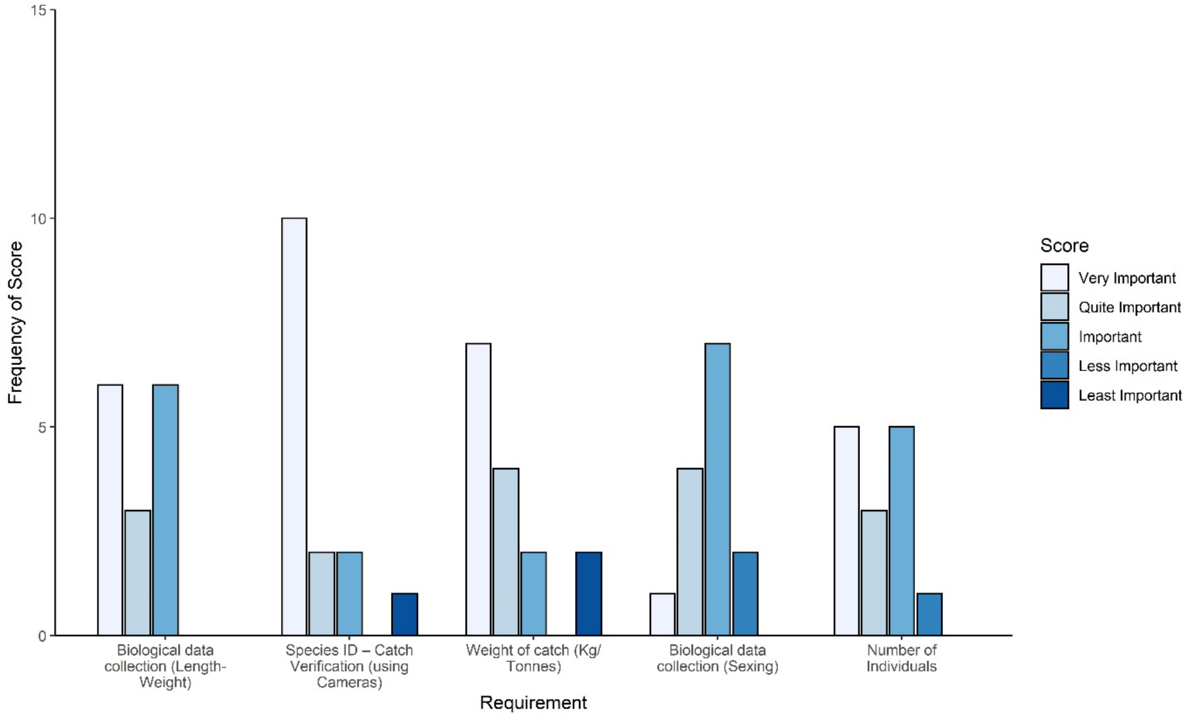

Figure 31 Stakeholder responses on catch document requirements achieved through REM

3.2.5.22 Question 28 responses: Alternative data collection requirements

When commenting on the use of REM to capture data for catch documentation requirements, one stakeholder mentioned how the ability of a vessel to capture this data would depend on the size and layout onboard. Another stakeholder questioned whether it was possible to obtain accurate weight readings onboard and if this was a useful use of REM as they can be weighed at port and reported.

In terms of management objectives, one stakeholder emphasised how understanding what is being removed by fishing activity, such as impacts on stocks and bycatch events, is key achieve to achieve sustainable fisheries. Therefore, species identification would be very useful compared to the number of individuals removed, albeit would be important to understand the health of the stock in terms of year classes.

Determining the sex of species was considered least important by stakeholders but it would be possible, to some extent, for REM technology to carry out this task for some species, chiefly large bycatch species. However, many fish species such as skates and ray would still require human observers to handle and report this. Overall, one stakeholder summarised this point by saying, "*Whilst sexing is important for population dynamics it would be very hard to capture outside of large bycatch species and perhaps not a realistic goal outside of smaller sampling e.g., Cefas observer programme)".*

3.2.5.23 Question 29 responses: Current projects with REM

When asked to document any projects with REM currently running in their organisations, six stakeholders responded with active REM projects ongoing. Cefas listed four current projects, including Scientific Remote Electronic Monitoring Programme (continuous monitoring & gear selectivity trials); Clean Catch UK; Spurdog Abundance Survey in the Southern North Sea; and SMARTFISH (development of AI).

Additionally, the majority of IFCAs participating in this project (4/5) stated some form of VMS project operating in their district. Currently, VMS and AIS vessel monitoring is used to monitor fishing activity within the NIFCA district while a small number of vessels are piloting the application of very low cost (£70) terrestrial vehicle trackers within the Cornwall IFCA district. This year, Devon and Severn IFCA stated they will "*commence an onboard camera/sensor project on towed gear vessels*" and have "*already introduced a requirement for all towed gear vessels operating in the district to have VMS operational onboard reporting at three minutes inside MPAs*". The Kent and Essex IFCA also use VMS to monitor and manage the Thames cockle fishery regulating order and stated they have a "*requirement for iVMS on vessels operating in our native oyster permit fishery, although due to low stock levels the fishery is currently closed.*"

3.2.5.24 Question 30 responses: Stakeholder experience with REM

A few stakeholders highlighted various reports on the results of REM projects and provided no other comments whereas others stated the following:

Cefas: “*Recently, with the initiation of the Scientific REM programme, we have had to adapt practices from various ad hoc short project to a longer-term view of running a programme. There are differences between the two approaches that have considerations such as data volume, staff resource for analysis, review level etc.”*

Kent and Essex IFCA: “*In the Thames cockle fishery, licensed vessels VMS report position, speed and bearing at 5-minute intervals within the district geofence (instead of the statutory 2 hrs for VMS+ for over 12m vessels). We manage the fishery spatially with 20 separate harvesting areas across the district, which can be opened and closed depending on our own stock assessment data. VMS is crucial to the effective sustainable management of this fishery which operated under an HRA authorisation in several different MPAs, especially from an enforcement perspective. VMS data has been pivotal in prosecution cases where we have proven that cockle vessels have fished illegally inside closed areas.*”

Cornwall IFCA: “*Too early to comment definitively but so far, the units are working well.*”

3.2.5.25 Question 31 responses: Stakeholder thoughts and/or comments

In a broad statement, one stakeholder summarised their views in the following statements:

“Improved monitoring of fishing activity in English waters will help ensure a well-evidenced, sustainable future for the fishing industry whilst helping protect the marine environment from the impact of fishing activity. An effective suite of REM technologies has the potential to deliver benefits across fisheries and the marine environment, generating information that could be used for multiple applications.”

During the setup of REM technology, one stakeholder commented that “*Ping times and sampling rates should be driven by the data rather than perceptions and opinions”* and recommended following ICES REM working group definition of REM. Emphasising the importance of understanding the management objectives for different REM set ups was also highlighted in the comments. However, the stakeholder stated that “*if managers opted for REM systems with cameras across all métiers - phasing in first instance the over 10m fleet - you collect 100% of fishing activity and can interrogate data in multiple ways for multiple objectives depending on available resources”.* This would allow managers to use as much or as little data as they required. However, a cost-benefit analysis would be advisable to ensure the investment of cameras on all métiers was worth it.

3.2.5.26 Question 32 responses: Benefits or problems of REM on English inshore fisheries

When considering the benefits of REM, many stakeholders mentioned the importance of collecting data to accurately monitor fishing activities; target patrol effort to focus on vessel of interest/illegal activity; evidence the location of fishing effort e.g., inside the district 6nm limit, or inside a MPA prohibited area; gather stock data; and make sound policy decisions. This data is crucial to develop and monitor our management of inshore stocks, as well as support compliance and monitoring functions at sea. For example, without technology, MPA networks will only designate but not protect sites of conservation interest and therefore fail to deliver the benefits they are designed to provide.

The application of REM with cameras was fully supported by stakeholders to evidence fishing operations such as the point of decision making on whether to discard or not/evidence of whether a fishing activity impacts or not on ETP bycatch. As well as highlighting non-compliance, it would also document good practice which one stakeholder said could contribute to *“market access/retention and positive marketing purposes”* and *“if the Future Catching Policy can resolve quota mismatch, then we believe cameras should be seen as a condition of access to fish what is after all a public resource and form part of the due diligence of fishing”.*

Alternatively, the main challenges with rolling out REM will be deciding which aspects of REM technology are most appropriate for English fisheries and general acceptance from the fishing industry. One stakeholder stated, “*REM is seen entirely as an enforcement tool, while this is the case, there will not be acceptance within the industry to use this technique for scientific data collection*” or “*from a safety perspective*”. Furthermore, some fishers may view it as an invasion of privacy.

One stakeholder questioned the resources to process and QA all the data generated from REM stating, “*while there is high potential for REM, there is not much appreciation of the reality. We struggle to deal with existing VMS/logbook data- it's resource intensive and has lots of quality issues. The UK has only just developed the required workflows and is still developing the infrastructure to make that data useable, and we only update it once a year. The same problems with REM are magnitudes greater. Who is going to process and QA this massive amount of data? Where is it going to be held, and how are standard useable outputs going to be generated? Whilst the technology might exist to gather the data quite easily, the resource required to make it usable from a scientific perspective is massive. Apple or Google could maybe manage it, but not IFCAs or the MMO*.”

Additionally, GDPR is viewed as a massive barrier and could add significantly to the data processing burden. “*The result is a massive risk that the opportunity to use these data for science is lost, and it simply becomes an enforcement tool with cameras deterring infringements and misreporting*.”

4. Recommended technologies and system setups

REM typically focuses on the application of cameras for the purposes of monitoring fishing activity; however, a typical REM system will apply a number of different technologies connected via a computer control box, all collecting data to contribute to the picture of a vessel's fishing activities. The application of these additional technologies enables effective monitoring of a fishery and adds capacity to the potential data gathered by the system. Such a system will include the use of a GPS unit for the purpose of recording vessel location, heading and speed; independently of the vessel's VMS; hydraulic sensors to monitor winch activity when gears are in use, and closed-circuit television (CCTV) cameras to provide an auditable record of all activities onboard. In addition, we have included within our research the application of in-water gear sensors and attachments to collect specific data toward targeted management objectives. A description of each possible EM technology used and their function within this study has been provided below.

4.1 Technologies and components.

Our recommended REM systems detailed below comprise of a control box (ruggedised hard drive with data ports, cellular and / or satellite connection, Wi-Fi, universal power supply (UPS) and often an onboard user interface such as a monitor or tablet), CCTV cameras, a GPS receiver, hydraulic pressure and / or winch rotation sensors.

4.1.1 Control Box

Control boxes are the onboard computers which store, manage, and provide functionality to the REM data collected. Control boxes are highly variable in their capability, with high spec boxes being employed in large vessels with a large array of cameras and sensors attached right down to boxes managing a single data stream. Control boxes are often designed so that they can be remotely accessed by technical support teams in order for remote system updates and configurations to occur, and also for regular remote health checks of the system to ensure continuous operability while at sea. The majority of control boxes on the market also have the ability to provide remote data transmission via Wi-Fi or cellular networks.

The vendors returned specifications on control boxes were evaluated against a standard, scored, and verified against the stakeholder responses to produce the matrix in Table 53 and short list of suitable vendors. The scoring criteria for the control boxes was previously outlined in Table 47. We would caveat, that though green scoring products ranked the highest, some of the high orange scored devices were still worthy of inclusion and may be better suited to the individual requirements of specific vessels. For instance, a very low risk, 6-7m day trip pole and line, or pot and trap vessel may not need more than one camera; if any, to meet the data requirements, with cellular only data transfer, and certainly wouldn’t need more than 512GB’s worth of internal storage.

The below control boxes were broken down in to three categories so they may be comparable on cost and functionality. High, Medium, and Low. On functionality and cost alone, the high spec control boxes (>8 cameras) were considered overly high specified for the purposes of English fisheries monitoring, both inshore and offshore. These models were clearly targeted at distant water, high seas fisheries, which while having some degree of overlap with the larger (>30m) industrial trawlers and seiners, generally fall over the requirement of the average >10m vessel.

Medium and low spec control boxes generally better suited the requirements of <10m and >10m fishing vessels.

Table 53 Control Box Assessment

Control Box Assessment										
Company	**Product**	**Internal Storage Grading**	**Score**	**# Camera & Attachment Grading**	**Score**	**Connectivity Grading**	**Score**	**AI/Machine Learning Grading**	**Score**	**Overall Score (x/40) 30 and over = green 20-29= orange Under 20=Red**
Satlink S.L.	Seatube Nano	Bespoke	8	1-4, 1-32	8	Wi-Fi, cellular & satellite	8	AI Capable	8	**32**
Satlink S.L.	Seatube Nano +	Bespoke	8	1-8, 1-32	8	Wi-Fi, cellular & satellite	8	AI Capable	8	**32**
Teem Fish / SnapIT	AI Hub (Onboard control box)	2 TB	8	4+3	7	Wi-Fi & cellular	7	AI Capable	8	**30**
Archipelago	Marine Observe EM Control Centre	4TB	5	20+10	8	Wi-Fi & cellular	7	AI Capable	8	**28**
Integrated Monitoring	Yellowfin 351	512GB	4	1-6, + 4	8	No Wi-Fi	5	AI Capable	7	**24**
Succorfish Ltd	IVMS Device hardware and software	Bespoke	8	1 + 0	3	No Wi-Fi	5	AI Capable	7	**23**
Integrated Monitoring	Yellowfin 7108	4TB	5	Bespoke cameras, no sensors	4	No Wi-Fi	5	AI Capable	8	**22**
Archipelago	EM Observe Control Centre	No internal storage	0	8+6	7	No Wi-Fi	5	AI Capable	8	**20**

THALOS	OceanLive	Bespoke	8	1-8, + many	8	Satellite or physical swap only	1	In development	3	**20**
CVision AI	Shoresight	Info lacking	1	4+0, no sensors	3	Wi-Fi & cellular	7	AI Capable	8	**19**
Anchor Lab	BlackBox VX	2 TB	8	4-8, cameras only	4	No Wi-Fi	5	Not yet	0	**17**
Integrated Monitoring	Minnow	No internal storage	0	1-2, + 1	5	No Wi-Fi	5	AI Capable	7	**17**
Anchor Lab	BlackBox VX-Mini	2TB	8	2, cameras only	3	No Wi-Fi	5	No info	0	**16**
Archipelago	LIME	No internal storage	0	0+4, no cameras	3	No Wi-Fi	5	No	0	**8**

4.1.2 Cameras

The primary role of a camera and CCTV system is to collect video data for the purpose of validating information collected by other means. Of course, cameras can be used to count when a net is being hauled or shot, but from an analysis and data management standpoint this is incredibly expensive. Therefore, cameras are best used alongside other devices to streamline and best target the monitoring requirement. Even going to the length of only initiating recording when a specific activity is taking place – therefore maximising efficiency on data capture, storage and review, so long as this fits within the management requirements of that fishery. If fisheries managers have a greater interest in using video records for enforcement, then a great deal more video footage would need to be collected and audited.

Stakeholder interest in the use of cameras put more emphasis on the application for the >10m fleet, but for all vessels cameras will be required to verify activities when modelling fishing effort in a given area, or corroborating fisher logs or self-reporting mechanisms. False positive results could be generated by other non-fishing behaviours across different métiers. For instance, pot and trap vessels would generate a false positive image when modelling 'drift' time –i.e., when the fisher takes a break, remaining inactive while processing catches or repairing gear; or when fishing for baits, as shown by Mendo & James (2020). Furthermore, cameras (in combination with other technologies – such as RFID scanners) enable additional data to be collected on fishing effort where time doesn't correlate directly with fishing impact (i.e., soak time / bottom time of a trawl is very clearly defined). Setting time doesn't determine the number of pots/creels that are deployed while fishing.

The cameras and the camera housing need to be constructed of material that can resist the harsh environment on board the vessels and that are resistant to tampering. In practicality this means the use of a minimum of IP66 (waterproof rating) camera, though obviously a higher rating like IP67 or IP68 would be preferable.

The recommended camera placement is highly dependent on management objectives set within the fishery. For instance, if fish species identification is more important for a particular fleet and métier, then it would be sensible to capture footage from above the catch sorting belt. If the focus is on bycatch or discard monitoring, then the camera would be better placed over the hauling area with a good field of view where species are likely to be cut from the line, discarded, or thrown back. Likewise, if the management objectives required reporting on the use of mitigation devices, for instance; monitoring bird strikes on warp or towing cables, determining the use of streamer lines with tension meters, and validating this would require additional cameras solely focused on this role. Camera placement is also heavily dependent upon individual vessel design, and it is not unusual for vessels of a similar size class to have a different number of cameras on board.

Within our recommended REM designs, we feel most monitoring requirements can be achieved by one or two cameras. However, for larger or high-risk vessels, where there are multiple monitoring requirements and management objectives involved, three or more cameras may be required to sufficiently capture the necessary data. This is particularly pertinent if coverage of the whole vessel is required e.g., for compliance monitoring or enforcement of future catching policy. At an average cost of £300-450 per camera, these additional costs are not seen as prohibitive. *The camera numbers provided in the REM designs should therefore be considered the minimum number required for the monitoring requirements identified*.

Generally, all cameras will have a wide-field of view to ensure maximum spatial coverage. Many vendors offer cameras with different fields of view. It would be generally expected that the higher spec REM cameras should cover up to 140 degrees. Of course, all cameras will have blind-spots, and with fewer cameras, can be circumnavigated for malpractice to continue out of sight. Determining the number of cameras tasked with an enforcement role would require greater coverage of the vessel, therefore, these would be better paired with higher specification control boxes and prioritised for non-compliant and high-risk fleets.

4.1.3 GPS

GPS functionality was included with all REM control boxes and a primary requirement across all stakeholders. All REM systems will include position reporting functionality, independent of the vessels system, therefore, this objective is easily fulfilled. The most significant consideration in position reporting is the variation in reporting frequency;i.e., the number of position reports transmitted over time, the resolution of which provides a significant management function in determining fishing effort across the métiers.

Of note, some of the vendors reported that their usual reporting frequency over satellite would be a single report every hour, falling far below the reporting intervals requested by the stakeholders, but the transmitted report would contain position and activity data recorded every 10 seconds within that hour. If the live position reporting requirement is unnecessary for a particular métier, or if the position data cannot be acted on in a useable timeframe, then this may be the best approach for cost-effective position reporting – low frequency but high-resolution data capture.

The EFCA (2019) report indicated that a vessel equipped with GPS and 4 sensors will generate 500KB of data per day. In the grand scheme of data generation through REM, this is incredibly minute. Generating 72GB of data across the 2185 vessels in the analysis fleet, according to the reported 2017 fishing effort by métier data courtesy of Poseidon Aquatic Resource Management & AVS Developments Ltd in pursuance of the development of the Fishing Impact Decision Information Toolkit. Given the small data volume, we would recommend a ping rate (the frequency of reporting) of one ping every three minutes. As indicated to be the minimum required across the IFCAs in the stakeholder responses, if this data were usable in real time, if not, then a 10 second position record, reported every hour, or day would be more appropriate and cost-effective. It was noted that for some fishing métiers, the position reporting frequency could be significantly lower without causing any negative impacts to fisheries managers, for instance, slow moving vessels which fish over a large area in a linear pattern, would be effectively monitored at lower ping rates.

A three-minute, or higher, position report rate would be cost-effective, even free, if all REM systems use an unlimited data sim, this would also allow for no-additional cost data transfer, and is our recommended approach, detailed in Section 6.3.2.2. Without an unlimited data sim, vessels would incur a rather high data charge for the minimal position reporting data transmitted.

4.1.4 Winch sensors – Hydraulic / Electrical

Hydraulic pressure sensors allow the pressure spikes generated when the drum/winch is engaged to be recorded and be paired with the GPS data and logged with the control box. These data points are then used to determine when gear hauling is occurring. Usually, generic sensors are used and then added on to the EMS.

On certain vessel designs the same monitoring objective can be met by using an electrical sensor instead. This operates by measuring when the electrical controls for the drum/winch are engaged rather than the hydraulics.

4.1.5 RFID Scanner and Tags

RFID tags have proven themselves to be a particularly low cost and accurate way of verifying gear deployment and return in pot fisheries (Fujita *et al*., 2018; Course and Pasco, 2021). They are usually employed in conjunction with a winch sensor, usually hydraulic, to confirm fishing activity. Winches may have multiple functions on board the vessel, use of RFID tags allows the categorical confirmation of gear being used. It also allows an individual pot or creel to be identified. These data can also be used at the end of a trip to identify specific gear that has been lost. RFID scanners and tags enable differentiation between different gears where multiple nets or creels are deployed.

4.1.6 Electronically linked mitigation devices

We found no currently available PET mitigation devices linked to REM systems that are applicable to English fisheries. Some available technologies, however, do exist to reduce bycatch and improve overall selectivity such as LED lights, strobes and pingers. For REM technologies to determine that the mitigation devices are in use, and working, a camera and or microphone would be required to determine that light or sound is being emitted correctly from the device, or for the mitigation devices to self-determine and wirelessly report that they are functioning as intended.

One vendor in particular is developing a longlining hook attachment to electronically collect and transmit data on device usage. Whilst another has developed a tension meter attached to streamer sensors to determine that the streamers have been used correctly when setting or hauling catch.

4.1.7 Weighing technologies

Incorporating weighing technologies into an REM system can provide incredibly useful and robust data for fisheries scientist and managers. There are a number of ways of practically doing this; such technologies can be directly wired into the control box or can transmit wirelessly over Bluetooth or localised Wi-Fi. In order to ensure accuracy of measurements while operating on the deck of a rolling fishing vessel, weight scales need to be motion compensated in order to provide the exact weight of catch. In addition, the scale needs to be made from non-corrosive materials, able to endure life at sea without suffering rust or salt damage. These two elements combined dramatically increases the cost of the unit.

Weighing scales were not listed as any of the technologies produced by the vendors approached in this study. However, within the literature, three types of weighing scale were identified as applicable to English fisheries and offered the potential to be linked into a REM System. A single weighing scale or platform, a conveyor-style weighing system or “flow scales” used in factory and processing vessels (MRAG Americas, 2019., Course and Pasco, 2021) and an integrated conveyor, species identification and measuring system - Automated Shellfish Species, Size and Sex Identification System (AS3ID); currently in development by St. Andrews University under the Seafood Innovation Fund. Marel, one of the weighing technology vendors were approached for updated and specific information on their products but were unresponsive. Information on their products and costs were collected from the literature and Marel’s website.

In reviewing their applicability, weighing scales or platforms would be most applicable to English fisheries, specifically where uniform units are used (I.e., fish are weighed in a basket, crate, or box) while being processed. Costs for these scales have been reported at around £4000. Example scales include the Marel M2200/M1100 or Pol S-185 (MRAG Americas, 2019; Course and Pasco, 2021).

Conveyor-style or flow scales are only appliable to the largest of fishing vessels, factory, or processing vessels. The report by MRAG Americas (2019) on the application of flow scales in the Alaska groundfish fishery, where catch weight verification by flow scales have been made mandatory, Marel quoted $30,400 (approximately £22,000 – September 2021) per scale to replace all flow scales being used in that industry. This is a significant cost to roll out as part of an REM system and would only be applicable to the largest of fishing vessels and onboard processors. We would not recommend using this technology unless the vessel operator purchases for their own use. Course and Pasco (2021) reported that there is value in fishers investing in a flow scale to accurately report landed weights back to local regulators, and more importantly to the fishers, to avoid over or under filling fisher boxes destined for market.

Lastly, the Automated Shellfish Species, Size and Sex Identification System (AS3ID), is a prototype device developed by the University of St Andrews, under the Seafood Innovation Fund, the device is capable of automatically identifying species, size and sex of brown crabs and lobsters by taking high resolution 2D and 3D images (St Andrews, 2021). This product will likely be commercially available by 2023, at a cost of £10,000-£15,000. At present the device has been designed for crustaceans and other shellfish, but has the potential application for fish, although this has not been developed yet. These devices have been tested on vessels under 10m in length and offer the potential to significantly increase the robustness and quality of observer and self-reported fisher data on shellfish catches.

4.1.8 In water technologies – gear sensors, oceanographic samplers, net cameras.

A number of vendors specifically developed standalone products capable of integration with REM systems, with the wider literature showing that there is a lot of research and development taking place in this area. Such examples of in-water technologies include gear sensors, net cameras, and oceanographic samplers.

The literature demonstrated the capability of net trawl cameras for the purpose of determining catch composition within trawls, with applications for allowing fishers to actively decide to release the contents of the trawl if the composition is unsatisfactory. This holds significant potential for reducing bycatch of non-target species at the point of catch on the seabed, improving efficiency for fishers and reducing the mortality of trawling on non-target species. Such an application could theoretically have wider knock-on impacts to reducing trawl intensity in areas that yield poor target catches, therefore, improving fisher success and selectivity, with the potential for much wider cost savings.

Rosen, *et al.* (2013) demonstrated that in water catch analysis can yield a 96% accuracy on species identification from still images, and the application of tools to take length measurements can yield a >95% accuracy, including fish that are incomplete within the frame, curved or obscured. Additionally, Sokolova *et al.,* (2021) have demonstrated that machine learning tools have significant potential for actively determining the catch composition, specific to this study, a 76% accuracy success in automatic identification and counting of *Nephrops Norvegicus.* Demonstrably, this technology can be linked into the REM system, feeding catch quantification and reporting data, along with a live feed of the catch to a monitor in the wheelhouse.

Other applications of in-water cameras include scientific application for the verification of benthic environments and habitat type, through a camera mounted at the head of the trawl, or on the trawl door. Most of the UKs marine environment habitat maps are largely based on prediction and modelling. Although ranked as a lesser priority among the stakeholders, using net cameras mounted on bottom towed gears can collect a significant amount of benthic environment data to verify these habitat predictions, while potentially having an overlapping role in collecting catch data and feeding this back to the fishers in real time.

One of the vendors is currently developing a bespoke fishing sensor than can be attached to most fishing gears and collects data at predefined intervals: water depth, temperature, salinity, turbidity, light intensity, and triple axis movement. In addition to collecting this valuable oceanographic data, it includes such applications for determining fishing activity on mobile gear vessels. This would help with gear marking for identification purposes; provide information on the time of deployment; and capture environmental data (e.g., temperature, salinity, chlorophyll etc) to predict changes in oceanic conditions, with application for strengthening our understanding on fisheries ecology.

4.1.9 Live-reporting functionality – cellular, satellite and Wi-Fi connectivity

At the bare minimum and for the most cost-effective design, fisheries managers will want to collect data on fishing effort. Specifically, identification of gear, time of gear setting, time of gear hauling and vessel position reported on a 3–5-minute frequency. This can be done cost effectively using a GPS and gear sensors, stored on an onboard hard drive, and reported over cellular networks. This information can provide a fleetwide quantification of fishing effort within the 12nm zone in near-real time, enabling fisheries manager to track and plot fishing effort within their jurisdiction. Overlaying such information against other collected data sources will enable fisheries managers to determine soak time of nets, trawl or dredge impact on the benthos, fishing within geofenced areas, predict interactions with sightings of protected, endangered, or threatened species or perhaps most importantly, determine catch effort on fishing stocks against reported landings.

Most stakeholders weighed in favour of cellular reporting for the inshore. Of course, this is entirely sensible given the relatively low cost of a mobile communication costs, the cellular coverage consistency around the English coastline, the non-prohibitive costs incurred with satellite reporting and the spatial requirement of inshore fishing vessels. Cellular networks and a low-cost tariff can provide sufficient capability to focus on reporting fishing effort within the inshore using small amounts of GPS and vessel activity data (determined by position and sensor activity). This would meet the needs of the stakeholder requirements for high frequency position and activity reports, reliably and at a low cost. To determine fishing effort beyond cellular range, the data can be uploaded via cellular network when returning closer to shore (if not time sensitive or the vessel considered low risk), and for larger vessels satellite reporting can be prioritised.

Significantly low risk vessels, that operate without the requirement for near-real time reporting have the option to proceed without any live reporting and simply upload the data via port Wi-Fi on return to port. This may suit fisheries managers when they know the data cannot be acted on in real-time, due to resourcing, infrastructure, or cost constraints, and therefore the data can still be collected, transmitted, analysed, and included in the fisheries managers reporting obligations.

4.1.10 Self-reporting and fisher input

A good REM system should include some degree of fisher self-reporting, and application of REM for validation. There are a number of benefits to this in improving analysis efficiencies by focusing on key events which may be anecdotally or officially captured in an electronic logbook. Additionally, for existing programmes collecting self-reported data, REM has been shown to increase self-reporting accuracy and data reliability on unobserved trips (Emery, *et al.,* 2019; Morrell, 2019).

We would recommend REM systems which include a fisher input facility and display (keyboard and screen or tablet). This offers future potential application for an integrated electronic logbook, reporting and quota management system within the fisheries management structure, as well as future potential for live feedback and catch composition data collection for fishers.

4.1.11 Specific designs by vessel

The modular framework excel sheet describes the recommended designs by métier but it will vary by vessel within each. This is reflected within the modular framework in instances where either a 2 or 3 camera system are recommended for example. Individual vessel design within the same length range can vary considerably.

In best practice examples of current REM programmes, an individual Vessel Monitoring Plan (VMP) is prepared prior to installation and completed during and afterwards in order to adapt the installation to the individual vessel characteristics and optimize the quality of data recorded. The VMP is subsequently updated whenever a change to the REM system or change to the design (e.g., processing area) of the vessel is made, thus a current record of all deployed systems is maintained. Individual VMPs would need to be set up for each vessel receiving REM hardware in order to operate in line with current best practices.

A VMP serves as the documentation used to describe the project objectives, EM system responsibilities, vessel responsibilities, safety information, any relevant protocols, system components, data collection, feedback, and project contacts for each of the involved vessels along with any changes to the above during monitoring. Any changes to the REM system should be fully documented with regards to version numbers, rationale for changes, date, and personnel responsible.

The VMP should be made in cooperation between the vessel owner or master and the regulatory authorities with the REM vendor involved in order to deploy the system as efficiently as possible. This initial stage is often done in conjunction with an initial survey of the vessel, though this varies by programme. The main purpose of such a survey is to be able to determine an optimal camera/sensor layout for that individual vessel prior to the installation of the system. The input of the operator prior to the installation of the system is key to efficiently rolling out a programme as the information provided by them allows the final tailoring of the required pieces of equipment per vessel, e.g. will 2 cameras be sufficient or will a third be required due to a specific vessel design.

A VMP is often combined with an installation checklist which details what specifically i.e., identifiable units by serial and version numbers, was installed. Whether as two separate or a single combined document the following should be recorded in order to follow current best practices and EFCA recommendations;

- Individual components, serial numbers, software/firmware version numbers, and photographs of such;
- Location of where each component was installed;
- Field of view screen shot of all cameras,
- Test of all attached sensors,
- Verification of live testing of all components, including onboard and any back-end verification; and;
- A general schematic of the individual REM system is usually included.

The REM designs proposed for each métier broadly have the same key components, a control box (with the required level of functionality), a series of 2-4 cameras, a series of 2-4 sensors, two additional hard drives, a monitor, and a keyboard.

Some indicative schematics of REM systems for inshore vessels that fall within the recommendations of the modular framework of a single camera system, multi camera system and a single camera plus RFID scanner are shown in Figure 32, and Figure 33.

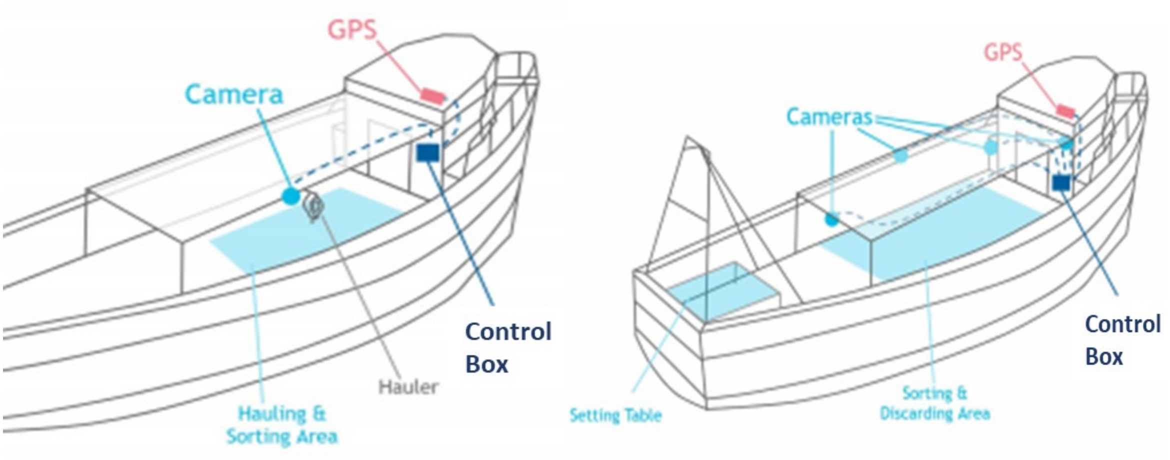

Figure 32 Single camera system design (Left); Multi-camera system design (Right)

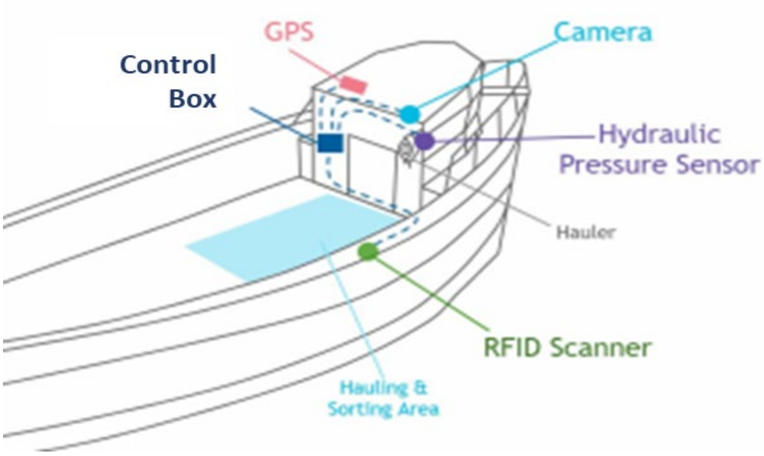

Figure 33 Single camera design plus RFID scanner system

Within the framework, each métier was evaluated for the most applicable additional technologies which could be integrated into the REM design to further increase the data collected. Table 54 outlines a high-level overview of the technologies included, and the number of each of the core components applied to the <>10m vessels. It should be noted that the development of underwater gear and oceanographic sensors is a particularly dynamic area currently and further and/or more cost-effective options could become available in the short to medium term.

Table 54 REM key component and minimum requirement designs for <>10m vessels. Additional technologies identified in the literature and vendor surveys included below

Key technology components	REM system Design		Additional Extra Components
	<10m	>10m	
Control Box	1	1	Weight Plate
Cameras	2	3	Integrated weight-length, species ID, conveyor.
Sensors	3	3	RFID scanner + 20 Tags
Hard drives (500GB <10m and 1TB >10m)	2	2	E-mitigation devices
Keyboard and Monitor / Tablet	1	1	Oceanographic sampler
			Net Cameras

5. Split Matrix - Individual Métiers

This section describes the métier level design of the modular framework. As described in the methods, each métier has had the REM designs developed around (A) high, (B) cost-efficient and (C) low-cost monitoring requirements.

Each of these were given as score, based on the achievable level of impact (High, Medium and Low) a REM system will have in fulfilling the monitoring requirements, as determined through the stakeholder engagement; and the level of risk presented by that métier against achieving GES, as identified in the Objective 1 risk assessment, Section 2.2.

For each REM system design, the number and type of technologies used were cross-examined against the data collection requirements stipulated by stakeholders, and the typical layout of these vessels to ensure that each design was appropriate for this métier. Determining what impact, the REM technologies and data collected would have been based on the experience and use of the proposed systems by the report authors; a low score was typically seen as insufficient to meet the data collection requirements, although may have partially fulfilled these. Medium scoring REM designs were seen as satisfactory to fulfilling most of the monitoring and data collection requirements. These were in general balanced against the risk level of the métier; therefore, high risk métiers were generally scored lower. High scoring REM designs were seen to fulfil all of the data collection requirements, and even go above and beyond the stipulated minimum requirements. Based on the experience and use of the proposed systems by the report authors, the most appropriate methodology for each was given in comments, and cost implications for a particular approach identified. As a rule, the recommended REM system designs were scored high, unless otherwise stipulated in the text.

Higher risk métiers generally had higher data collection and monitoring requirements. They also required more technologies to ensure that the data collection and monitoring requirements were fulfilled. Therefore, in most cases, low-cost monitoring systems were given a low score. Lower risk métiers featured the opposite trend, where low cost and cost-effective REM system designs were seen to adequately fulfil the monitoring requirement balanced against the risk presented by that métier. The three REM designs were RAG colour coded according to this determined level of impact for each fishing métier. The definitions for each colour code are given in Table 55.

Table 55 Modular Framework Colour Definitions

Colour	Definition
🟥	Red presents a high level of risk and a low ability to meet the monitoring requirements of the given métier.
🟧	Amber presents a moderate level of risk and the ability to meet some of the monitoring requirements of the given métier.
🟩	Green presents a low level of risk and the ability to meet the monitoring requirements of the given métier; plus, the potential to undertake additional monitoring if required.

The costs for each design were calculated based on the type and number of different technologies incorporated to each approach. These were allocated a per unit value, based on the vendor engagement and information available in the wider literature. Additional costs for installation, annual maintenance, running costs, software, licencing, and data transmission were included within the cost framework. Further details on this can be found in section 6.3.

5.1 Boat dredge (DRB)

Devon and Severn (25), Kent and Essex (14) and Southern (25) IFCA regions are where the largest numbers of boat dredges are registered (Appendix 2). Based on port registration, these vessels are likely to be fishing primarily in both the inshore and offshore environment in the English Channel, somewhat simplifying the approach to providing, installing, and managing REM on these vessels.

Table 56 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 56 Boat dredge (DRB) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bycatch	Below surface data	Biological Data collection	Video Discard Review
<=10m	Medium	Yes	Yes	Yes	Yes	No	Yes	No	No
>10m	Medium	Yes	Yes	Yes	Yes	No	Yes	Yes	No

5.1.1 Recommended REM technology design

Taking into consideration the medium level of risk assigned to the dredge fishing vessels (as identified through the Objective 1 risk assessment; section 2.2.1), the high impact that dredge gears have on the benthos and the concerns that shellfish stocks are currently data poor; we believe the most effective REM design will be one that maximises data collection for both vessels <>10m. This can be easily achievable through applying in water gear technologies to enable benthic environment data collection and through utilising shellfish identification systems being developed by St Andrews University to maximise shellfish biological data collection.

The split matrix designs for Boat Dredge (DRB) vessels <>10m are shown in Table 57 and Table 58 below.

Table 57 Split Matrix – Boat Dredge (DRB) – Over 10m

Fishing Vessel Métier		Vessel size	Monitoring Objectives				Cost implications	Cost per vessel per year
Level 3	Level 4		Design	REM Technologies	Impact of REM	Justification		(Given as £)
Dredges	Boat Dredge (DRB)	>10m	**A**	**4 (3) Cameras, 1 Shellfish identification system, 1 winch sensor, 1 in water camera/oceanographic sensor**	**Low**	**2 cameras to record dredge operations, including setting, hauling - one per side of the vessel and 1 or 2 cameras focused on species processing. A high ping rate on the GPS to reflect benthic impact. Gear in/out sensors and Hydraulic sensors to determine when gear is in the water/on the bottom. Additional catch data collected through the application of a Shellfish identification system. Additional environmental data collected through in water cameras or oceanographic sensors.**	**3 cameras could be viable dependant on vessel specific design.**	**£7,042.00**
			B	2 cameras, 1 weight-scale, 1 winch sensor	Medium	1 camera to record dredge operations, including setting, hauling, and 1 to record species processing. A high ping rate on the		£5,350.00

						GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.		
			C	1 camera, 1 winch sensor.	High	1 camera to record dredge operations, including setting, hauling. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water.		£3,964.00

Table 58 Split Matrix – Boat Dredge (DRB) – Under 10m

Fishing Vessel Métier		Vessel size	Monitoring Objectives				Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4		Design	REM Technologies	Impact of REM	Justification		
Dredges	Boat Dredge (DRB)	<10m	**A**	**2 cameras, 1 Shellfish identification system, 1 winch sensor, 1 in water camera/oceanographic sensor per dredge.**	**Low**	**1 camera to record dredge operations, including setting, hauling, and 1 camera to record species processing. A high ping rate on the GPS to reflect benthic impact. Gear in/out sensors and Hydraulic sensors to determine when gear is in the water/on the bottom. Additional catch data collected through the application of a Shellfish identification system. Additional environmental data collected through in water cameras or oceanographic sensors.**		**£6,062.00**
			B	1 camera, 1 weight-scale, 1 winch sensor	Medium	1 camera to record dredge operations, including setting, hauling, and species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water. Additional catch data collected		£4,416.00

Fishing Vessel Métier		Vessel size	Monitoring Objectives				Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4		Design	REM Technologies	Impact of REM	Justification		
						through the application of weight-scales.		
			C	1 camera, 1 winch sensor.	High	1 camera to record dredge operations, including setting and hauling. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water.		£3,216.00

5.2 Pots and Traps (FPO)

Cornwall (155), North-Eastern (132), Devon and Severn (118) IFCA regions dominate this métier (Appendix 2). UK under 10m vessels make up most of the fleet as commercial potting mainly operates in inshore waters and therefore the spatial distribution of the fishing activity of these vessels is local to their registered port.

Table 59 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 59 Pots and Traps (FPO) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bycatch	Below surface data	Biological Data collection	Video Discard Review
<=10 m	Low	Yes	Yes	Yes	No	No	No	No	No
>10m	Low	Yes	Yes	Yes	No	No	No	Yes	No

5.2.1 Recommended REM technology design

Taking into consideration the very low level of risk assigned to the pot and trap fishing vessels, (as identified through the objective 1 risk assessment; section 2.2.2), the low impact that these have on the benthos and the concerns that shellfish stocks are currently data poor; we believe the most effective REM design will be one that takes the low-cost approach to data collection for both vessels <>10m. This can be easily achievable through a single camera, a winch sensor and RFID scanners, in addition, to collecting biological data through a plate weight scale.

We would recommend utilising shellfish identification system being developed by St Andrews University to maximise shellfish biological data collection in a reference fleet among the pots and trap vessels. For this we would recommend the cost-effective approach.

The split matrix designs for Pots and Traps (FPO) vessels <>10m are shown in Table 60 and Table 61 below.

Table 60 Split Matrix – Pots and Traps (FPO) – Over 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Traps	Pots and Traps (FPO)	>10m	A	2 cameras, 1 shellfish scanner, 1 RFID scanner + 20 tags. 1 winch sensor, 1 oceanographic sensor.	Low	1 camera to record setting, hauling, and 1 camera focused on species processing. A high ping rate on the GPS to capture small spatial of impacts. RFID and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of a Shellfish identification system. Additional environmental data collected through in water cameras or oceanographic sensors.		£5,580.00
			B	2 cameras, 1 shellfish scanner, 1 RFID scanner + 20 tags. 1 winch sensor,	Low	1 camera to record setting, hauling, and 1 camera focused on species processing. A high ping rate on the GPS to capture small spatial of impacts. RFID and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of a Shellfish identification system.		£4,780.00
			C	**1 camera** **1 winch sensor,** **1 RFID Scanner + 20**	**Low**	**A high ping rate on the GPS to capture small spatial impact.**		**£3,394.00**

				tags. 1 weight scale	🟩	Hydraulic sensor and RFID tags to determine when gear is in the water.		

Table 61 Split Matrix – Pots and Traps (FPO) – Under 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year
Level 3	Level 4			REM Technologies	Impact of REM	Justification		(Given as £)
Traps	Pots and Traps (FPO)	<10m	A	2 cameras, 1 shellfish scanner, 1 RFID scanner + 20 tags. 1 winch sensor, 1 oceanographic sensor.	Low	1 camera to record setting, hauling, and 1 camera focused on species processing. A high ping rate on the GPS to capture small spatial of impacts. RFID and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the Shellfish identification system. Additional environmental data collected through in water cameras or oceanographic sensors.		£5,452.00
			B	2 cameras, 1 shellfish scanner, 1 RFID scanner + 20 tags. 1 winch sensor,	Low	1 camera to record setting, hauling, and 1 camera focused on species processing. A high ping rate on the GPS to capture small spatial of impacts. RFID and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of a Shellfish identification system.		£4,612.00

			C	**1 camera 1 winch sensor, 1 RFID Scanner + 20 tags. 1 weight scale**	**Low**	**A high ping rate on the GPS to capture small spatial impact. Hydraulic sensor and RFID tags to determine when gear is in the water.**		**£2,526.00**

5.3 Gillnets (GN)

In the UK, there are 288 licensed GN vessels, all of which are UK flagged (Appendix 2). Much of the fleet are <10m vessels (97%) which are mainly distributed in the Cornwall, (75), Sussex (48) and Devon and Severn (37) IFCA regions and along the south coast, somewhat simplifying the approach to providing, installing, and managing REM on these vessels.

Table 62 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 62 Gillnets (GN) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort	Video verification	Catch Verification	Protected species bycatch	Below surface data	Biological Data collectio	Video Discard
<=10 m	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes
>10m	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes

5.3.1 Recommended REM technology design

Taking into consideration the medium level of risk assigned to the gillnet fishing vessels, (as identified through the objective 1 risk assessment; section 2.2.3), the low impact that these have on the benthos and the concerns for protected species bycatch; we believe the most effective REM design will be one that takes a cost-effective approach to data collection for both vessels <>10m. This can be best achievable through a minimum of two cameras (perhaps one, depending on vessel design), a winch sensor and RFID scanners. Most inshore gillnetters will shoot and haul from a single point, meaning that catch focused data collection can be easily achieved with a single camera in most cases.

We would recommend using weight scales to maximise biological data collection in a reference fleet of gillnetters. For this we would recommend the cost-effective approach.

The split matrix designs for Gillnets (GN) vessels <>10m are shown in Table 63 and Table 64 below.

Table 63 Split Matrix – Gillnets (GN) – Over 10m

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Nets	Gillnets (GN)	>10m	A	3 (2) Cameras, 1 integrated weight-scale, 1 winch sensor, 1 RFID Scanner + 20 tags 1 in water oceanographic sensor	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and 1 camera on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out or RFID sensors and Hydraulic sensors to determine when gear is in the water. Additional catch data collected through the application of weight-scales and measuring boards. Additional environmental data collected through oceanographic sensors.	2 cameras could be viable dependant on vessel specific design.	£5,146.00
			B	2 (1) Cameras, 1 integrated weight-scale, 1 winch sensor 1 RFID Scanner + 20 tags.	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design.	£4,260.00

			C	1 camera, 1 winch sensor 1 RFID Scanner + 20 tags.	Low	1 camera to record setting and hauling. A medium ping rate on the GPS to capture small spatial impact. Hydraulic sensor used to determine when gear is in the water.		£3,274.00

Table 64 Split Matrix – Gillnets (GN) – Under 10m

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Nets	Gillnets (GN)	<10m	A	2 cameras, 1 integrated weight-scale, 1 winch sensor, 1 RFID Scanner + 20 tags 1 in water oceanographic sensor.	Low	1 camera to record setting, hauling, and one camera to record bycatch and species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out or RFID sensors and Hydraulic sensors to determine when gear is in the water. Additional catch data collected through the application of weight-scales. Additional environmental data collected through oceanographic sensors.		£4,252.00
			B	2 (1) Cameras, 1 integrated weight-scale, 1 winch sensor 1 RFID Scanner + 20 tags.	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design.	£3,326.00
			C	**1 camera, 1 winch sensor 1 RFID Scanner + 20 tags.**	**Low**	**1 camera to record setting and hauling and ETP bycatch. A medium ping rate on the GPS to capture small spatial impact. Hydraulic sensor used to determine when gear is in the water.**		**£2,526.00**

5.4 Drift net (GND)

In the UK, there are 57 licensed GND vessels (Appendix 2). Much of the fleet are <10m vessels which are mainly distributed in the Kent and Essex (21) IFCA region and along the south coast, somewhat simplifying the approach to providing, installing, and managing REM on these vessels.

Table 65 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 65 Drift nets (GND) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification required.	Catch Verification	Protected species bycatch	Below surface data collection	Biological Data collection	Video Discard Review
<=10 m	Low	Yes	Yes	Yes	Yes	Yes	No	No	Yes
>10 m	Low	Yes	Yes	Yes	Yes	Yes	No	No	Yes

5.4.1 Recommended REM technology design

Taking into consideration the low level of risk assigned to the drift gillnet fishing vessels, (as identified through the objective 1 risk assessment; section 2.2.4), the low impact that these have on the benthos and the concerns for protected species bycatch; we believe the most effective REM design will be one that takes a cost-effective approach to data collection for both vessels <>10m. This can be best achievable through a minimum of two cameras (perhaps one, depending on vessel design), a winch sensor and RFID scanners. Most gillnetters will shoot and haul from a single point, meaning that catch focused data collection can be easily achieved with a single camera in most cases.

We would recommend using weight scales to maximise biological data collection in a reference fleet of drift netters. For this we would recommend the cost-effective approach.

The split matrix designs for Drift nets (GND) vessels <>10m are shown in Table 66 and Table 67 below.

Table 66 Split Matrix – Drift net (GND) – Over 10m

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year
Level 3	Level 4			REM Technologies	Impact of REM	Justification		(Given as £)
Nets	Drift net (GND)	>10m	A	3 (2) Cameras, 1 integrated weight-scale, 1 winch sensor, 1 RFID Scanner + 20 tags 1 in water oceanographic sensor	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and 1 camera on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out or RFID sensors and Hydraulic sensors to determine when gear is in the water. Additional catch data collected through the application of weight-scales and measuring boards. Additional environmental data collected through oceanographic sensors.	2 cameras could be viable dependant on vessel specific design.	£5,146.00
			B	2 (1) Cameras, 1 integrated weight-scale, 1 winch sensor 1 RFID Scanner + 20 tags.	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design.	£4,260.00

			C	1 camera, 1 winch sensor 1 RFID Scanner + 20 tags.	Low	1 camera to record setting and hauling and ETP bycatch. A medium ping rate on the GPS to capture small spatial impact. Hydraulic sensor used to determine when gear is in the water.		£3,274.00

Table 67 Split Matrix – Drift net (GND) – Under 10m

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Nets	Drift net (GND)	<10m	A	2 cameras, 1 integrated weight-scale, 1 winch sensor, 1 RFID Scanner + 20 tags 1 in water oceanographic sensor.	Low	1 camera to record setting, hauling, and one camera to record bycatch and species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out or RFID sensors and Hydraulic sensors to determine when gear is in the water. Additional catch data collected through the application of weight-scales. Additional environmental data collected through oceanographic sensors.		£4,252.00
			B	2 (1) Cameras, 1 integrated weight-scale, 1 winch sensor 1 RFID Scanner + 20 tags.	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design.	£3,326.00
			C	**1 camera, 1 winch sensor**	**Low**	**1 camera to record setting and hauling and ETP bycatch. A medium ping rate on the GPS to capture small spatial impact. Hydraulic sensor**		**£2,526.00**

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
				1 RFID Scanner + 20 tags.	🟩	**used to determine when gear is in the water.**		

5.5 Set gillnet (GNS)

In the UK, there are 89 licensed GNS vessels (Appendix 2). Most of the fleet are <10m vessels which are mainly distributed in the Kent and Essex (18), Devon and Severn (17), and Cornwall (11), IFCA regions and along the south coast, somewhat simplifying the approach to providing, installing, and managing REM on these vessels.

Table 68 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 68 Set gillnets (GNS) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bycatch	Below surface data	Biological Data collectio	Video Discard Review
<=10m	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes
>10m	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes

5.5.1 Recommended REM technology design.

Taking into consideration the medium level of risk assigned to the set gillnet fishing vessels, (as identified through the objective 1 risk assessment; section 2.2.3), the low impact that these have on the benthos and the concerns for protected species bycatch; we believe the most effective REM design will be one that takes a cost-effective approach to data collection for both vessels <>10m. This can be best achievable through a minimum of two cameras (perhaps one, depending on vessel design), a winch sensor and RFID scanners. Most gillnetters will shoot and haul from a single point, meaning that catch focused data collection can be easily achieved with a single camera in most cases.

We would recommend using weight scales to maximise biological data collection in a reference fleet of set gillnetters. For this we would recommend the cost-effective approach.

The split matrix designs for Set gillnets (GNS) vessels <>10m are shown in Table 69 and Table 70 below.

Table 69 Split Matrix – Set gillnet (GNS) – Over 10m

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year
Level 3	Level 4			REM Technologies	Impact of REM	Justification		(Given as £)
Nets	Set gillnet (GNS)	>10m	A	3 (2) Cameras, 1 integrated weight-scale, 1 winch sensor, 1 RFID Scanner + 20 tags 1 in water oceanographic sensor	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and 1 camera on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out or RFID sensors and Hydraulic sensors to determine when gear is in the water. Additional catch data collected through the application of weight-scales and measuring boards. Additional environmental data collected through oceanographic sensors.	2 cameras could be viable dependant on vessel specific design.	£5,146.00
			B	2 (1) Cameras, 1 integrated weight-scale, 1 winch sensor 1 RFID Scanner + 20 tags.	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out and Hydraulic sensor to determine when gear is in the water. Additional catch	1 camera could be viable dependant on vessel specific design.	£4,260.00

						data collected through the application of weight-scales.		
			C	**1 camera, 1 winch sensor 1 RFID Scanner + 20 tags.**	**Low**	**1 camera to record setting and hauling and ETP bycatch. A medium ping rate on the GPS to capture small spatial impact. Hydraulic sensor used to determine when gear is in the water.**		**£3,274.00**

Table 70 Split Matrix – Set gillnet (GNS) – Under 10m

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Nets	Set gillnet (GNS)	<10m	A	2 cameras, 1 integrated weight-scale, 1 winch sensor, 1 RFID Scanner + 20 tags 1 in water oceanographic sensor.	Low	1 camera to record setting, hauling, and one camera to record bycatch and species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out or RFID sensors and Hydraulic sensors to determine when gear is in the water. Additional catch data collected through the application of weight-scales. Additional environmental data collected through oceanographic sensors.		£4,252.00
			B	2 (1) Cameras, 1 integrated weight-scale, 1 winch sensor 1 RFID Scanner + 20 tags.	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design.	£3,326.00
			C	**1 camera, 1 winch sensor**	**Low**	**1 camera to record setting and hauling and ETP bycatch. A medium ping rate on the GPS to capture small spatial impact. Hydraulic sensor**		£2,526.00

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
				1 RFID Scanner + 20 tags.	🟩	**used to determine when gear is in the water.**		

5.6 Trammel net (GTR)

In the UK, there are 41 licensed GTR vessels (Appendix 2). Much of the fleet are <10m vessels which are mainly distributed in the Sussex (21) IFCA region and along the south coast, somewhat simplifying the approach to providing, installing, and managing REM on these vessels.

Table 71 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 71 Trammel nets (GTR) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort	Video verification	Catch Verification	Protected species	Below surface data	Biological Data	Video Discard
<=10 m	Low	Yes	Yes	Yes	Yes	Yes	No	No	Yes
>10 m	Low	Yes	Yes	Yes	Yes	Yes	No	No	Yes

5.6.1 Recommended REM technology design

Taking into consideration the low level of risk assigned to the trammel net fishing vessels(as identified through the objective 1 risk assessment; section 2.2.5), the low impact that these have on the benthos and the concerns for protected species bycatch; we believe the most effective REM design will be one that takes a cost-effective approach to data collection for both vessels <>10m. This can be best achievable through a minimum of two cameras (perhaps one, depending on vessel design), a winch sensor and RFID scanners. Most gillnetters will shoot and haul from a single point, meaning that catch focused data collection can be easily achieved with a single camera in most cases.

We would recommend using weight scales to maximise biological data collection in a reference fleet of trammel netters. For this we would recommend the cost-effective approach.

The split matrix designs for Trammel nets (GTR) vessels <>10m are shown in Table 72 and Table 73 below.

Table 72 Split Matrix – Trammel net (GTR) – Over 10m

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Nets	Trammel net (GTR)	>10m	A	3 (2) Cameras, 1 integrated weight-scale, 1 winch sensor, 1 RFID Scanner + 20 tags 1 in water oceanographic sensor	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and 1 camera on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out or RFID sensors and Hydraulic sensors to determine when gear is in the water. Additional catch data collected through the application of weight-scales and measuring boards. Additional environmental data collected through oceanographic sensors.	2 cameras could be viable dependant on vessel specific design.	£5,146.00
			B	2 (1) Cameras, 1 integrated weight-scale, 1 winch sensor 1 RFID Scanner + 20 tags.	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out and Hydraulic sensor to determine when gear is in the water. Additional catch	1 camera could be viable dependant on vessel specific design.	£4,260.00

						data collected through the application of weight-scales.		
			C	**1 camera, 1 winch sensor 1 RFID Scanner + 20 tags.**	**Low**	**1 camera to record setting and hauling. A medium ping rate on the GPS to capture small spatial impact. Hydraulic sensor used to determine when gear is in the water.**		**£3,274.00**

Table 73 Split Matrix – Trammel net (GTR) – Under 10m

Fishing Vessel Métier		**Vessel size**	**Designs**	**Monitoring Objectives**			**Cost implications**	**Cost per vessel per year**
Level 3	**Level 4**			**REM Technologies**	**Impact of REM**	**Justification**		**(Given as £)**
Nets	Trammel net (GTR)	<10m	A	2 cameras, 1 integrated weight-scale, 1 winch sensor, 1 RFID Scanner + 20 tags 1 in water oceanographic sensor.	Low	1 camera to record setting, hauling, and one camera to record bycatch and species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out or RFID sensors and Hydraulic sensors to determine when gear is in the water. Additional catch data collected through the application of weight-scales. Additional environmental data collected through oceanographic sensors.		£4,252.00
			B	2 (1) Cameras, 1 integrated weight-scale, 1 winch sensor 1 RFID Scanner + 20 tags.	Low	1 camera to record setting, hauling, 1 camera focused on bycatch and on species processing. A medium ping rate on the GPS to reflect slow moving fishing activity. Gear in/out and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design.	£3,326.00

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
			C	**1 camera, 1 winch sensor 1 RFID Scanner + 20 tags.**	**Low**	**1 camera to record setting and hauling and ETP bycatch. A medium ping rate on the GPS to capture small spatial impact. Hydraulic sensor used to determine when gear is in the water.**		£2,526.00

5.7 Hand and pole lines (LHP)

In the UK, there are 238 licensed LHP vessels (Appendix 2). Most of the fleet are <10m vessels which are mainly distributed in the Cornwall (159) and Devon and Severn (56) IFCA regions, somewhat simplifying the approach to providing, installing, and managing REM on these vessels.

Table 74 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 74 Hand and pole lines (LHP) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bvcatch	Below surface data	Biological Data collectio	Video Discard Review
<=10 m	Low	Yes	Yes	Yes	No	No	No	No	No
>10m	Low	Yes	Yes	Yes	No	No	No	No	No

5.7.1 Recommended REM technology design

Taking into consideration the low level of risk assigned to the hand and pole line vessels (as identified through the objective 1 risk assessment; section 2.2.6). We believe the most effective REM design will be one that takes a cost-effective approach to data collection for both vessels <>10m. This can be best achievable through a one camera and integrated weight scale design. Most liners will shoot and haul from a single point, meaning that catch focused data collection can be easily achieved with a single camera in most cases.

The split matrix designs for Hand and pole lines (LHP) vessels <>10m are shown in Table 75 and Table 76 below.

Table 75 Split Matrix – Hand and pole lines (LHP) – Over 10m

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Rods and Lines	Hand and pole lines (LHP)	>10m	A	2 cameras, 1 integrated weight-scale	Low	2 cameras to record casting, hauling, and species processing. A high ping rate on the GPS to reflect slow moving and small spatial footprint fishing activity. Additional catch data collected through the application of weight-scales.	Considering the low number of data inputs, costs have been minimised by using a lower specification control box.	£3,442.00
			B	**1 camera** **1 integrated weight-scale**	**Low**	**1 camera to record casting, hauling, and species processing. A high ping rate on the GPS to reflect slow moving and small spatial footprint fishing activity. Additional catch data collected through the application of weight-scales.**		**£3,356.00**
			C	1 camera	Low	1 camera to record casting, hauling. A high ping rate on the GPS to reflect slow moving and small spatial footprint fishing activity.		£2,456.00

Table 76 Split Matrix – Hand and pole lines (LHP) – Under 10m

Fishing Vessel Métier		Vessel size	Designs	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Rods and Lines	Hand and pole lines (LHP)	<10m	A	2 cameras, 1 integrated weight-scale	Low	2 cameras to record casting, hauling, and species processing. A high ping rate on the GPS to reflect slow moving and small spatial footprint fishing activity. Additional catch data collected through the application of weight-scales.	Considering the low number of data inputs, costs have been minimised by using a lower specification control box.	£3,314.00
			B	**1 camera** **1 integrated weight-scale**	**Low**	**1 camera to record casting, hauling, and species processing. A high ping rate on the GPS to reflect slow moving and small spatial footprint fishing activity. Additional catch data collected through the application of weight-scales.**		**£3,188.00**
			C	1 camera	Low	1 camera to record casting, hauling. A high ping rate on the GPS to reflect slow moving and small spatial footprint fishing activity.		£2,388.00

5.8 Hooks and lines (LX)

In the UK, there are 70 licensed LX vessels (Appendix 2). Much of the fleet are <10m vessels which are mainly distributed in the Southern (23), Devon and Severn (56) and Sussex (16) IFCA regions, somewhat simplifying the approach to providing, installing, and managing REM on these vessels.

Table 77 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 77 Hooks and lines (LX) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bycatch	Below surface data	Biological Data collection	Video Discard Review
<=10m	Low	Yes	Yes	Yes	No	No	No	No	No
>10m	Low	Yes	Yes	Yes	No	No	No	No	No

5.8.1 Recommended REM technology design

Taking into consideration the very low level of risk assigned to the hook and line vessels (as identified through the objective 1 risk assessment; section 2.2.7). We believe the most effective REM design will be one that takes a minimum cost approach to data collection for both vessels <>10m. Which, given the low level of risk presented by Hooks and Lines, this could be an acceptable option. The proposed design in Table 78 and Table 79 has been given a moderate rating for achieving the fisheries monitoring and management objectives. This can be achievable through a one camera and a winch sensor system. Most liners will shoot and haul from a single point, meaning that catch focused data collection can be easily achieved with a single camera in most cases.

The split matrix designs for Hooks and lines (LX) vessels <>10m are shown in Table 78 and Table 79Table 76 below.

Table 78 Split Matrix – Hooks and lines (LX) – Over 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Rods and lines	Hooks and lines (LX)	>10m	A	2 cameras, 1 integrated weight-scale, 1 RFID scanner + 20 tags. 1 winch sensor, 1 oceanographic sensor.	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. RFID and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras or oceanographic sensors.		£5,060.00
			B	2 (1) cameras, 1 winch sensor 1 integrated weight-scale,	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design. Low-cost control box design	£3,470.00
			C	**1 camera** **1 winch sensor.**	**Medium**	**1 camera to record setting, hauling and species processing. A high ping rate on the GPS. Hydraulic sensor**	**Considering the low number of data inputs, costs have been**	**£2,484.00**

						to determine when gear is in the water.	minimised by using a lower specification control box.	

Table 79 Split Matrix – Hooks and lines (LX) – Under 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Rods and lines	Hooks and lines (LX)	<10m	A	2 cameras, 1 integrated weight-scale, 1 RFID scanner + 20 tags. 1 winch sensor, 1 oceanographic sensor.	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. RFID and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras or oceanographic sensors.		£4,252.00
			B	2 (1) cameras, 1 winch sensor 1 integrated weight-scale,	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design.	£3,302.00
			C	**1 camera** **1 winch sensor.**	**Medium**	**1 camera to record setting, hauling and species processing. A high ping rate on the GPS. Hydraulic sensor**	**Considering the low number of data inputs, costs have been minimised by**	**£2,416.00**

					🟧	**to determine when gear is in the water.**	**using a lower specification control box.**	

5.9 Longlines (LL)

In the UK, there are 39 licensed LL vessels (Appendix 2). Most of the fleet are <10m vessels which are mainly distributed along the south cost, and Eastern IFCA, somewhat simplifying the approach to providing, installing, and managing REM on these vessels.

Table 80 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 80 Longlines (LL) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bycatch	Below surface data	Biological Data collectio	Video Discard Review
<=10 m	Low	Yes	Yes	Yes	No	No	No	No	No
>10m	Low	Yes	Yes	Yes	No	No	No	No	No

5.9.1 Recommended REM technology design

Taking into consideration the very low level of risk assigned to the longline vessels (as identified through the objective 1 risk assessment; section 2.2.8). We believe the most effective REM design will be one that takes a minimum cost approach to data collection for both vessels <>10m. It is for this reason that the proposed design results in an amber rating in Table 81 and Table 82 below. Which given the risk rating this could be acceptable considering the difference in cost of the three different options. This can be best achievable through a one camera and a winch sensor. Most longliners will shoot and haul from a single point, meaning that catch focused data collection can be easily achieved with a single camera in most cases.

The split matrix designs for longlines (LL) vessels <>10m are shown in Table 81 and Table 82 below.

Table 81 Split Matrix – Longlines (LL) – Over 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Rods and lines	Longlines (LL)	>10m	A	2 cameras, 1 integrated weight-scale, 1 RFID scanner + 20 tags. 1 winch sensor, 1 oceanographic sensor.	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. RFID and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras or oceanographic sensors.		£5,060.00
			B	2 (1) cameras, 1 winch sensor 1 integrated weight-scale,	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design. Low-cost control box design	£3,470.00
			C	**1 camera 1 winch sensor.**	**Medium**	**1 camera to record setting, hauling and species processing. A high ping rate**	**Considering the low number of data inputs,**	**£2,484.00**

					🟨	on the GPS. Hydraulic sensor to determine when gear is in the water.	costs have been minimised by using a lower specification control box.	

Table 82 Split Matrix – Longlines (LL) – Under 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Rods and lines	Longlines (LL)	<10m	A	2 cameras, 1 integrated weight-scale, 1 RFID scanner + 20 tags. 1 winch sensor, 1 oceanographic sensor.	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. RFID and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras or oceanographic sensors.		£4,252.00
			B	2 (1) cameras, 1 winch sensor 1 integrated weight-scale,	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design.	£3,302.00
			C	**1 camera** **1 winch sensor.**	**Medium**	**1 camera to record setting, hauling and species processing. A high ping rate on the GPS. Hydraulic sensor**	**Considering the low number of data inputs, costs have been**	**£2,416.00**

						to determine when gear is in the water.	**minimised by using a lower specification control box.**	

5.10 Set longlines (LLS)

In the UK, there are 11 licensed LLS vessels (Appendix 2). Too few to develop a bespoke REM design, so will follow the same structure as longlines in general.

Table 83 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 83 Set Longlines (LLS) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bycatch	Below surface data	Biological Data collection	Video Discard Review
<=10m	Low	Yes	Yes	Yes	No	No	No	No	No
>10m	Low	Yes	Yes	Yes	No	No	No	No	No

5.10.1 Recommended REM technology design

Taking into consideration the very low level of risk assigned to the set longline vessels (as identified through the objective 1 risk assessment; section 2.2.8). We believe the most effective REM design will be one that takes a minimum cost approach to data collection for both vessels <>10m. Which, given the low level of risk presented by Hooks and Lines, this could be an acceptable option. The proposed design in Table 84 and Table 85Table 79 has been given a moderate rating for achieving the fisheries monitoring and management objectives. This can be achievable through a one camera and a winch sensor system. Most liners will shoot and haul from a single point, meaning that catch focused data collection can be easily achieved with a single camera in most cases.

The split matrix designs for Set longlines (LLS) vessels <>10m are shown in Table 84 and Table 85 below.

Table 84 Split Matrix – Set longlines (LLS) – Over 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year
Level 3	Level 4			REM Technologies	Impact of REM	Justification		(Given as £)
Rods and lines	Set longline (LLS)	>10m	A	2 cameras, 1 integrated weight-scale, 1 RFID scanner + 20 tags. 1 winch sensor, 1 oceanographic sensor.	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. RFID and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras or oceanographic sensors.		£5,060.00
			B	2 (1) cameras, 1 winch sensor 1 integrated weight-scale,	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design. Low-cost control box design	£3,470.00

			C	1 camera 1 winch sensor.	Medium	1 camera to record setting, hauling and species processing. A high ping rate on the GPS. Hydraulic sensor to determine when gear is in the water.	Considering the low number of data inputs, costs have been minimised by using a lower specification control box.	£2,484.00

Table 85 Split Matrix – Set longlines (LLS) – Under 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Rods and lines	Set longline (LLS)	<10m	A	2 cameras, 1 integrated weight-scale, 1 RFID scanner + 20 tags. 1 winch sensor, 1 oceanographic sensor.	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. RFID and Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras or oceanographic sensors.		£4,252.00
			B	2 (1) cameras, 1 winch sensor 1 integrated weight-scale,	Low	2 cameras to record setting, hauling, and species processing. A high ping rate on the GPS. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.	1 camera could be viable dependant on vessel specific design.	£3,302.00
			C	**1 camera 1 winch sensor.**	**Medium**	**1 camera to record setting, hauling and species processing. A high ping rate on the GPS. Hydraulic sensor**	**Considering the low number of data inputs, costs have been**	**£2,416.00**

						to determine when gear is in the water.	**minimised by using a lower specification control box.**	

5.11 Bottom otter trawl (OTB)

In the UK, there are **316** licensed OTB vessels (Appendix 2). In general, these are reasonably evenly distributed around the UK across the 10 IFCAs. Installing, coordinating, and managing REM on these vessels will need to be a nationwide approach.

Table 86 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 86 Bottom otter trawl (OTB) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bycatch	Below surface data	Biological Data collectio	Video Discard Review
<=10m	High	Yes	Yes	Yes	Yes	No	Yes	No	Yes
>10m	High	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes

5.11.1 Recommended REM technology design

Taking into consideration the very high level of risk assigned to the bottom otter trawl fishing vessels, (as identified through the objective 1 risk assessment; section 2.2.9), the high impact that these gears have on the benthos and the concerns for non-compliance with fisheries regulations; we believe the most effective REM design will be one that maximises data collection for both vessels <>10m. In addition to cameras, high frequency vessel reporting and gear sensors; this can be achievable through applying weight scales, in water gear technologies to enable benthic environment data collection.

The split matrix designs for Bottom otter trawl (OTB) vessels <>10m are shown in Table 87 and Table 88 below.

Table 87 Split Matrix – Bottom otter trawl (OTB) – Over 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Bottom Trawls	Bottom otter trawl (OTB)	>10m	**A**	**2 Cameras, 1 integrated weight-scale, 1 winch sensor, 1 in water camera 1 oceanographic sensor.**	**Low**	**1 camera to record trawl operations, including setting, hauling and 1 camera focused on species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water/on the bottom. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras and oceanographic sensors.**		**£5,670.00**
			B	2 cameras, 1 weight-scale, 1 winch sensor	Medium	1 camera to record trawl operations, including setting, hauling, and 1 to record species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.		£4,150.00

			C	1 camera, 1 winch sensor.	High	1 camera to record trawl operations, including setting, hauling. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water.		£3,164.00

Table 88 Split Matrix – Bottom otter trawl (OTB) – Under 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Bottom Trawls	Bottom otter trawl (OTB)	<10m	**A**	**2 Cameras, 1 integrated weight-scale, 1 winch sensor, 1 in water camera 1 oceanographic sensor.**	**Low**	**1 camera to record trawl operations, including setting, hauling and 1 camera focused on species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water/on the bottom. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras and oceanographic sensors.**		**£4,862.00**
			B	2 cameras, 1 weight-scale, 1 winch sensor	Medium	1 camera to record trawl operations, including setting, hauling, and 1 to record species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.		£3,302.00
			C	1 camera, 1 winch sensor.	High	1 camera to record trawl operations, including setting, hauling. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water.		£2,416.00

5.12 Multi-rig otter trawl (OTT)

In the UK, there are **12** licensed OTT vessels (Appendix 2). There are an insufficient number of vessels to develop a bespoke REM design, so these will be grouped with bottom otter trawls and treated in a similar fashion.

Table 89 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 89 Multi-rig otter trawl (OTT) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bycatch	Below surface data	Biological Data collection	Video Discard Review
<=10 m	High	Yes	Yes	Yes	Yes	No	Yes	No	Yes
>10 m	High	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes

5.12.1 Recommended REM technology design

Taking into consideration the very high level of risk assigned to the multi-rig otter trawl fishing vessels, (as identified through the objective 1 risk assessment; section 2.2.9), the high impact that these gears have on the benthos and the concerns for non-compliance with fisheries regulations; we believe the most effective REM design will be one that maximises data collection for both vessels <>10m. In addition to cameras, high frequency vessel reporting and gear sensors; this can be achievable through applying weight scales, in water gear technologies to enable benthic environment data collection.

The split matrix designs for Multi-rig otter trawl (OTT) vessels <>10m are shown in Table 90 and Table 91 below.

Table 90 Split Matrix – Multi-rig otter trawl (OTT) – Over 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Bottom Trawls	Multi-rig otter trawl (OTT)	>10m	**A**	**2 Cameras, 1 integrated weight-scale, 1 winch sensor, 1 in water camera 1 oceanographic sensor.**	**Low**	**1 camera to record trawl operations, including setting, hauling and 1 camera focused on species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water/on the bottom. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras and oceanographic sensors.**		**£5,670.00**
			B	2 cameras, 1 weight-scale, 1 winch sensor	Medium	1 camera to record trawl operations, including setting, hauling, and 1 to record species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear		£4,150.00

						is in the water. Additional catch data collected through the application of weight-scales.		
			C	1 camera, 1 winch sensor.	High	1 camera to record trawl operations, including setting, hauling. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water.		£3,164.00

Table 91 Split Matrix – Multi-rig otter trawl (OTT) – Under 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Bottom Trawls	Multi-rig otter trawl (OTT)	<10m	**A**	**2 Cameras, 1 integrated weight-scale, 1 winch sensor, 1 in water camera 1 oceanographic sensor.**	**Low**	**1 camera to record trawl operations, including setting, hauling and 1 camera focused on species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water/on the bottom. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras and oceanographic sensors.**		**£4,862.00**
			B	2 cameras, 1 weight-scale, 1 winch sensor	Medium	1 camera to record trawl operations, including setting, hauling, and 1 to record species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.		£3,216.00
			C	1 camera, 1 winch sensor.	High	1 camera to record trawl operations, including setting, hauling. A high ping rate on the GPS to reflect benthic		£2,416.00

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
					🟥	impact. Hydraulic sensor to determine when gear is in the water.		

5.13 Beam trawl (TBB) and Pair bottom trawl (PTB)

In the UK, there are **121** licensed TBB and 10 PTB vessels (Appendix 2). The vast majority of these are >10m in size, distributed around Eastern (31), Devon and Severn (26) and Cornwall (15). Given the are an insufficient number of pair-bottom trawls to develop a bespoke REM design, these are grouped with beam trawls and treated in a similar fashion.

Table 92 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 92 Beam trawl (TBB) and Pair bottom trawl (PTB) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bycatch	Below surface data	Biological Data collection	Video Discard Review
<=10 m	High	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
>10 m	High	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

5.13.1 Recommended REM technology design

Taking into consideration the very high level of risk assigned to the beam and pair bottom trawl fishing vessels, (as identified through the objective 1 risk assessment; section 2.2.10), the high impact that these gears have on the benthos and the concerns for bycatch and non-compliance with fisheries regulations; we believe the most effective REM design will be one that maximises data collection for both vessels <>10m. In addition to cameras, high frequency vessel reporting and gear sensors; this can be achievable through applying weight scales, in water gear technologies to enable benthic environment data collection.

The split matrix designs for Beam trawl (TBB) and Pair bottom trawl (PTB) vessels <>10m are shown in Table 93 and Table 94 below.

Table 93 Split Matrix – Beam trawl (TBB) and Pair bottom trawl (PTB) – Over 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Bottom Trawls	Beam trawl (OTT)	>10m	**A**	**2 Cameras, 1 integrated weight-scale, 1 winch sensor, 1 in water camera 1 oceanographic sensor.**	**Low**	**1 camera to record trawl operations, including setting, hauling and 1 camera focused on species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water/on the bottom. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras and oceanographic sensors.**		**£5,670.00**
			B	2 cameras, 1 weight-scale, 1 winch sensor	Medium	1 camera to record trawl operations, including setting, hauling, and 1 to record species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear		£4,150.00

					🟧	is in the water. Additional catch data collected through the application of weight-scales.		
			C	1 camera, 1 winch sensor.	High	1 camera to record trawl operations, including setting, hauling. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water.		£3,164.00

Table 94 Split Matrix – Beam trawl (TBB) and Pair bottom trawl (PTB) – Under 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Bottom Trawls	Beam trawl (OTT)	<10m	**A**	**2 Cameras, 1 integrated weight-scale, 1 winch sensor, 1 in water camera 1 oceanographic sensor.**	**Low**	**1 camera to record trawl operations, including setting, hauling and 1 camera focused on species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water/on the bottom. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras and oceanographic sensors.**		**£4,862.00**
			B	2 cameras, 1 weight-scale, 1 winch sensor	Medium	1 camera to record trawl operations, including setting, hauling, and 1 to record species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.		£3,216.00

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
			C	1 camera, 1 winch sensor.	High	1 camera to record trawl operations, including setting, hauling. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water.		£2,416.00

5.14 Nephrops trawl (TBN)

In the UK, there are **8** licensed TBN vessels distributed in Northumberland (5), North-Eastern (2), and Kent and Essex (1) (Appendix 2). These are distinctly too few to warrant developing a separate REM design, so have been treated in a similar fashion to OTB, however, due to the lighter impact of their gear are considered a much lower risk, and therefore justifies using a less expensive REM design.

Table 95 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 95 Nephrops trawl (TBN) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bvcatch	Below surface data	Biological Data collection	Video Discard Review
<=10 m	Medium	Yes	Yes	Yes	Yes	No	No	No	Yes
>10 m	Medium	Yes	Yes	Yes	Yes	No	No	Yes	Yes

5.14.1 Recommended REM technology design

Taking into consideration the medium level of risk assigned with the Nephrops trawls, (as identified through the objective 1 risk assessment; section 2.2.11), the moderate impact that these gears have on the benthos and the concerns that shellfish stocks are currently data poor; we believe the most effective REM design will be one that provides a cost-effective approach to data collection for both vessels <>10m. In addition to cameras, high frequency vessel reporting and gear sensors; this can be achievable through applying shellfish scanners to maximise biological data collection.

The split matrix designs for Nephrops trawl (TBN) vessels <>10m are shown in Table 96 and Table 97 below.

Table 96 Split Matrix – Nephrops trawl (TBN) – Over 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Bottom Trawls	Nephrops trawl (TBN)	>10m	A	2 Cameras, 1 shellfish scanner, 1 winch sensor, 1 in water camera 1 oceanographic sensor.	Low	1 camera to record trawl operations, including setting, hauling and 1 camera focused on species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water/on the bottom. Additional catch data collected through the application of a shellfish scanner. Additional environmental data collected through in water cameras and oceanographic sensors.		£6,870.00
			B	**2 cameras, 1 shellfish scanner, 1 winch sensor**	**Low**	**1 camera to record trawl operations, including setting, hauling, and 1 to record species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of a shellfish scanner.**		**£5,350.00**

			C	1 camera, 1 winch sensor.	Medium	1 camera to record trawl operations, including setting, hauling. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water.		£3,164.00

Table 97 Split Matrix – Nephrops trawl (TBN) – Under 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Bottom Trawls	Nephrops trawl (TBN)	<10m	A	2 Cameras, 1 shellfish scanner, 1 winch sensor, 1 in water camera 1 oceanographic sensor.	Low	1 camera to record trawl operations, including setting, hauling and 1 camera focused on species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water/on the bottom. Additional catch data collected through the application of a shellfish scanner. Additional environmental data collected through in water cameras and oceanographic sensors.		£6,062.00
			B	**2 cameras, 1 shellfish scanner, 1 winch sensor**	**Low**	**1 camera to record trawl operations, including setting, hauling, and 1 to record species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of a shellfish scanner.**		**£4,502.00**

			C	1 camera, 1 winch sensor.	Medium	1 camera to record trawl operations, including setting, hauling. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water.		£2,416.00

5.15 Midwater otter trawl (OTM) and midwater pair trawl (PTM)

In the UK, there are **7** licensed OTM and **3** PTM vessels, distributed in Cornwall (1 & 2), Devon and Severn (2 & 1), North-Eastern (2), North-Western, and Southern with one each (Appendix 2). These are distinctly too few to warrant developing a separate REM design, so have been treated in a similar fashion to OTB, however, due to the pelagic and not benthic impact of their gear, these are considered a much lower risk, and therefore justifies using a less expensive REM design.

Table 98 provides an overview of the data collection and monitoring requirements identified through the stakeholder engagement for these vessels.

Table 98 Midwater otter trawl (OTB) and midwater pair trawl (PTM) monitoring requirements

Vessel Size	Risk Level	Monitoring Requirements							
		Position Review	Fishing Effort Review	Video verification	Catch Verification	Protected species bycatch	Below surface data	Biological Data collectio	Video Discard Review
<=10m	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes
>10m	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes

5.15.1 Recommended REM technology design

Taking into consideration the medium level of risk assigned to the midwater otter trawl fishing vessels, (as identified through the objective 1 risk assessment; section 2.2.12), the limited number of vessels, but focusing on the high impact that these gears can have PET bycatch and the concerns for non-compliance with fisheries regulations; we believe the most effective REM design will be one that takes a minimal data collection approach for both vessels <>10m. We propose a design that only uses cameras and winch sensors to determine fishing effort and validate catch on hauling.

The split matrix designs for Midwater otter trawl (OTB) and midwater pair trawl (PTM) vessels <>10m are shown in Table 99 and Table 100 below.

Table 99 Split Matrix – Midwater otter trawl (OTM) – Over 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Pelagic Trawls	Midwater otter trawl (OTM)	>10m	A	2 Cameras, 1 integrated weight-scale, 1 winch sensor, 1 in water camera 1 oceanographic sensor.	Low	1 camera to record trawl operations, including setting, hauling and 1 camera focused on species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water/on the bottom. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras and oceanographic sensors.		£5,670.00
			B	2 cameras, 1 weight-scale, 1 winch sensor	Low	1 camera to record trawl operations, including setting, hauling, and 1 to record species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.		£4,150.00
			C	**1 camera, 1 winch sensor.**	**Low**	**1 camera to record trawl operations, including setting, hauling. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water.**		**£3,164.00**

Table 100 Split Matrix – Midwater otter trawl (OTM) – Under 10m

Fishing Vessel Métier		Vessel size	Design	Monitoring Objectives			Cost implications	Cost per vessel per year (Given as £)
Level 3	Level 4			REM Technologies	Impact of REM	Justification		
Pelagic Trawls	Midwater otter trawl (OTM)	<10m	A	2 Cameras, 1 integrated weight-scale, 1 winch sensor, 1 in water camera 1 oceanographic sensor.	Low	1 camera to record trawl operations, including setting, hauling and 1 camera focused on species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water/on the bottom. Additional catch data collected through the application of weight-scales. Additional environmental data collected through in water cameras and oceanographic sensors.		£4,862.00
			B	2 cameras, 1 weight-scale, 1 winch sensor	Low	1 camera to record trawl operations, including setting, hauling, and 1 to record species processing. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water. Additional catch data collected through the application of weight-scales.		£3,216.00
			C	**1 camera, 1 winch sensor.**	**Low**	**1 camera to record trawl operations, including setting, hauling. A high ping rate on the GPS to reflect benthic impact. Hydraulic sensor to determine when gear is in the water.**		**£2,416.00**

6. Modular Framework

6.1 Determining the level of monitoring and REM analysis for each métier

Each métier in the sample frame was evaluated in the context of the identified risk under Objective 1, the specific impacts of that gear type as identified in the literature, the monitoring requirements set by the stakeholders and the global literature detailing the proportion of REM data that needs to be reviewed in order to satisfy the monitoring requirement and provide a statistically robust sample to extrapolate fleetwide impacts.

For context, monitoring rates for fisheries implementing REM vary widely, based on the overall management objectives. Capture of video footage, as the bulk component of REM data analysis, can be used to census all fishing effort, or be used to capture a sample, which can then be extrapolated to determine fleetwide impacts of fishing. This footage, or a proportion of it, can then be audited to verify practices, records, and logbook entries. An audit model for monitoring fishing effort has most applied in Canada, the USA and Australia where mature mandatory REM programmes are in place. The census approach, which monitors 100% of fishing effort, is generally applied to programmes where the focus is on monitoring marine mammal or seabird interactions with fishing.

Assuming that an audit approach is preferable, as this is generally more cost-efficient than a census approach, we have outlined the minimum analysis requirements against the series of core monitoring objectives synthesised from the stakeholder engagement. This has been represented in Table 101. This information has been synthesised from the following literature (Babcock and Pikitch 2003; Mangi *et al*., 2015; Wolfaardt 2016; Debski, Pierre and Knowles 2016) and stakeholder responses.

Table 101 Monitoring objectives mapped against the minimum REM data analysis requirements to provide a statistically robust sample to extrapolate fleetwide impacts

Monitoring objective and minimum analysis requirement to be statistically robust						
Position review and fishing effort monitoring (independent of fishing in protected areas)	**Fishing impact target species (common species, stock and quota monitoring)**	**Fishing impact bycatch non-target species (common species, stock and quota monitoring)**	**Fishing impact bycatch non-target species (uncommon species (<35% of catch), stock and quota monitoring)**	**Fishing impact (rare species (0.1% of catch), stock and quota monitoring, and interactions with protected species)**	**Determining discarding and other fishing malpractices**	**Validating fishing logbooks**
5%	5%	10%	20%	50%	20%	10%

To map this against the stakeholder responses, the question of what level of analysis would you expect applies to each of the below risk categories – based on this, it is very clearly apparent that as the level of risk increases, the expected proportion of monitoring also increases, as shown in the stakeholder responses and the synthesis in Table 102 below.

Table 102 Stakeholder responses mapping the percentage of monitoring and analysis against the identified level of risk

% Of data analysis required.	Very Low Risk	Low Risk	Medium Risk	High Risk	Very High Risk
Recommended	5%	10%	20%	50%	100%
Range	0-20%	5-20%	20-100%	50-100%	50-100%

Of course, logistically, and cost-effectively, achieving over 50% analysis for all but the highest risk métiers isn't feasible and wouldn't be recommended unless such an approach can be justified, and may be more applicable to specific vessels, regions, or seasons where the local risks are significantly higher. In practice, coverage should be representative, considering factors including seasonal or inter-vessel differences, timing of sets and location/area of fishing. The study by Emery et al., (2019) reported on the Australian Fisheries Management Authority (AFMA) integrated REM system used to validate fisher-reported logbook data with a set 10% target for all hauls; however, in addition, implemented a census approach to all gillnet sets in the Australian Sea Lion Management Zones.

As a standard, Wolfaardt (2015), and Debski, Pierre and Knowles (2016) have shown that, in the context of statistically modelling bycatch monitoring, there is a point of diminishing returns for increasing percentage coverage, therefore little stands to be gained for the increasing costs of monitoring. Arguably, the same applies to monitoring fishing activities against different management objectives. Therefore, when analysing the stakeholder responses, and considering the synthesised monitoring requirements inferred; displayed in Table 103, we were able to map out an appropriate amount of coverage for each fishing métier.

One particularly difficult task was to determine the appropriate level of coverage across several different requirements, and how to reflect this in terms of time. A single analyst can analyse footage against multiple objectives simultaneously, depending on the vessel type, fishing method and structural design. For instance, on a gillnet, longliner and pots and traps vessel, it is possible to monitor for catch, specific bycatch and discard at the point of hauling, as one camera trained on the hauling area will capture all these simultaneously. Likewise, it is possible to monitor for both the use of bycatch mitigation at the point of setting and hauling, while validating reported fishing activity i.e., a camera trained at the derricks of a trawl or dredge can verify when these are in use against bycatch mitigation objectives; for instance, night setting or application of streamer lines.

However, with some tasks, such as species identification and catch quantification on a trawler, separate cameras would need to be used to record the fish processing area, fishing moving on a conveyor, and catch composition below deck. Therefore, in this scenario a single camera and video feed is not sufficient for enforcement purposes as a second camera would be required to cover on-deck activity. Taking this into consideration, we can reduce the monitoring and analysis requirement across the fleet to reflect some degree of overlap in monitoring tasks and balance this against the minimum monitoring that should be achieved, and the realistic monitoring analysis possible.

Table 103 Monitoring requirements by fishing métier

Métier					Monitoring Requirements							
Level 3	Level 4	Vessel Size	Total Number of English vessels	Risk Level as determined through the Objective 1 risk assessment	Position Review	Fishing Effort Review	Video verification required	Video Catch Review	Protected species bycatch reporting	Below surface data collection	Biological Data collection	Video Discard Review
Dredge	Boat dredge (DRB)	<10m	53	Medium	Yes	Yes	Yes	Yes	No	Yes	No	No
		>10m	59	Medium	Yes	Yes	Yes	Yes	No	Yes	Yes	No

Métier		**Vessel Size**	**Total Number of English vessels**	**Risk Level as determined through the Objective 1 risk assessment**	**Monitoring Requirements**							
Level 3	**Level 4**				Position Review	Fishing Effort Review	Video verification required	Video Catch Review	Protected species bycatch reporting	Below surface data collection	Biological Data collection	Video Discard Review
Trap	Pots and traps (FPO)	<10m	664	Low	Yes	Yes	Yes	No	No	No	No	No
		>10m	112	Low	Yes	Yes	Yes	No	No	No	Yes	No
Nets	Gillnets (GN)	<10m	277	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes
		>10m	11	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes
	Drift net (GND)	<10m	54	Low	Yes	Yes	Yes	Yes	Yes	No	No	Yes
		>10m	3	Low	Yes	Yes	Yes	Yes	Yes	No	No	Yes
	Set gillnet (GNS)	<10m	78	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes
		>10m	11	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes
	Trammel net (GTR)	<10m	39	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes
		>10m	2	Medium	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Rods and Lines	Hand and pole lines (LHP)	<10m	235	Low	Yes	Yes	Yes	No	No	No	No	No
		>10m	3	Low	Yes	Yes	Yes	No	No	No	No	No
	Hooks and lines (LX)	<10m	70	Low	Yes	Yes	Yes	No	No	No	No	No
		>10m	0	Low	Yes	Yes	Yes	No	No	No	No	No
Longlines	Longlines (LL)	<10m	36	Low	Yes	Yes	Yes	No	No	No	No	No
		>10m	3	Low	Yes	Yes	Yes	No	No	No	No	No
	Set longlines (LLS)	<10m	5	Low	Yes	Yes	Yes	No	No	No	No	No
		>10m	6	Low	Yes	Yes	Yes	No	No	No	No	No
Trawl	Bottom otter trawl (OTB)	<10m	231	High	Yes	Yes	Yes	Yes	No	Yes	No	Yes
		>10m	85	High	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes

Métier					Monitoring Requirements							
Level 3	Level 4	Vessel Size	Total Number of English vessels	Risk Level as determined through the Objective 1 risk assessment	Position Review	Fishing Effort Review	Video verification	Video Catch Review	Protected species bycatch reporting	Below surface data	Biological Data	Video Discard
	Multi-rig otter trawl (OTT)	<10m	3	High	Yes	Yes	Yes	Yes	No	Yes	No	Yes
		>10m	9	High	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
	Beam trawl (TBB)	<10m	39	High	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
		>10m	82	High	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Nephrops trawl (TBN)	<10m	4	Medium	Yes	Yes	Yes	Yes	No	Yes	No	Yes
		>10m	4	Medium	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Pelagic trawl	Midwater otter trawl (OTM)	<10m	5	Medium	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
		>10m	2	Medium	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

The study by Pennington and Helle (2011), concluded that REM should not replace human observation. Instead, REM should enhance human observation, assimilating more of the repetitive tasks allowing human observers to focus on priority duties. Human observers and EM should be complementary in application, their combined efforts can provide higher quality and more robust monitoring information than either approach alone. Pennington and Helle (2011) noted that human observation gave a closer match to actual catch figures than REM, especially for species of special concern. Greater discrepancies and over-estimates existed in the REM dataset which still needed independent onboard verification.

We would recommend a holistic approach, utilising at sea observers; able to perform tasks cameras are unable to fulfil. Specifically, observers are effective at providing independent biological samples (catch length-weights, tissue samples, sexing, tag identification), while also adding a representative approach to monitoring for events not picked up by sensors or cameras through their presence onboard. In line with this thinking, we have included a monitoring approach, based on what we think is practically achievable for physically monitoring vessels against the level of risk. This information, together with the REM monitoring percentage, has been reflected as a percentage and a calculation of time based on that percentage to determine the proportional amount of monitoring time in hours for each. Physical and electronic monitoring time, and resources have been outlined in Table 104 below. From these calculations, we were able to produce a cost based on the time required to implement across these two monitoring methods; this has been shown in section 6.3.4.2.

The below calculation of monitoring hours required through REM has been based on the percentage of monitoring time required against fishing effort across the fleet (annual fishing hours multiplied by the number of vessels). This value was divided by the predicted analysis efficiency of a REM analyst, using analytical tools to speed up the review. Based on our experience, a trained analyst can, at a minimum, achieve a 1:4 efficiency on monitoring time. As such, the values generated were divided by four.

This value equalled the total review time required by REM analysts across the fleet and on a per vessel basis. This was multiplied by an hourly wage for staff to generate a total review cost. See Figure 34 giving an illustration of the calculation used in determining REM analyst time and costs.

$$\frac{\left(\dfrac{\text{Annual fishing hours * number of vessels}}{\text{Monitoring requirement (\%)}}\right)}{\text{1 : 4 analysis time vs fishing duration}} = \begin{matrix}\text{Total monitoring}\\ \text{manhours * hourly wage}\end{matrix} = \text{Review Cost}$$

Figure 34 calculation of REM analyst review hours and costs

The below calculation of monitoring hours required through observer deployment has been based on the percentage of monitoring time required, and that value divided by an average 12-hour day for national observer deployments. Of course, this is an average, so should account for deployments >12 hours in length, where larger vessels operating offshore will likely remain actively fishing for several days at a time. We are only providing a value of at sea monitoring time in the form of 12-hour trips. This value doesn't account for travel time included with getting to and from the port, it is assumed that the observers travel would be included with the day that they work. As with the REM monitoring costs, the observer costs have been shown in section 6.3.4.2, these do not account for expenses covering food, or travel.

See Figure 35 giving an illustration of the calculation used in determining observer time and costs.

$$\left(\frac{\text{Annual fishing hours * number of vessels}}{\text{Observer requirement (\%)}}\right) = \begin{matrix}\text{Total observation}\\ \text{manhours * hourly wage}\end{matrix} = \text{Observation Cost}$$

Figure 35 calculation of observer time and costs

The number of observers required has been calculated based on an assumed 180 days/trips annually, therefore, the trip value was divided by 180 for each métier. This figure for the number of observers has been given as a decimal, as it is a mathematical calculation. One would round the observer requirement to the next whole number to determine your minimum pool size, however, on a national scale, this may not be necessary, as the pool would be large enough to allow for coverage across several fleets and métiers. This calculation provides a total pool size of 82 observers but doesn't account for a normal contingency requirement expected with managing and maintaining a healthy pool of observers. The contingency provided adds capacity allowing for unexpected observer dropouts, periods of unavailability, observer welfare concerns and helps maintain the pool size while new observers are being sourced and trained. A healthy pool can have anywhere between 10%-20% additional capacity to the minimum requirement. This would increase the pool size to 91-99 observers. Less may be needed to manage the programmes nationally, given local variation in fleets and fishing activity.

In addition to determining the monitoring analysis hours required in running a REM programme, consideration needs to be given to the management, coordination, and reporting by analysts and staff which contribute to the overall cost of implementation, but also on the resources required to successfully implement the programme overall. The calculations of management, coordination and reporting hours shown in Table 105, were based on a percentage of total fishing time, and generally reflected as either 2%, 5% or 10% of the fishing time, depending on the monitoring requirements and level of risk by a particular métier. The costs for these have been given in section 6.3.4.2.

Verifying fisher logbook data was not a core focus on the REM designs, nor the information collected through the stakeholder engagement, as established mechanisms for this are already in place with port side sampling schemes. However, if this were included as a requirement, we would recommend increasing the monitoring percentage by 10%. In the instance where an audit approach has been applied, 100% of all fishing effort is captured, and a review of 10% of the footage collected is generally considered adequate to pass an audit for verifying fisher reported data (Mangi, *et al*., 2015).

Table 104 Minimum observation requirements, based on the level of risk, stakeholder inputs and impacts of different gears. Calculations are based on total fleet fishing time, providing a proportion of this for analysis of REM data or deployment of observers, and the calculated hours and resources required to implement nationally. Based on assumptions and conditions shown below the table

Métier		Vessel Size	Total Number of English vessels	Minimum % of REM review required[145]	Manhours required to review vessel *	Manhours required to review across the fleet*	Number of analysts required **	Observer Coverage Possible	Observer Coverage Hours per vessel	Observer Coverage Hours per fleet	Number of observer trips required. ***	Number of observers required. ****
Level 3	Level 4											
Dredge	Boat dredge (DRB)	<10m	53	20%	49	2,597	1.43	10%	98	5,194	433	2.40
		>10m	59	20%	79	4,632	2.54	10%	157	9,263	772	4.29
Trap	Pots and traps (FPO)	<10m	664	5%	9	6,225	3.42	5%	38	24,900	2,075	11.53
		>10m	112	5%	15	1,680	0.92	5%	60	6,720	560	3.11
Nets	Gillnets (GN)	<10m	277	20%	27	7,479	4.11	20%	108	29,916	2,493	13.85
		>10m	11	20%	44	479	0.26	20%	174	1,914	160	0.89
		<10m	54	10%	14	729	0.40	5%	27	1,458	122	0.68

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[145] % Of REM reviewed is given as a minimum value based on what is achievable and considered practical. Specific instances of higher review can be warranted when such a situation arises requiring a higher level of coverage. For instance, temporal behaviors of fishing fleets and protected species in particular regions may lead to a higher risk of encounters. In such a circumstance, these fleets would benefit from a seasonal higher level of review beyond the national minimum.

Métier		Vessel Size	Total Number of English vessels	Minimum % of REM review required[145]	Manhours required to review vessel *	Manhours required to review across the fleet*	Number of analysts required **	Observer Coverage Possible	Observer Coverage Hours per vessel	Observer Coverage Hours per fleet	Number of observer trips required. ***	Number of observers required. ****
Level 3	Level 4											
	Drift net (GND)	>10m	3	10%	22	65	0.04	0%	-	-	-	-
	Set gillnet (GNS)	<10m	78	20%	27	2,106	1.16	5%	27	2,106	176	0.98
		>10m	11	20%	44	479	0.26	5%	44	479	40	0.22
	Trammel net (GTR)	<10m	39	10%	14	527	0.29	5%	27	1,053	88	0.49
		>10m	2	10%	22	44	0.02	0%	-	-	-	-
Rods and Lines	Hand and pole lines (LHP)	<10m	235	5%	5	1,263	0.69	10%	43	10,105	842	4.68
		>10m	3	5%	9	26	0.01	5%	35	104	9	0.05
	Hooks and lines (LX)	<10m	70	5%	5	376	0.21	5%	22	1,505	125	0.70
		>10m	0	5%	9	-	-	0%	-	-	-	-
Longlines	Longlines (LL)	<10m	36	5%	5	194	0.11	5%	22	774	65	0.36
		>10m	3	5%	9	26	0.01	0%	-	-	-	-
	Set longlines (LLS)	<10m	5	5%	5	27	0.01	0%	-	-	-	-
		>10m	6	5%	9	52	0.03	0%	-	-	-	-
Trawl		<10m	231	50%	84	19,346	10.63	20%	134	30,954	2,580	14.33

Métier		**Vessel Size**	**Total Number of English vessels**	**Minimum % of REM review required[145]**	**Manhours required to review vessel ***	**Manhours required to review across the fleet***	**Number of analysts required ****	**Observer Coverage Possible**	**Observer Coverage Hours per vessel**	**Observer Coverage Hours per fleet**	**Number of observer trips required. *****	**Number of observers required. ******
Level 3	**Level 4**											
	Bottom otter trawl (OTB)	>10m	85	50%	134	11,369	6.25	20%	214	18,190	1,516	8.42
	Multi-rig otter trawl (OTT)	<10m	3	20%	34	101	0.06	0%	-	-	-	-
		>10m	9	20%	54	482	0.26	0%	-	-	-	-
	Beam trawl (TBB)	<10m	39	50%	118	4,583	2.52	20%	188	7,332	611	3.39
		>10m	82	50%	188	15,375	8.45	20%	300	24,600	2,050	11.39
	Nephrops trawl (TBN)	<10m	4	10%	24	94	0.05	0%	-	-	-	-
		>10m	4	10%	38	150	0.08	0%	-	-	-	-
Pelagic trawl	Midwater otter trawl (OTM)	<10m	5	10%	17	84	0.05	0%	-	-	-	-
		>10m	2	10%	27	54	0.03	0%	-	-	-	-
Total			**2185**		**1,133**	**80,639**	**44.31**		**1,716**	**176,566**	**14,714**	**81.74**

* Assuming an analyst efficiency of 1:4 on review time: total fishing time.

** Assuming a 35-hour working week / 1820 hour working year.

*** Assuming 12-hour long day trips as an average.

**** Assuming 180 sea days per year, per observer.

Table 105 Management, coordination and reporting time requirements, monitoring requirements across the métiers. Calculations based on total fleet fishing time, providing a proportion of this for analysis of REM data or deployment of observers, and the calculated hours and resources required to implement nationally. Based on assumptions and conditions shown below the table

Métier		Vessel Size	Total Number of English vessels	Manhours required to review across the fleet*	Observer Coverage Hours per fleet	Management time, % of total.	Coordination, % of total time.	Reporting time, % of total.	Manhours required to Manage a programme **	Manhours required to Coordinate a programme **	Manhours required to Report a programme **
Level 3	Level 4										
Dredge	Boat dredge (DRB)	<10m	53	2,597	5,194	5%	5%	5%	390	390	390
		>10m	59	4,632	9,263	5%	5%	5%	695	695	695
Trap	Pots and traps (FPO)	<10m	664	6,225	24,900	5%	5%	2%	1,556	1,556	623
		>10m	112	1,680	6,720	5%	5%	2%	420	420	168
Nets	Gillnets (GN)	<10m	277	7,479	29,916	5%	10%	5%	1,870	3,740	1,870
		>10m	11	479	1,914	5%	10%	5%	120	239	120
	Drift net (GND)	<10m	54	729	1,458	5%	10%	5%	109	219	109
		>10m	3	65	-	5%	5%	5%	3	3	3
	Set gillnet (GNS)	<10m	78	2,106	2,106	5%	10%	5%	211	421	211
		>10m	11	479	479	5%	10%	5%	48	96	48
	Trammel net (GTR)	<10m	39	527	1,053	5%	10%	5%	79	158	79
		>10m	2	44	-	5%	5%	5%	2	2	2

Métier		Vessel Size	Total Number of English vessels	Manhours required to review across the fleet*	Observer Coverage Hours per fleet	Management time, % of total.	Coordination, % of total time.	Reporting time, % of total.	Manhours required to Manage a programme **	Manhours required to Coordinate a programme **	Manhours required to Report a programme **
Level 3	Level 4										
Rods and Lines	Hand and pole lines (LHP)	<10m	235	1,263	10,105	5%	5%	5%	568	568	568
		>10m	3	26	104	5%	5%	2%	6	6	3
	Hooks and lines (LX)	<10m	70	376	1,505	5%	5%	2%	94	94	38
		>10m	0	-	-	0%	0%	0%	-	-	-
Longlines	Longlines (LL)	<10m	36	194	774	5%	5%	5%	48	48	48
		>10m	3	26	-	5%	5%	2%	1	1	1
	Set longlines (LLS)	<10m	5	27	-	5%	5%	2%	1	1	1
		>10m	6	52	-	5%	5%	2%	3	3	1
Trawl	Bottom otter trawl (OTB)	<10m	231	19,346	30,954	5%	10%	10%	2,515	5,030	5,030
		>10m	85	11,369	18,190	5%	10%	10%	1,478	2,956	2,956
	Multi-rig otter trawl (OTT)	<10m	3	101	-	5%	5%	2%	5	5	2
		>10m	9	482	-	5%	5%	2%	24	24	10
		<10m	39	4,583	7,332	5%	10%	10%	596	1,191	1,191

Métier		Vessel Size	Total Number of English vessels	Manhours required to review across the fleet*	Observer Coverage Hours per fleet	Management time, % of total.	Coordination, % of total time.	Reporting time, % of total.	Manhours required to Manage a programme **	Manhours required to Coordinate a programme **	Manhours required to Report a programme **
Level 3	Level 4										
	Beam trawl (TBB)	>10m	82	15,375	24,600	5%	10%	10%	1,999	3,998	3,998
	Nephrops trawl (TBN)	<10m	4	94	-	5%	5%	2%	5	5	2
		>10m	4	150	-	5%	5%	2%	8	8	3
Pelagic trawl	Midwater otter trawl (OTM)	<10m	5	84	-	5%	5%	2%	4	4	2
		>10m	2	54	-	5%	5%	2%	3	3	1
Total			**2185**	**80,639**	**176,566**				**12,860**	**21,884**	**18,170**

* Assuming an analyst efficiency of 1:4 on review time: total fishing time.

** Assuming a 35-hour working week / 1820 hour working year.

6.2 Modular Framework

Table 106 below provides an excerpt of the Modular Framework – detailing the first 50 groups of vessels we would recommend are prioritised for the roll out of REM. These have been structured in a descending order, marking the highest priority vessels determined through a combination of the identified risk as determined through the Objective 1 risk assessment (section 2.2), the level of monitoring required, the monitoring impact achievable by the recommended REM design, the number of vessels within this cohort and the overall cost to roll out. A more detailed breakdown of how this has been achieved is given below.

Determining the top 50 groups to begin the roll out of REM has been structured around a number of contributing factors. Primarily, the risk assessment framework conducted in the delivery of Objective 1 has highlighted métiers which are of the most significant concern (section 2.2). Taking into consideration the feedback provided by the stakeholders, the monitoring requirement was allocated a score of low (10), medium (20) or high (30) for each métier determined by the level of risk, the concerns from stakeholders of the impact of those métiers and the data collection requirements to mitigate those risks. In combination, these two scores were ordered by the number of vessels registered to each IFCA region. The justification behind this approach is two-fold. Firstly, the greater number of vessels within each region carries the potential for a more significant impact to the inshore fishing zone and secondly, targeting these groups initially provides REM the opportunity to have the greatest impact to fisheries management - creating a priority list for the implementation of the programme. This has been colour coded using the RAG status, to maintain consistency with the risk assessment in Objective 1 (Section 2.2).

Each group within this list was counter-scored and cost checked against the achievable impact of REM, based on the recommended design which filled the most monitoring objectives, or did so in the most cost-effective manner. This layer provided an additional level of weighting to the priority list, providing a calculated score which was used to determine the final and recommended order of implementation.

As a rule, the under and over 10m fleet were ranked fairly consistently by risk, impact and REM requirements. It can be warranted that vessels greater than 10m are more likely to have a higher individual impact. However, when considering the impact on the inshore environment, this has to be offset against the far more numerous under 10m fleet, which collectively may have a higher impact overall. In addition, size restrictions within 6nm, and the ability to venture offshore displaces some of the over 10m fleet fishing effort away from the inshore coastal zone, leading to the assumption that the under 10m fleet will have a proportionally have a greater concentration of fishing effort within the inshore zone. Given the focus of this study is primarily on the impact of fishing within the inshore, greater weighting has been given to the number of vessels in the matrix by region. As such, an additional layer has been added to the framework prioritising vessels within the IFCA regions which firstly form a group of larger than 10, and then 5 and below.

REM designs for EU and devolved nation vessels have been intentionally omitted from the Modular Framework, focusing solely on the cost to deliver REM on English vessels. The characteristics of EU and devolved nation vessels are the same as those of the English fleet, so the proposed designs in the Modular Framework can be transferable to all vessels fishing in English waters and set as a minimum standard to fulfil the data collection requirements under licencing conditions to permit fishing within English waters.

The cost and data collection requirements (as stipulated by the stakeholders) of REM on the under 10m fleet is significantly lower than the over 10m fleet. Therefore, the same investment will go further in terms of representative sampling across the under 10m vessels. Where we have scored both <>10m vessels equally for risk, monitoring requirement and impact (in most cases) the artificial weighting on vessel numbers results in a preference for the under 10m vessels in most groups.

An alternative model – Regionalised implementation

One consideration not given within the Matrix is the regional distribution of vessels. When considering how best to roll out REM nationally, a more regionalised approach could be beneficial, one for the purposes of targeting specific fleets, and to aid logistics in the supply and installation of hardware on vessels. Going by vessel numbers alone, Cornwall, Devon and Severn would be a recommended starting point supporting 501 and 376 registered vessels respectively, within our fleet of 2185. In addition, considering their proximity, Cornwall, and Devon and Severn would be ideal candidates to start with, followed by: Sussex and Southern; and, North-Eastern and Eastern. Each of these have between 205-235 vessels, and again their proximity loans itself toward simpler logistics. Layering the risk level of each of the métiers over this vessel count produces a slightly different outlook. Grouping the métiers by the level of risk (High, Medium, and Low) placed Devon and Severn highest at 47 high risk vessels, followed by Kent and Essex, Northumberland and North-Western with 43, 42 and 41 vessels respectively. However, medium risk vessels were far more numerous in Cornwall and Devon and Severn than any of the other counties, with a clearance of 90-100 to the next step down at 250 and 240 each; broadly speaking the same pattern is followed for the low risk métiers.

Applying this structure gave the same outlook of Cornwall, Devon, and Severn first; followed by: Sussex and Southern; then, North-Eastern and Eastern. Adding a weighting (High = 10, Medium = 5 and Low = 1) to the risk didn't change the overall structure, where high risk vessels are relatively evenly distributed nationally, the number of medium risk vessels located within these counties maintained the structure. Therefore, taking a more simplified and regionalised approach to the modular framework, is an alternative method of implementation which we would recommend. See Table 107 for details.

Table 106 Excerpt – Modular Framework – Top 50

Order of implementation	Fishing Vessel Métier			Vessel Size (<10m or >10m)	Recommended REM System Design[146]	Assessment Criteria for the role out of the Modular Framework				Financial Cost to implement REM per vessel per year (£)		Financial Cost to implement REM per fleet per year (£' 000s)	Scoring	
	Level 3	Level 4	Region			Number of Vessels in the métier	Residual Risk Analysis Score	Level of monitoring required and cost implications[147]	Achievable impact of REM Design	Purchase, installation and annual running costs.	Analysis costs, Observation costs, Management costs.		Additional justification (if required)	Overall Score
1	Bottom Trawls	TBB	Eastern	>10m	A	31	30	30	30	£5,670.00	£7,843.75	£418.926		90
2	Bottom Trawls	TBB	Devon and Severn	>10m	A	26	30	30	30	£5,670.00	£7,843.75	£351.358		90
3	Bottom Trawls	TBB	Cornwall	>10m	A	15	30	30	30	£5,670.00	£7,843.75	£202.706		90
4	Bottom Trawls	TBB	North-Western	<10m	A	14	30	30	30	£4,862.00	£4,915.42	£136.884		90
5	Bottom Trawls	OTB	Kent and Essex	<10m	A	38	29	30	30	£4,862.00	£3,503.54	£317.891		89
6	Bottom Trawls	OTB	Sussex	<10m	A	34	29	30	30	£4,862.00	£3,503.54	£284.428		89
7	Bottom Trawls	OTB	Southern	<10m	A	28	29	30	30	£4,862.00	£3,503.54	£234.235		89
8	Bottom Trawls	OTB	North-Western	<10m	A	27	29	30	30	£4,862.00	£3,503.54	£225.870		89
9	Bottom Trawls	OTB	Northumberland	>10m	A	18	29	30	30	£5,670.00	£5,595.21	£202.774		89
10	Bottom Trawls	OTB	Cornwall	<10m	A	24	29	30	30	£4,862.00	£3,503.54	£200.773		89
11	Bottom Trawls	OTB	Devon and Severn	<10m	A	23	29	30	30	£4,862.00	£3,503.54	£192.407		89

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[146] A - Maximum data collection; B - Cost-efficient data collection; C - Minimum data collection

[147] (Hours review per vessel). <20 – Low; 20-40 – Medium; >40 - High

Order of implementation	Fishing Vessel Métier			Vessel Size (<10m or >10m)	Recommended REM System Design [146]	Assessment Criteria for the role out of the Modular Framework				Financial Cost to implement REM per vessel per year (£)		Financial Cost to implement REM per fleet per year (£' 000s)	Scoring	
	Level 3	Level 4	Region			Number of Vessels in the métier	Residual Risk Analysis Score	Level of monitoring required and cost implications [147]	Achievable impact of REM Design	Purchase, installation and annual running costs.	Analysis costs, Observation costs, Management costs.		Additional justification (if required)	Overall Score
12	Bottom Trawls	OTB	Devon and Severn	>10m	A	17	29	30	30	£5,670.00	£5,595.21	£191.509		89
13	Bottom Trawls	OTB	Northumberland	<10m	A	22	29	30	30	£4,862.00	£3,503.54	£184.042		89
14	Bottom Trawls	OTB	Eastern	<10m	A	19	29	30	30	£4,862.00	£3,503.54	£158.945		89
15	Bottom Trawls	OTB	Cornwall	>10m	A	13	29	30	30	£5,670.00	£5,595.21	£146.448		89
16	Bottom Trawls	OTB	North-Western	>10m	A	13	29	30	30	£5,670.00	£5,595.21	£146.448		89
17	Bottom Trawls	OTB	North -Eastern	<10m	A	13	29	30	30	£4,862.00	£3,503.54	£108.752		89
18	Dredge	DRB	Devon and Severn	>10m	A	25	27	30	30	£7,042.00	£3,282.91	£258.123		87
19	Dredge	DRB	Southern	<10m	A	25	27	30	30	£6,062.00	£2,049.21	£202.780		87
20	Dredge	DRB	Kent and Essex	>10m	A	14	27	30	30	£7,042.00	£3,282.91	£144.549		87
21	Dredge	DRB	Devon and Severn	<10m	A	11	27	30	30	£6,062.00	£2,049.21	£89.223		87
22	Nets	GN	Cornwall	<10m	C	75	20	20	30	£2,526.00	£1,932.23	£334.367		70
23	Nets	GN	Sussex	<10m	C	48	20	20	30	£2,526.00	£1,932.23	£213.995		70
24	Nets	GN	Devon and Severn	<10m	C	37	20	20	30	£2,526.00	£1,932.23	£164.955		70
25	Nets	GN	Southern	<10m	C	33	20	20	30	£2,526.00	£1,932.23	£147.122		70
26	Nets	GN	North-Eastern	<10m	C	30	20	20	30	£2,526.00	£1,932.23	£133.747		70
27	Nets	GN	Kent and Essex	<10m	C	27	20	20	30	£2,526.00	£1,932.23	£120.372		70
28	Nets	GNS	Kent and Essex	<10m	C	18	20	20	30	£2,526.00	£844.44	£60.668		70
29	Nets	GNS	Devon and Severn	<10m	C	17	20	20	30	£2,526.00	£844.44	£57.298		70

Order of implementation	Fishing Vessel Métier			Vessel Size (<10m or >10m)	Recommended REM System Design [146]	Assessment Criteria for the role out of the Modular Framework				Financial Cost to implement REM per vessel per year (£)		Financial Cost to implement REM per fleet per year (£' 000s)	Scoring	
	Level 3	Level 4	Region			Number of Vessels in the métier	Residual Risk Analysis Score	Level of monitoring required and cost implications [147]	Achievable impact of REM Design	Purchase, installation and annual running costs.	Analysis costs, Observation costs, Management costs.		Additional justification (if required)	Overall Score
30	Nets	GN	Northumberland	<10m	C	12	20	20	30	£2,526.00	£1,932.23	£53.499		70
31	Nets	GNS	Cornwall	<10m	C	11	20	20	30	£2,526.00	£844.44	£37.075		70
32	Nets	GTR	Sussex	<10m	C	21	19	10	30	£2,526.00	£603.52	£65.720		59
33	Nets	GND	Kent and Essex	<10m	C	21	17	10	30	£2,526.00	£603.52	£65.720		57
34	Poles and Lines	LHP	Cornwall	<10m	B	159	14	10	30	£3,188.00	£626.88	£606.565	Only camera and weighing scales. No other means of collecting data applicable on these vessels.	54
35	Pots and Traps	FPO	Cornwall	<10m	A	140	14	10	30	£3,326.00	£598.80	£549.472	Additional data collection value in utilising an integrated shellfish species identification technology.	54
36	Pots and Traps	FPO	North-Eastern	<10m	A	105	14	10	30	£3,326.00	£598.80	£412.104	Additional data collection value in utilising an integrated shellfish species identification technology.	54
37	Pots and Traps	FPO	Devon and Severn	<10m	A	93	14	10	30	£3,326.00	£598.80	£365.006	Additional data collection value in utilising an integrated shellfish species identification technology.	54
38	Pots and Traps	FPO	Eastern	<10m	A	81	14	10	30	£3,326.00	£598.80	£317.909	Additional data collection value in utilising an integrated shellfish species identification technology.	54
39	Pots and Traps	FPO	Southern	<10m	A	69	14	10	30	£3,326.00	£598.80	£270.811	Additional data collection value in utilising an integrated shellfish species identification technology.	54
40	Pots and Traps	FPO	Sussex	<10m	A	57	14	10	30	£3,326.00	£598.80	£223.713	Additional data collection value in utilising an integrated shellfish species identification technology.	54

Order of implementation	Fishing Vessel Métier			Vessel Size (<10m or >10m)	Recommended REM System Design [146]	Assessment Criteria for the role out of the Modular Framework				Financial Cost to implement REM per vessel per year (£)		Financial Cost to implement REM per fleet per year (£' 000s)	Scoring	
	Level 3	Level 4	Region			Number of Vessels in the métier	Residual Risk Analysis Score	Level of monitoring required and cost implications [147]	Achievable impact of REM Design	Purchase, installation and annual running costs.	Analysis costs, Observation costs, Management costs.		Additional justification (if required)	Overall Score
41	Poles and Lines	LHP	Devon and Severn	<10m	B	56	14	10	30	£3,188.00	£626.88	£213.633	Only camera and weighing scales. No other means of collecting data applicable on these vessels.	54
42	Pots and Traps	FPO	Northumberland	<10m	A	56	14	10	30	£3,326.00	£598.80	£219.789	Additional data collection value in utilising an integrated shellfish species identification technology.	54
43	Pots and Traps	FPO	Kent and Essex	<10m	A	38	14	10	30	£3,326.00	£598.80	£149.142	Additional data collection value in utilising an integrated shellfish species identification technology.	54
44	Pots and Traps	FPO	North-Eastern	>10m	A	27	14	10	30	£3,394.00	£958.08	£117.506	Additional data collection value in utilising an integrated shellfish species identification technology.	54
45	Pots and Traps	FPO	Devon and Severn	>10m	A	25	14	10	30	£3,394.00	£958.08	£108.802	Additional data collection value in utilising an integrated shellfish species identification technology.	54
46	Pots and Traps	FPO	Cornwall	>10m	A	15	14	10	30	£3,394.00	£958.08	£65.281	Additional data collection value in utilising an integrated shellfish species identification technology.	54
47	Pots and Traps	FPO	North-Western	<10m	A	14	14	10	30	£3,326.00	£598.80	£54.947	Additional data collection value in utilising an integrated shellfish species identification technology.	54
48	Pots and Traps	FPO	Isles of Scilly	<10m	A	11	14	10	30	£3,326.00	£598.80	£43.173	Additional data collection value in utilising an integrated shellfish species identification technology.	54
49	Pots and Traps	FPO	Eastern	>10m	A	11	14	10	30	£3,394.00	£958.08	£47.873	Additional data collection value in utilising an integrated shellfish species identification technology.	54
50	Hooks and Lines	LX	Southern	<10m	C	23	13	10	20	£2,416.00	£343.31	£63.464		43

This table is an excerpt of the top 50 rows in the Modular Framework excel sheet. The full framework contains a total of 163 rows. Please refer to this for more details on records beyond the top 50.

Table 107 Alternative framework - Regionalised scoring criteria for rolling out REM

	Number of high-risk vessels.					Number of medium risk vessels.							Number of low-risk vessels.								
Region	OTB	OTM	OTT	Sum of high	x10 weighting	TBB	DRB	TBN	GN	GNS	Sum of medium risk	X3 weighting	GND	GTR	FPO	LHP	LL	LLS	LX	Sum of low risk - no	Score
Cornwall	37	1	1	39	390	16	11		81	17	125	625	6	2	155	161	5	2	6	337	**1352**
Devon and Severn	40	2	5	47	470	30	36		37	17	120	600	5		118	57	6	1	22	209	**1279**
Sussex	38			38	380	11	5		49	10	75	375	7	21	66	7	5		16	122	**877**
Southern	29	1		30	300		27		34	10	71	355		2	75	6	6		23	112	**767**
North-Eastern	22	2	1	25	250	4	5	2	31	1	43	215		2	132	1	4	1		140	**605**
Eastern	26		1	27	270	40	6		8	6	60	300	10	2	92	1	10	3		118	**688**
Kent and Essex	41		2	43	430	5	20	1	28	18	72	360	23	9	40	2	2		3	79	**869**
Northumberland	40		2	42	420	1		5	13	4	23	115		1	65	1	1	3		71	**606**
North-Western	40	1		41	410	14	2		6	4	26	130	6	2	21			1		30	**570**
Isles of Scilly	3			3	30				1	2	3	15			12	2				14	**59**
Sub-total	**316**	**7**	**12**			**121**	**112**	**8**	**288**	**89**			**57**	**41**	**776**	**238**	**39**	**11**	**70**		

6.3 Cost framework - REM equipment and programme costs

As outlined in Section 3.2.5, the responses from vendors showed an incredibly high degree of variability in REM system designs, capabilities, and specifications. The cost breakdown and payment options for these were no exception. Some vendors quoted a single per unit price of an REM system design (based on the number of cameras, sensors, internal data storage, backup hard drives, cellular and satellite modems); others quoted itemised costs at a per unit level; while other vendors offered unique and generally incomparable costs packages inclusive of a variety of different services. Such an example could for instance include: leasing, licencing, limited maintenance and technical support, rolled in with fleet management software (fleetwide or vessel limited), e-logbook and reporting tools, with a fixed amount of cellular/satellite communication data, and two year warranty for all products and services. As such, distilling these costs down proved quite a challenge. To overcome this, we broke the costs down to three categories: the REM hardware and system; the annually reoccurring fees, and then project management and data review tools.

The costs associated with a REM monitoring programme include:

Equipment and purchasing costs:
- System hardware purchase/lease costs; and,
- Installation costs.

Annual reoccurring equipment costs:
- Maintenance and servicing costs;
- Communication and transmission costs;
- Data storage costs; and,
- Hardware licencing costs (where applicable).

Project set up costs:
- Project management cost covering labour, coordination, staff and project management, documentation and reporting;
- Staff training costs;
- Software customisation; and,
- AI customisation costs (where applicable).

Ongoing implementation costs:
- Project coordination and reporting;
- Video analyst labour costs;
- Review software licencing costs; and,
- Technical hardware/software support as required.

Cost range per year	£0-50k	🟧
	£50-100k	🟧
	£100-200k	🟧
	£200-300k	🟧
	£300-400k	🟫
	£400k+	🟥

Figure 36 below is an excerpt from the Modular Framework excel document, giving the reader an indication of the financial design of the framework based on the average annual cost of a REM system per métier. This value has been multiplied across the number of vessels per IFCA region (<>10m), giving an annual cost combining the installation, maintenance and operating costs incurred over the course of a year. These have been broken down in more detail across section 6.3 below.

The design of this table has been kept consistent with Objective 1 for ease of reference. Values have been given for the devolved administrations for reference purposes only. Values were not given for EU vessels.

		Total cost per vessel/year - based on the recommended REM technologies and level of monitoring (rounded to the nearest hundred)																													
		<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m
		8,111	10,325	3,925	4,352	4,458	6,387	3,130	3,641	3,370	4,634	3,130	3,641	3,815	3,907	2,775	2,625	2,504	2,625	2,759	2,759	8,366	11,265	2,689	3,600	5,408	6,542	9,777	13,514	4,885	5,962
Region (classified by)		**DRB**		**FPO**		**GN**		**GND**		**GNS**		**GTR**		**LHP**		**LL**		**LLS**		**LX**		**OTB**		**OTM**		**OTT**		**TBB**		**TBN**	
EU (flag state)	BEL																														
	DEU																														
	DNK																														
	ESP																														
	FRA																														
	IRL																														
	LTU																														
	NLD																														
	POL																														
	PRT																														
	SWE																														
Total																															

We cannot propose to roll out REM on EU registered vessels.

Costs given for each metier (<>10m), multiplied by the number of vessels in each region (£ per 1000).

		<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m
England (home port)	Cornwall	57	41	550	65	334	38	19	0	37	28	0	7	607	8	14	0	5	0	17	0	201	146	3	0	0	7	10	203	0	0	**1852**	**543**
	Devon and Severn	89	258	365	109	165	0	16	0	57	0	0	0	214	4	17	0	0	3	61	0	192	192	3	4	0	33	39	351	0	0	**1217**	**953**
	Eastern	8	52	318	48	36	0	28	4	20	0	6	0	4	0	28	0	8	0	0	0	159	79	0	0	5	0	88	419	0	0	**708**	**601**
	Isles of Scilly	0	0	43	4	4	0	0	0	3	5	0	0	8	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	**84**	**9**
	Kent and Essex	49	145	149	9	120	6	66	7	61	0	28	0	8	0	3	3	0	0	8	0	318	34	0	0	11	0	39	14	0	6	**859**	**223**
	North Eastern	16	31	412	118	134	6	0	0	3	0	6	0	4	0	8	3	0	3	0	0	109	101	3	4	0	7	0	54	5	6	**700**	**332**
	North Western	0	21	55	30	27	0	19	0	10	5	6	0	0	0	0	0	0	3	0	0	226	146	3	0	0	0	137	0	0	0	**482**	**205**
	Northumberland	0	0	220	39	53	6	0	0	3	14	3	0	4	0	0	3	0	8	0	0	184	203	0	0	0	13	0	14	15	12	**482**	**311**
	Southern	203	21	271	26	147	6	0	0	34	0	6	0	23	0	17	0	0	0	63	0	234	11	3	0	0	0	0	0	0	0	**1001**	**64**
	Sussex	8	41	224	39	214	6	22	0	34	0	66	0	27	0	14	0	0	0	44	0	284	45	0	0	0	0	68	54	0	0	**1005**	**186**
Sub-total		**430**	**609**	**2606**	**487**	**1235**	**70**	**169**	**11**	**263**	**51**	**122**	**7**	**897**	**12**	**100**	**8**	**13**	**16**	**193**	**0**	**1933**	**958**	**13**	**7**	**16**	**59**	**381**	**1108**	**20**	**24**	**8390**	**3427**
Total		**1039**		**3094**		**1305**		**180**		**314**		**129**		**908**		**108**		**28**		**193**		**2890**		**21**		**75**		**1489**		**43**			

Costs given as an indicative value for each metier (<>10m), multiplied by the number of vessels in each devolved administration. For reference purposes only. (£ per 1000).

UK (home port)	Scotland	65	506	3262	339	111	6	0	0	27	14	0	0	137	0	6	3	5	13	0	0	510	1600	3	72	0	222	88	27	34	78	**4248**	**2880**
	Wales	24	41	671	74	156	0	13	0	91	0	22	0	92	0	22	0	5	0	66	0	192	45	0	0	0	0	68	41	0	0	**1423**	**201**
	Northern Ireland	41	114	534	35	13	0	0	0	3	0	3	0	0	0	3	0	0	0	0	0	184	698	0	22	0	7	10	0	10	30	**801**	**905**
	Channel Islands	8	0	393	44	31	6	0	0	3	0	0	0	34	0	14	5	0	0	22	0	50	56	0	4	0	0	0	0	0	0	**556**	**115**
Sub-total		**138**	**661**	**4859**	**492**	**312**	**13**	**13**		**125**	**14**	**25**		**263**		**44**	**8**	**10**	**13**	**88**		**937**	**2399**	**3**	**97**		**229**	**166**	**68**	**44**	**107**	**7027**	**4101**
Total		**799**		**5351**		**325**		**13**		**139**		**25**		**263**		**52**		**23**		**88**		**3336**		**100**		**229**		**234**		**151**			

Costs given as an indicative value for each metier (<>10m), multiplied by the number of vessels where the location is unknown. For reference purposes only. (£ per 1000).

?	Unknown	89	165	1519	213	263	6	0	0	17	5	6	0	118	4	11	0	3	0	30	3	427	608	0	7	5	137	68	14	34	12	**2591**	**1174**
Total		**254**		**1732**		**269**		**0**		**21**		**6**		**122**		**11**		**3**		**33**		**1035**		**7**		**143**		**82**		**46**			
Grand total		**2,092**		**10,177**		**1,899**		**192**		**474**		**161**		**1,294**		**171**		**54**		**315**		**7,261**		**128**		**447**		**1,805**		**241**			

Cost range per year		
	£0-50k	
	£50-100k	
	£100-200k	
	£200-300k	
	£300-400k	
	£400k+	

Figure 36 Rough cost breakdown for rolling out REM across English and devolved nations fishing vessels.

6.3.1 Equipment and purchasing costs

6.3.1.1 System hardware purchase/lease costs

Alternative lower cost payment methods are available from a number of vendors and include leasing (spreading the cost over the lifespan of the system), equipment buy-back at the end of contract and bulk purchase discounts of equipment – leasing values were not provided by vendors (maintaining commercial sensitivity) but can be discussed on a case-by-case or per client basis. Some leasing options provided by vendors includes several additional services for technical support, maintenance, communications and upgrades within the contracts.

Bulk purchase discounts typically ranged between 10-15% dependent on the number of units purchased and the additional services (licencing, software, analysis tools) included within the contract. For those vendors that included a discount on cost for hardware, 10% was applied and included with the framework calculations.

It should be noted that while costs for some REM systems do appear quite expensive, a number of vendors only produce one product for both the inshore and offshore. The only difference in the setup is the additional number of add-on cameras or sensors included in the design for larger vessels. Therefore, the cost of the control box is given as standard. A handful of vendors do produce smaller REM products designed specific for the inshore and smaller fishing vessel. As these products will give better value and cost efficiency, these were short-listed, and their average cost used in the modular framework design. While these products are currently limited in number, this is an emerging market, with numerous vendors citing that smaller, REM ‘lite’ systems were in development and will be commercially available in the next two years.

6.3.1.2 Installation costs

Installation costs were given as a per unit value for most vendors or as a time-cost where vendors would subcontract local marine electricians to complete installations. Therefore, exact costs couldn’t be determined given marine electricians’ rates can vary quite widely. Therefore, in addition to the variability in the products, the design (number of cameras and sensors) determining time requirement for installation, there was some degree variation introducing an unknown cost dependent on what a marine electrician would charge. For installation purposes, either approach would be appropriate, but on considering a national roll out of REM (and of course determined by the ownership and responsibility for the equipment), it may be more efficient for the fisheries managers or regulators to contract or hire marine electricians nationally covering the major fishing ports. Alternatively, the cost could be put back on to the fishers, who would typically use and have good connections with local marine electricians – this approach may also work out comparatively cheaper to implement as most vendors that responded are distributed globally, therefore, would look to recuperate logistical costs of sourcing or dispatching a marine electrician. Larger vessels would probably be able to manage a self-install of the REM hardware, having a qualified marine electrician included in the crew. This approach does raise the question of certification and inspection, so while cheaper, would still need to be approved for use before the data collection begins. A regular or annual certification and inspection / audit programme would be recommended to ensure compliance with the data collection needs for REM by fisheries managers. Such a cost has not been included within the design but depending on the approach does highlight some institutional knowledge and training requirements for staff or independent contractors and should be rolled into the management plan.

Where given, costs for installation varied between £200-300 to install a low specification setup on a <10m vessel (1-2 cameras, control box, 1-2 sensors, cellular/Wi-Fi functionality) or broadly speaking 1 day for a qualified marine electrician familiar with the set-up requirements and design of the vessel. Installation of middle of the range REM systems were quoted between £500-1000 (2-4 cameras, control box, 4 sensors, cellular/Wi-Fi functionality), and for larger vessels, with a greater monitoring regime and therefore, a more comprehensive REM design, costs ranged from £1000-2000, or 2-4 days for a marine electrician. It should be noted that these were not always set costs, with some variability given in the installation price, contingent on the purchase of other services in the package. Installation costs of up to £2500-3000, were quoted by some vendors, however, we thought these extremely large values were more in line REM systems designed for large scale offshore vessels and hence generally less applicable to English inshore fisheries.

The European Fisheries Control Agency (EFCA, 2019) indication of installation costs broadly aligned with the information collected in this study, quoting "For a smaller vessel (less than 12 m) the installation can be done in half a day for around € 500 and € 1000. This in contrast to a medium size vessel (15 – 40 m) where the price varies between € 2,500 and € 3,500 and for a larger vessel (more than 40 m) could be around € 4,000."

Hardware and installation costs are perceivably high as this is an initial investment cost to any REM programme, however, this cost is only applicable for the first year and once paid, doesn't repeat again for the lifespan of the hardware. Most REM systems will have a 5-year lifespan (Course, *et al.*, 2020; Course, 2021). Table 108 below demonstrates the first-year investment cost, and alongside this, we have included the annual breakdown over five years to provide a comparable metric to demonstrate alongside the other annually occurring costs for maintenance, licencing, tech support and communications.

Table 108 Purchasing and installation costs for REM equipment on key component and minimum requirement designs for <>10m vessels. Exact design costs by métier will vary in accordance with data collection and additional technology requirements

	REM system Design					
	<10m			>10m		
Technology	Number	Cost	Total	Number	Cost	Total
Control Box	1	£1,200.00	£1,200.00	1	£4,350.00	£4,350.0
Cameras	2	£430.00	£860.00	4	£430.00	£1,720.0
Sensors	2	£140.00	£280.00	4	£140.00	£560.00
Hard drives (500GB and 1TB)	2	£60.00	£120.00	2	£100.00	£200.00
Keyboard and Monitor	1	£150.00	£150.00	1	£150.00	£150.00
Installation	1	£300.00	£300.00	1	£1,000.00	£1,000.0
Consumables (wiring)	1	£150.00	£150.00	1	£150.00	£150.00
Total			£3,140.00			£8,050.0
Total Over 5 Years			£628.00			£1,610.0

Additional technologies	Cost	Cost per year over 5 ye
Weighing Plate	£4,000.00	£800.00
Weighing Conveyor	£7,000.00	£1,400.00
Integrated weight-length conveyor with species ID capability	£10,000.00	£2,000.00
RFID scanner + 20 Tags	£550.00	£110.00
E-mitigation devices	£6,000.00	£1,200.00
Oceanographic sampler	£4,000.00	£800.00
Net Cameras	£3,600.00	£720.00

6.3.2 Annually reoccurring equipment costs

6.3.2.1 Maintenance and servicing costs provided by vendors

Maintenance and servicing costs, as to be expected, also varied considerably by vendor and combination of products purchased. Some vendors include maintenance and technical support time within their contracts where products are leased, while others include a warranty period for all products purchased which comes with limited maintenance and technical support, while yet others-based maintenance cost on marine electrician fees. In general, the quoted prices ranged between £100-1000 a year, some extremes went to £2000, but these were generally for larger and more comprehensive REM designs targeted at industrial high seas vessels, not applicable to this study. Taking an average across the vendors, the annual maintenance cost came in at £370. This was used as a standard cost across the fleet, as the quoted prices didn’t seem to differ between low-high specification designs. Referring back to the literature, the EFCA (2019) report quotes €400-1000 annually for maintenance which fits in with our information. Given the lower end price range of £100-500 appeared across all low, medium, and high spec control boxes (excluding the extreme examples) Table 109 was produced to reflect the annual cost across the analysis fleet. These values have been reflected in the total financial cost in the Modular Framework, section 6.1.

Table 109 Annual Maintenance cost based on the Vendor responses across the analysis fleet of 2185 vessels

Gear type	Number of English registered Vessels		Price range for annual maintenance (£370 averaged across the vendors)	
	<10m	>10m	<10m	>10m
Otter Trawl	239	96	£88,430.00	£35,520.00
Beam Trawl	44	98	£16,280.00	£36,260.00
Scallop dredge	59	53	£21,830.00	£19,610.00
Potting	664	112	£245,680.00	£41,440.00
Netting	448	27	£165,760.00	£9,990.00
Lines (incl. handline)	346	12	£128,020.00	£4,440.00

6.3.2.2 Data transmission methodologies and costs

Sim and satellite transmission costs quoted by vendors were quite mixed and almost impossible to standardise, with costs of each highly dependent on national provider charges and the service package being sold. However, some clarity can be gleamed from the available literature on this subject. The EFCA (2019) report quotes 15GB per month at €15 per month for remote sensor data and reporting via cellular comms over a 3G/4G network. This would be satisfactory for all position and activity reporting data volumes and would support some degree of video or snapshot reporting at a cost of €180 per vessel per year – however, since the publication of the EFCA (2019) report, unlimited sim data packages appear to have reduced, as predicted in the report. Considering the below recommendation to include video data transfer over unlimited data low-cost sim packages, it may prove cost effective to prioritise mobile networks for all data uploads at a slightly higher cost per vessel of £192-£288; which may reduce further with time and can be reduced further by directly contracting national mobile network providers. Comparably, unlimited satellite costs would be €800 per month or €9,600 per vessel, per year – significantly more expensive and probably unjustified for all but the highest risk vessels where there is a constant enforcement and live video reporting is required.

Based on English fishing fleet data; courtesy of Poseidon Aquatic Resource Management & AVS Developments Ltd in pursuance of the development of the Fishing Impact Decision Information Toolkit and available information across the literature, we were able to produce the below calculations giving approximate data volumes nationally. The EFCA (2019) technical specifications for REM document indicates that 4 sensors (GPS, hydraulic, hold temperature etc.) collecting data every 10 seconds while a vessel is fishing will generate 500KB of data per day. Based on this information, and the reported 2017 data of fishing effort (days) across each métier <10m and >10m, we were able to calculate the approximate data volume that would be transferred by cellular or satellite networks if strictly reporting positional information and additional sensor data. Transmitting this data over mobile networks within cellular range or satellite, were it based on the total data volume would generate entirely negligible costs when considering the scale of the programme – confirming the outcome of the EFCA report (2019). Likewise, viewing this data volume on a per vessel basis demonstrated that this quantity of data was also entirely negligible. In total, 72GB position and sensor data, which would be generated across a year is almost insignificant and were this on a single sim from any mobile network provider, the cost would be around £12-20. However, the difficulty in determining this cost is of course drilled down to the cost of the sim and tariff with mobile network companies, or the cost of satellite antennae, on a per vessel basis. Therefore, every vessel would need a sim and data allowance package, which for position reporting alone, would be incredibly expensive. As detailed later in the report - utilising a 3G/4G data transfer methodology on an unlimited monthly data allowance sim does provide a more cost-effective means of data transfer for a rather small incremental cost.

Table 110 Calculated sum of GPS and Sensor data volumes (GB) transmitted over cellular or satellite networks in near-real time based on the 2017 fishing effort data[148]

Sum of GPS and Sensor data volumes (GB)	<10m	>10m	Total
Otter Trawl	3.542	7.669	11.211
Beam Trawl	0.167	5.898	6.064
Scallop dredge	2.172	3.316	5.487
Potting	20.123	8.956	29.078
Netting	11.325	1.561	12.885
Lines (incl. handline)	7.149	0.576	7.725
Total	**44.476**	**28.290**	**72.765**

Determining the data volume and transfer requirement for video data proved to be a little more complicated. Taking the same fishing effort data[149] the number of fishing days was multiplied by the assumed daily fishing effort for each métier <10m and >10m. This in turn provided the annual number of fishing hours for each métier in the

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[148] courtesy of Poseidon Aquatic Resource Management & AVS Developments Ltd in pursuance of the development of the Fishing Impact Decision Information Toolkit

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two size classes. The Fujita, et al., (2018) - EM design manual and cost calculator tool gave a per camera hour data volume of 0.5GB, and the EFCA (2019) REM technical specifications indicated a per camera hour data value of 0.5GB, although this information wasn't directly collected from REM Vendors in the survey, this was later corroborated with a select handful of vendors, with one citing rates of between 0.2 and 0.3GB per hour depending upon on deck activity.

Onboard video compression and parsing will be an incredibly important component for data transmission, the question of "do you include video compression functionality" was included with the vendors survey; but in hindsight, quantifying the compression ratio between vendors would have been useful information to collect, as the responses on this were mixed. Several vendors indicated that their products comply with H264 and H265 CODECs as the two for video compression standards, where some indicated they did include video compression, and some provided no responses at all. The H265, or otherwise known as High Efficiency Video Coding is the latest iteration in video coding standard, offering 25-50% better compression than the H264 predecessor. Therefore, this does significantly increase the video compression ratios for higher resolution (4k or 8k video resolution) and standard high definition (1080p) data capture where this has been incorporated into the REM design, leaning toward a better data capture, storage and transfer rate for these vendors and products. Total annual data volumes (TB) across the fleet, and average annual data volume per vessel (TB) have been provided in Table 110 and Table 111.

Table 111 Calculated sum of the quantity of video data captured (TB) transmitted over cellular or port-based Wi-Fi networks based on 2017 fishing effort data[150]

Gear type	Sum of the annual quantity of video data captured (TB)		
	<10m	>10m	Total
Otter Trawl	69.620	364.338	433.958
Beam Trawl	2.675	373.931	376.606
Scallop dredge	33.385	127.652	161.037
Potting	312.035	263.473	575.508
Netting	164.150	74.228	238.378
Lines (incl. handline)	83.250	36.520	119.770
Total	**665.115**	**1,263.754**	**1,928.869**

Table 112 Calculated average of the quantity of video data captured (TB) and transmitted over cellular or port-based Wi-Fi networks based on 2017 fishing effort data[151]

Gear type	Number of English registered Vessels		Average quantity of data for vessels	
	<10m	>10m	<10m	>10m
Otter Trawl	239	96	0.291	3.795
Beam Trawl	44	98	0.061	3.816
Scallop dredge	59	53	0.566	2.409
Potting	664	112	0.470	2.352
Netting	448	27	0.366	2.749
Lines (incl. handline)	346	12	0.241	3.043

In Table 112, the data capture range for under 10m vessels (with the exception of beam trawls) falls to an approximate range of 250-550GB annually, roughly 20-40GB per month. Therefore, the smaller and typically inshore vessels may lend themselves better to cellular based uploads of video data. However, the larger over 10m vessels clearly have a significantly higher per vessel fishing effort and collect more data through the facility for more sensors, cameras, and data collection methodologies. The data capture range for these over 10m vessels falls between the approximate values of 2.0-4.0TB annually, 170-340GB per month. Taking the EFCA (2019) reports indication of transfer rates over a 4G network (15-25GB per hour), we can

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then determine that at the lower band assuming some interference with shared port traffic (15GB per hour) the under 10m vessels would have a typical monthly transfer time of 2-3 hours to complete. For the over 10m vessels, this would range between 11-22 hours over the course of the month. Therefore, considering the volume of information involved, this may lend better to Wi-Fi based data transfer and shared terminal across all vessels (<>10m) in the port.

In terms of calculating the costs for these, cellular (3G/4G/5G) upload of all data could be achieved for all vessels on an unlimited monthly airtime package, available from most mobile networks at £16-24 per month (at the time of writing, 09/21). In terms of generated cost across the fleet, this would cost £192-288 per vessel per year, and £419,520-629,280 annually across the fleet; taken from the reference sample of the top 15 métiers (>40 vessels); 2185 vessels registered to English ports considered within this study. We are unable to provide a comparative value for the cost of installing and maintaining Wi-Fi terminals across all English ports, but on this subject the EFCA (2019) report recommends a cellular based approach over the use of Wi-Fi based on reducing cellular costs and improving feasibility of fast data transfer with the introduction of 5G technologies in the near future.

Comparing this approach to the standard hard drive exchange methodology implemented by most REM programmes globally, unlimited data sim packages are more expensive than the anticipated annual cost of £262,200 for couriering hard drives each month (assuming a cost of £10 a month, £5 per each hard drive trip from and returned to the vessel). However, while cheaper, at a national scale, the added benefit of adopting a cellular or Wi-Fi methodology is the time and monetary savings in coordinating the collection, processing, upload, formatting and return of the hard drives, which although not quantified, would have an extremely high indirect cost.

A cellular based approach does have an advantage over using Wi-Fi networks as the responsibility and maintenance cost falls to the network providers, the only indirect cost will be the in ensuring that the data transfers complete without fault and maintaining the servers and platform which support the upload of information. A Wi-Fi based approach, while potentially more secure, and offering a greater degree of control over the data management, will face these same costs of maintaining servers and upload platforms with the added cost for maintaining the Wi-Fi terminals locally within each port. This can be contracted out, therefore not requiring any specific internal expertise to do so but will still come with a cost not quantified here. As such, utilisation of cellular networks for all data transfer would be our recommended methodology, and these values (above) are reflected in the total financial cost in the Modular Framework, section 6.1.

6.3.2.3 Data storage costs

Some vendors offer a limited amount of server or cloud-based storage to support the data collection. This would be quite expensive to implement at a national level (considering the volume of data likely to be involved) and therefore we would not recommend this approach. Instead, English fisheries management organisations would be better placed to add capacity to existing data storage facilities or consider the data storage requirement while addressing the infrastructure needs to roll out a national REM programme.

6.3.3 Project Set Up Costs

6.3.3.1 Project management, data analysis and video review tools and software

Generally, the costs for project management, data analysis and video review tools and software were the most variable by vendor. Some vendors quoted bespoke packages based on the number of vessels under the contract, and a service package based around the amount of business generated through these vessels or a tiered structure covering functionality and scale i.e., the upper-end offering a “fleet” package irrespective of the number of vessels, video review and fleet management software and a high allowance for data traffic (includes satellite bandwidth); alternatives also offered a fleet wide approach, but with a scaled back service package.

Vendors who quoted an individual, per vessel software licence cost quoted between £350-£3000. As such it was very difficult to get a reliable estimate for an average price. The EFCA (2019) technical specifications report quoted €250 (approximately £213 – Sept 2021) for a software licence per vessel. Therefore, this is the price that we have quoted in determining the licencing software costs.

Included separately within this, some vendors have designed their cost models for data display, review and analysis software around the number and type of licences chosen, not by the number of vessels, i.e., the software can be used for reviewing the data from as many vessels as the user wishes, what the user pays for is the server licence and a variable number of personal or machine based licences (determining the number of people or computers that have access to the software). The price for this can cost approximately £30,000 for an organisation to have a server licence and unlimited number of users under that licence.

Overall, the services on offer were very expensive across all vendors, but with good reason. An effective analysis software and fleet management tool will have taken significant investment in research and development by the vendor but can translate into significant analytical time savings for clients. Considering the fleet management and analysis software’s available, viewing the cost nationally on a per vessel basis utilising a non-vessel limited software provider cost £30,000 a year, does demonstrate that the cost-effectiveness of the tool, for instance, a “fleet” licence could cost as little as £15 per vessel, across the 2185 registered English vessels within our sample frame. Therefore, this is the price that we have quoted in determining the licencing software costs.

Ultimately, who purchases the cameras / services determines the most appropriate designs for integrated packages. Consideration will need to be given to the approach to REM and how this will be trialled and rolled out across different ownership methodologies. In addition, voluntary or mandated approaches to REM will include numerous complications in determining the best design to finance and implement a REM programme nationally. This would be a substantial project to undertake and has not been included here. However, at a cursory level such approaches could include:

- National purchase (Government ownership) and leasing approach to vessel operators;
- National purchase (Government ownership) and cost recovery options through vessel licences;
- Operator purchase (ownership) and grant based investment schemes; and
- Operator purchase (ownership) and an agreed short-list of approved vendors with fixed (low cost) rates.

6.3.3.2 Staff training costs

This aspect was not covered within the questionnaire as it is dependent upon the operational model chosen by regulators in the roll out of REM. It should be noted that should some or all aspects of operating the REM system be brought within Government then there will be costs associated with training staff in the use and maintenance of software etc.

6.3.3.3 Software customisation costs

This aspect was also not covered within the questionnaire as it will be very specific to each fishery but there are likely to be some costs incurred with the initial customisation of off the shelf review software to a particular fishery. The simpler the REM system deployed the more likely that these costs will be minimised.

6.3.3.4 AI customisation costs

Similarly, to the previous point this aspect was also not covered within the questionnaire as again, if employed, its customisation would be very specific to an individual fishery. Depending upon the monitoring goals within the fishery in which it is used it may be possible to use an existing algorithm and build upon it or a bespoke solution may be required.

6.3.4 Programme implementation costs

6.3.4.1 Project coordination and reporting

Whilst all vendors do provide these services it was not possible to provide estimates for this study given the high degree of specificity required for the vendors to provide estimates. There are also several models in use where REM is used by national regulators. Often this remains contracted to the private sector, other times it will be completely carried out by Government officials, along with blended approaches. It is important to note that regardless of whether a government agency or a private contractor conducts these tasks there are still costs to be incurred.

6.3.4.2 Determining analysis and monitoring costs.

The volume of data generated by the installation of REM on English fishing vessels was calculated based on the fishing time per vessel (estimated hours multiplied by fishing days[152]) and multiplied by a value for data generated per camera/sensor hour for each vessel. These figures were then multiplied by the number of vessels registered to English ports for each métier (<>10m), to determine an annual approximation of fishing hours across the fleet. This is representative of the level of data collection (hours of data to review) in order to achieving 100% data capture for all fisheries with REM. The total number of hours for each métier (<>10m) was then divided by the monitoring requirement stipulated by the results from the stakeholder engagement survey. This determined the number of hours of data that would need to be reviewed across each métier.

Assumptions were made on the approximate review rate of a trained fisheries analyst over a 35-hour working week, or 1820 working hours across the year. Most REM analysts working efficiently can achieve a 1:4-hour review rate for fisheries data once trained, an experienced analyst may be able to achieve higher than this (Course, 2021), but on average this is likely to vary with the specific data

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requirements of each métier. For instance, a high risk métier, such as beam trawls, will have a higher review requirement but also significantly more data collected for monitoring that a low risk métier, such as pots and traps; and therefore, will take longer to review. This 1:4 ratio, is considered the minimum achievable efficiency rate, therefore was used as standard across the calculations. This time includes responsibilities for evidencing, analysis, documenting, and report writing.

The total annual monitoring hours for each vessel and métier was quartered based on the 1:4 review rate, determining the total time input for a single analyst to complete. To determine the cost to undertake this analysis, the number of manhours to review was multiplied by £14, assuming an £14/hour or £25,000 per year salary.

For direct comparison, the possible level of observer coverage which can be available instead of and alongside REM was included with the monitoring cost matrix on the “Observation Costs” tab. This used the same calculations on vessel and fleet hours and multiplied it for the cost of a consultant fisheries observer contracted for 180 days a year, salaried at £115 per sea day or approximately £20,700 a year.

Alongside the above, the management time and projected cost in terms of manhours over a year to manage, coordinate and report on a national REM and observer data collection programme was incorporated into the financial design. Inputs into the time for each of these categories were given as a percentage of the total monitoring time across REM and observers and informed through the feedback of the stakeholder engagement. As such each métier had a different management time and cost requirement based on how involved the monitoring regime is, dictated by level of risk, and the number of vessels in each.

It is anticipated that this cost will include but not be limited to, covering management costs, data management, technical support, national reporting obligations, oversight and coordination of analysts, observers, enforcement agents and fisheries scientists. Costs given do not include employer overheads.

6.3.4.3 REM system software licencing

Generally, the costs of REM software licencing were not provided. Only two of the fifteen vendors quoted provided a cost - £350 and £1000 respectively. As there is a such a wide degree of variance in the way that REM vendors charge for software licencing, they are practically incomparable. It is important to note that many vendors indicated a willingness to negotiate on this aspect depending upon the scale of the programme and other considerations.

Some vendors quoted bespoke packages based on the number of vessels under the contract, and a service package based around the amount of business generated through these vessels, therefore, the licence being included or not quantified. The EFCA (2019) technical specifications report quoted €250 (~£213 – Sept 2021) for a software licence per vessel. Therefore, this is the price that we have quoted in determining the licencing software costs.

6.3.4.4 Technical support

Technical support costs, where quoted independently of integrated packages, averaged around £1000-1300 a year for 15 hours of tech support, per vessel. An average of £1,100 was taken for the provision of 15 hours technical support per year. From the responses returned, it was unclear whether this was specific to the REM design or to additional services provided with the fleet management and/or analysis software, though it is more likely that is solely for the REM system itself.

It was generally acknowledged by vendors that in the initial stages of a programme there can be a higher rate of technical support but as programmes mature this generally settles at a low level.

6.3.5 Interactive cost-based design

The modular framework was designed to have interactable functionality, taking the framework one step above being a guidance document, to a usable tool; enabling the user to switch between REM designs and switch on / off monitoring components in order to determine a somewhat bespoke costing design. There is room for greater development of this framework to transform it into an interactive implementation tool in a follow-on project.

7. REM Programme Management

The following list summarises best practice recommendations for the implementation of a new REM programme;

- Define fishery monitoring objectives, data requirements, and key performance indicators as a first step to focus programme design on monitoring goals;
- Evaluate the full suite of tools and approaches to meet the required monitoring objectives;
- Include the fishing industry in the design process and provide incentives for its ongoing participation;
- Consult with REM vendors in the early phases of programme development and during programme updates;
- Evaluate whether new REM programmes can leverage existing methodologies or infrastructure to improve the efficiency of programme delivery;
- Carefully consider different REM service delivery models (i.e., how the programme is structured and who fulfils the requirements) to determine the best fit for each fishery; and
- Assess the infrastructure requirements of a REM programme in relation to the geography of the fishery.

Through the delivery of this project, we envision that there will be significant benefits across the multitude of stakeholders involved with the English Inshore fishery. The improved data collection and data management processes involved will help build a clear picture of the UKs fisheries, in turn, aiding fisheries policy, regulation and managers in meeting and reporting on the England’s commitment to the delivery of GES to the Ecosystem Objective as set out within the Fisheries Act 2020; and committed to achieving GES in English seas by 2024.

The Modular Framework has been designed around applying the most effective REM systems on a risk-based approach that will (i) help promote compliance, (ii) collect data for data-poor fisheries, (iii) protect sensitive species and (iv) contribute to achieving GES. With the ultimate intended use of helping inform decision making on a new of a fisheries data collection and monitoring regime underpinned science.

7.1 National implementation

7.1.1 Phased implementation

The REM modular framework highlights where we think REM should first be applied to maximise the achievable impact in progressing toward achieving GES in English seas. This, however, may not be the most pragmatic or practical approach to implementing REM nationally. As such, we would recommend taking an approach which exercises phased implementation within the structure of the modular framework to spread capital costs, enable cost-effective implementation (e.g., installation costs). Roll out in tranches, spatially and temporally arranged, will help manage these costs and allocate resources towards installing, testing, and certifying REM equipment in manageable portions. Such an example could for instance follow the regionalised approach suggested in Section 6.2, giving an alternative to the framework in Table 107. Roll out of REM could be temporally delivered by targeting fisheries in Cornwall and Devon and Severn IFCA Districts, when fishing seasons are quietest – minimising the impact to fishers. As these two regions have the highest number of vessels, a significant proportion of the fleet could be targeted within the first tranche. Resources can then be focused on other regions, working along the south coast and then to the north of England where vessels and impacts may be fewer.

7.1.2 Holistic monitoring design

Compared to physical observation, REM programmes offer cost efficiencies through scalability, these therefore offer a cheaper per unit cost for monitoring effort than can be achieved through fisheries observers alone. However, REM has many limitations which cannot be overcome at present without human intervention. In order to ensure robust fisheries management nationally, we recommend a holistic approach to fisheries data collection, including a sampling regime that incorporates physical data collection to supplement fleetwide REM. Such an approach, alongside a stricter monitoring regime can allow fisheries managers to produce high precision estimations of fleetwide impacts.

7.1.3 Utilise existing resources

It was highlighted during the stakeholder consultation that, at present, English fisheries management have limited additional capacity to implement a national REM programme. REM for all its benefits will generate magnitudes more data for fisheries managers to process, manage, analyse, and report on than the mechanisms currently in place. Concerns raised by the stakeholders over how these data will be processed and quality assured, highlighting the significant investment in resources required in making this data usable at a national scale, as well as who the end users will be, how data could be distributed and controlled.

The inclusion of REM into English fisheries management should not constrain governmental resources and need not been the burden of MMO and IFCAs alone. One recommendation to put forward is that in line with proposals for the centralisation of an REM data management centre, the contracting of private sector electronic monitoring service providers can cost effectively provide the necessary resources to strengthen the REM data analysis, processing, and management. Contracting private sector companies, which have the internal capacity, and a proven efficient working model for managing, processing, and analysing and reporting on large REM datasets, and fisheries monitoring programmes would enable fisheries managers to prioritise their workflow. Such an approach could enable fisheries managers to dedicate more efforts to acting on the data, rather than the responsibility for dealing with it.

The fleetwide monitoring and analysis proportions given in Table 111, generate over 80,000-man hours of footage to review across the analysis fleet of 2185 vessels, assuming an average analyst can achieve a minimum of 1:4 efficiency in data review time: total time captured. This represents the requirement for a minimum of 44 full time analysts working for 1820 hours a year at a 35-hour working week: at a minimum cost of £1,129,000, on a fixed minimum £25,000 annual salary. This does not include the time required for report writing, staff holidays, sick leave, and the costs do not include overheads, variable and increasing salaries for experienced staff. Including these factors can easily increase the analysis time required to 100,000 hours in a year, at 55 full time staff, costing at least £1,400,000 in annal wages.

Consideration should be given to whether, in the long-term, REM programme management should be delivered publicly or privately.

7.1.4 Fisher engagement

Another key element is the involvement of fishers in the design of a REM programme and data collection. This thereby maximises the value, buy-in and uptake of REM. Taken from global experience, fisher buy-in significantly increases the successful implementation of a REM programme when applied successfully. Such examples of involvement include community led science and data collection – showing the value of the data fishers are collecting to the industry. Fisher logbooks and self-reporting have been found to provide significant volumes of data for scientists and managers. Working with fishers results in maximising cooperative research, through better engagement and communication and as a result the reliability of self-reported data is improved (Kraan *et al.,* 2013, Emery *et al.,* 2019).

Globally, mistrust, poor transparency, and a lack of cooperation between fisheries managers, implementing authorities and fishers has been a substantial limiting factor in application of new technologies and innovation in fishing behaviour. A lack of productive fisher engagement with REM can be one of the most significant obstacles to successful implementation of REM systems. We have also experienced this firsthand in a number of different REM projects. Whether rolled out on a voluntary or mandatory basis, prioritising user buy-in from fisher groups will be an effective mechanism supporting the implementation of REM fisheries data collection. For this reason, national implementation should seek to maximise open interactions and transparency with fishers and fisheries stakeholders. Consideration of the approach to fisher involvement, through engagement, workshops and demonstrations of the technology and its use will be included with the framework design to support the staggered roll out of the REM technologies across the inshore fleet. This should be targeted in such a way that particular fleets are engaged in the lead up to delivery of each stage in the framework.

7.1.5 Audit or Census approach

We would recommend an audit approach to collect 100% of data for all fisheries with a fixed audit / review requirement for all fishing vessels. A high audit level or census approach taken for the highest risk métiers is recommended. This will provide a fairer and complete sample of fishing activity across high-risk fisheries and enable for mass low-cost analysis (position and effort quantification) across the sector.

For medium and lower risk vessels we would recommend running a variable sample regime across the fleet. Most vessels will collect the minimum required information on fishing activities. A narrower selection of vessels is targeted for a more comprehensive data collection and monitoring regime, this can be focused on high risk or non-compliant vessels within the local fleets; or based on a random and variable sampling regime. This will reduce the monitoring and analysis cost overall, while also enabling a representative sample of the data to be collected and used as a reference for the whole fleet. Such an approach can include biological and biometric sampling through weight scale and calibrated measuring boards, oceanographic and in water data collectors using cameras, electronic samplers, self-reporting, fisheries observer, and fisheries scientists. Significant inter-vessel variability will likely result in a greater complexity for REM system setups and design; therefore, a variable sample regime may prove effective in collecting fleetwide data where some vessel configurations do not allow for space to include different technologies onboard.

7.2 Monitoring requirements

We would propose a monitoring structure that focuses on two data streams – near-real time reactionary approach to fishing activity. This would be through the transmission of position and activity data through cellular networks (default) and satellite networks for high priority vessels where the default is not available. High priority vessels will be those identified as high risk against the monitoring objectives. For low priority vessels where near-real time transmission is not required, or is less of a concern, then this can be retrospectively updated on return to cellular range.

The second data stream would be through the bulk transmission and remote storage of vessel data, large data volumes, such as video records are remotely synchronised with a vessel account utilising port-based Wi-Fi terminals. There are a number of advantages and drawbacks to this approach over the standard hard drive swap protocols for most REM programmes. First of all, once properly designed, tested and functioning, this method would prove to be a low input and passive form of data collection for fisheries managers. There should be few logistical complications in running a data exchange programme, and therefore minimal costs (time and monetary) in managing, organising, coordinating, and processing a continually flowing fleet of hard drives around the country. Now while such an approach, due to simplicity, does lean towards a greater degree regionally in the responsibility for collecting and processing hard drives (i.e. the IFCAs could for instance be designated as the responsible party for managing a network of vessels which courier hard drives to the IFCAs, who then upload, clean and reformat these before redistributing them to the vessel or pool), this does somewhat work against the recommendation for pursuing a centralised data management approach, for which we feel the benefits substantially outweigh the costs (more detail is contained in the infrastructure requirements (see section 7.3)).

Where monitoring objectives exceed the need for positional reporting alone and justify the need for near-real time reporting, then we would propose an audit system that incorporates some direct input from fishers themselves. For instance, timely reporting of interactions with protected species can help prompt a management response, which in turn can be fed back to fishers to help avoid certain areas. Such an example could include the hauling of spawn within nets or bycatch of cetaceans could be two situations where fisher reporting can rapidly inform management and other fishers, allowing for appropriate avoidance measures to be put in place. This of course will require external verification and auditing to ensure appropriate usage, but it doesn’t need completing in real time.

Very clearly identifiable in the stakeholder responses was the need for specific application of technologies for monitoring vessels with a high risk of protected species bycatch, focusing on the gillnetters primarily, and to some degree benthic and pelagic trawlers. Therefore, there is scope within these fisheries for a greater monitoring effort, using targeted cameras with specific tasks for bycatch monitoring, and the need for a faster turnaround on the review effort in order to feed meaningful bycatch data into the fisheries management and provide a statistically robust effort for modelling protected species catch nationally. Such an approach could be used to link several policies and government programmes together.

7.3 Infrastructure requirements

7.3.1 Data management

One of the most significant infrastructure requirements with REM data is in how to store and maintain the data collected. As indicated in Section 6.3.4.2, Table 111, the annual data generated through REM data collection nationally could be as high as 2,000TB. Aside from needing significant server space to host this, protocols would need to be put in place to ensure the data is stored, protected, meets the requirements of the data protection act, and a duty of care placed on deleting that data when no longer of use. Foremost, long term storage protocols may need to be considered to maintain a reference sample of all data collected and audited, while deleting the rest to conserve server availability. This will need to be addressed with sufficient staff capacity, IT expertise and training to cover all aspects of data management internally.

A centrally coordinated data centre for the management of the fishery is the recommendation of this report. This would be used to store the data at a national level, providing dedicated dashboards to each of the respective bodies involved in managing the fishery. The centre would host servers which aid in fishery data management and analysis through the use of powerful analytical tools, machine learning and AI. This would standardise data management processes and would significantly increase the capability of each of the organisations involved in fisheries science and management. Applications of this technology would encompass strengthening stock assessment processes, assisted by powerful analytical tools, and support the management of catch of non-quota species. Ultimately, such a design would not need to be limited to solely inshore fisheries management, and with expansion can encompass management of data collected by the offshore fleets as well.

Applying a centralised data management system would enable managers, scientists, and fishers to benefit from data feedback, ultimately identifying the previously untapped value of the application of data in managing the fishery. Data feedback and dissemination of results is a key component to effective fisheries industry-led data management systems This would provide managers and fishers access to benefits from the fisheries data collected toward mutually agreed goals. Fishers can act as key sources of primary information on catch and effort data (i.e., rates, composition, volume, size frequency) to scientists and fisheries managers. Using more digital-based solutions would lead to more effective decision making in real time for scientists and fisheries managers in respect to stock status, providing effective management and thus benefiting the fishery long-term.

Such information can be applied in real-time; to designate and communicate fisheries closure zones to different fleet segments based on impact, protecting stocks and juveniles, thereby increasing sustainability, reducing bycatch where non-target species are being caught and improving the long-term product value of catches within that area. This process of data supply, information refinement and feedback will lead to more effective area-based management of fisheries resources. This would allow fisheries managers to reward good actors, compliant with management decisions, and target restrictions to non-compliant vessel operators, without implementing blanket bans to all vessels within the fishery. Fishers could also benefit from a reduction in form filling and bureaucracy, for example, catch certificates for various markets could be completed from available data sources and electronically verified by relevant management authorities enabling catch to get to market quicker and at the highest possible quality. We would maintain a focus on solutions that ensure bringing all small-scale fisheries into the same digital data recording platform with all other fisheries.

Given the significant data volumes involved, and the cost-efficiencies found with scale, we would recommend a centralised data storage and management approach nationally, coupled with international and regional engagement. Nationally pooling of resources also provides the potential for future integration of powerful machine learning (ML) and analysis tools. One recommendation for the application and use of Artificial Intelligence (AI) or ML technologies would be to include front end standardisation of data collected with the devolved nations and the EU. The reasoning behind this is that the fisheries catches will be broadly similar across the North-East Atlantic region, the greatest way to strengthen the application of AI and ML is to ensure that the imagery collected used for training the AI or ML tool meets a minimum standard. Therefore, this investment in developing and training AI, can be shared across multiple users regionally, and the source of information used to collect a sufficient amount of data produced in a shorter timeframe, making it available sooner.

7.3.2 Data transmission

All stakeholder requirements point to a preference for port-based cellular or Wi-Fi transmission of REM data over courier delivered hard drives. This will incur fewer costs and reduced logistical complications of managing the receipt, delivery, download, processing, cleaning and redistribution of hard drives from all the vessels. Additionally, as highlighted in the ICES Annual Science Conference, Theme H, (9th September 2021) the courier exchange method is one of the more problematic limiting factors to wide scale REM implementation still to be addressed.

Port based Wi-Fi would require good fibre connections and multiple terminal access points across the port. This will require significant investment in infrastructure nationally, in addition to maintaining a port-based Wi Fi network around the country. Therefore, we would recommend an approach which utilises cellular networks, pushing much of the infrastructure requirements back on the cellular network providers. This approach should at least be considered initially while ports explore their capacity to handle the large data volumes collected by fishers in addition to data transmission infrastructure requirements, a data upload protocol and platform will need to be designed for fishers to remotely access the Wi-Fi or cellular network and upload the data with minimal intervention.

In order to do this effectively, we would recommend a remote cloud-based solution to manage the data collection and storage requirements. Such a system can be made specific to each fishing vessel (done through the fishing vessels registration and licence) and designed so that data collection is conducted through background synchronisation of fishing activity with the fishers' file.

7.3.3 Data access

Fishers would ideally have direct access to their own data to document fishing effort and catch records. The infrastructure would include functionality that stores all of the fisher's REM data alongside the national fisheries management tools. An audit system can be applied to show the fishers and fisheries managers the representative volume of their catch information that is used and analysed. This shows the fishers the value and worth of their data and that the data is being used properly and transparently, which helps maintain fisher investment in the programme.

7.4 Equipment audit and certification

A regular or annual certification and inspection/audit programme is recommended to ensure compliance with the data collection needs for REM by fisheries managers, as well as ensuring the maintenance and serviceability of the REM equipment is being satisfactorily performed. Such a cost hasn't been included within our design – but depending on the approach does highlight some institutional knowledge and training requirements for staff or independent contractors and should be rolled into the management plan.

In best practice examples of current REM programmes, an individual Vessel Monitoring Plan (VMP) is prepared prior to installation and completed during and afterwards in order to adapt the installation to the individual vessel characteristics and optimize the quality of data recorded. The VMP is subsequently updated whenever a change to the REM system or change to the design (e.g., processing area) of the vessel is made, thus a current record of all deployed systems is maintained. Individual VMPs would need to be set up for each vessel receiving REM hardware in order to operate in line with current best practices.

A VMP serves as the documentation used to describe the project objectives, EM system responsibilities, vessel responsibilities, safety information, any relevant protocols, system components, data collection, feedback, and project contacts for each of the involved vessels along with any changes to the above during monitoring. Any changes to the REM system should be fully documented with regards to version numbers, rationale for changes, date, and personnel responsible.

The VMP should be made in cooperation between the vessel owner or master and the regulatory authorities with the REM vendor involved in order to deploy the system as efficiently as possible. This initial stage is often done in conjunction with an initial survey of the vessel, though this varies by programme. The main purpose of such a survey is to be able to determine an optimal camera/sensor layout for that individual vessel prior to the installation of the system. The input of the operator prior to the installation of the system is key to efficiently rolling out a programme as the information provided by them allows the final tailoring of the required pieces of equipment per vessel, e.g. will 2 cameras be sufficient or will a third be required due to a specific vessel design.

7.5 Fleet modernisation – an integrated design and benefits to the stakeholders

We would recommend an integrated design into the application of REM, with a long-term goal of tying together multiple existing data streams, policy, and management regimes into one platform. Such an approach would look to modernised fisheries management, using this as the mechanism and platform to integrate a number of services into one standardised intelligent fisheries management system. By example, this system could include functionality for managing fisheries licences, quotas, determining and assigning catch volumes to a vessel. The application of such as system will drive science led stock assessments and offer the potential to enact near-real time changes to preserving the stock and managing the quota geospatially.

7.5.1 The MMO, IFCAs and fisheries managers

The MMO and IFCAs stand to benefit from REM through machine learning, AI, and software analytical tools, which can plot fishery positions in real-time; or retrospectively provide an auditable record; for fisheries managers and enforcement to act on real-time alerts to fisher activity with respect to spatial or temporal closures of areas to fishing effort; or provide an evidence trail to support prosecution of fishers identified to be non-compliant with regulations. Specifically, this can allow a targeted approach to spatial and temporal fisheries management in relation to protecting sensitive species and habitats and in contributing to achieving GES in the wider seas. This could benefit fishers where impacts and risks are considered to be lower, and not penalising them with blanket bans across the inshore fishery.

Fisheries managers should benefit from a better way of working, through mechanisms for more targeted information collection and by generating value from the information shared. Such developments include, inter alia: real time data collection and display of fishing behaviour, real-time monitoring of area closures, stock indicators, real time collection of catches – overlaying catches against indicators by area, enhanced quota management processes (e.g., drill down / cross-cutting quota management dashboards).

Fisheries authorities would benefit from information streams and mechanisms that provide them with the best available information to verify landings against catches, ensuring resource planning is as effective as possible with mobile resources being able to be deployed to maximise the number of inspections or to target high risk vessels, ports or nodes in the supply chain. The MMO are generally aware of the more non-compliant and high-risk fishing vessels / sectors in the fisheries and will greatly benefit from this additional form of cost-efficient monitoring to support regulation and licencing of vessels.

Specifically, for the inshore, each of the IFCAs stand to benefit from greater data gathering on their inshore fisheries, covering catches, fishing effort and practices to ultimately support sustainable management. Application of REM to the inshore fleet will be vastly more successful through support of the IFCAs, therefore, it is also important to recognise how they stand to benefit from its implementation, and how this can be used to meet each of IFCAs high level objectives.

7.5.2 CEFAS, fisheries scientists and scientific agencies

Fisheries scientists should equally be able to benefit from the improved near-real-time data collection and sharing possibilities identified. It is hoped that by enabling a visualisation and understanding of information collected across the sector this will lead to an increased understanding and ability for conflict resolution between fishers, managers, scientists etc.

Fisheries scientists stands to gain from the scientific evidence and data collection of impact of fishing effort on habitats. Positional recording, speed, track and recorded bottom times provide an indication of fishing effort, and impact on the marine ecosystem measurable against the GES. The application cameras onboard and under the surface provides evidence on the impact of trawling on the seafloor, recording the exact bottom-type being fished on, and documenting any rubble brought to the surface by the nets. Where data on marine bottom-types has been limited, and predictors used to map habitats around England, the application of cameras in this fashion can support the validation of habitat types by location.

There are a number of benefits of this approach, foremost REM technologies which supply live, near real-time or automated transmission of data to a central data hub without additional effort on the part of the fishers will increase efficiencies and decrease costs in running a REM programme. AI technical solutions would also typically be applied to refine data analysis of fishing time, patterns and catch quantification, enabling scientists and fisheries managers to focus on the real time issues such as the analysis of stock management and provision of timely scientific advice. Specifically, the role of cameras onboard these fisheries can assist with species identification at the point of catch through machine learning and recognition tools. This will be particularly useful for data poor and aggregated species fisheries.

7.5.3 Fishers and Industry

Fishers and Industry will benefit from better management practices, rewarding vessels shown to be compliant with fisheries regulations and not hindering low risk métiers with blanket bans to the sector. The application of REM can provide greater traceability for catches, which may provide a market incentive through increased value of landings, where species can be fully documented. Incentives may also be available through improved data sharing in a digitalised fishery., This will strengthen the data gathering and can be done through minimal additional effort on the part of the fishers, some of whom will value greater understanding and insight into their fishing environment and will benefit from increased sustainability and growing MSY of their target stocks, while others will benefit from data that justify their fishing effort.

While not immediately apparent as a benefit of REM for fishers, the increased data gathered and recommended central coordination of data can help move fishing toward a digitalised method of working. This could encompass the application of satellite and remote sensing data to provide many indirect benefits for fishers. For instance, chlorophyll-a concentrations, indicating phytoplankton blooms and impacts to attributed species of fisheries interest such as herring, sand eel and mackerel, which feed on planktonic species, these could include for example predictive models. Such information can be fed back to fishers in near real-time for a more targeted approach to harvesting these species, reducing searching and transit costs. Likewise, pre-catch intelligence gathering could be used to provide fishers information on where species are located and where not to fish, due to low catch rates, high impact of fishing or real-time interactions with PTE species. Such an example could include to ban métiers which will impact the benthic environment during periods of spawning of commercially important species, benefiting fishers indirectly through safeguarding stock recruitment.

Another potential benefit to raise is giving fishers their own data on fishing grounds and location of their stocks. Competing interests for marine space have seen fishers relocated off of traditional fishing grounds, putting the onus on fishers to prove that an area is commercially important to them. The data collected by REM will enable fishers to evidence their fishing effort, better able to dispute commercial losses over fisheries area closures.

7.6 National bargaining and leveraging

The directly incurred costs for purchasing the REM technologies covering the unit price, installation, and annually recurring fees (maintenance, licencing, transmission and technical support) over a five-year lifespan, were determined in this study. It is anticipated that after five years, the equipment will likely need updating or replacing. Some REM Vendors offer a leasing system within their budget, while upfront this may be a more expensive option, where the companies leasing the equipment look to make more money over the products lifespan, an agreement can be reached directly with the vendors to include a package to update the technologies every five years, or include other additional services therein, driving down the ultimate cost of the programme. Thereby keeping the costs for these upgrades lower than replacing the unit on the whole. As technologies improve, this may be a viable option for maintaining an up-to-date network and data collection platform. Such advances in telecommunications can then be capitalised on a lot sooner, thereby enabling much of the data (including live video outputs) to be transmitted to fisheries managers in real time.

One suggestion put forward by the stakeholders was that "*the UK could deliver a fully funded REM programme by diverting a percentage of the current national surface vessel budget. This would allow for technology to be introduced at greater speed and would remove the key resistance from fishers as the systems would be fully funded.*" It was assumed that the respondent meant surface compliance monitoring vessels. Such an approach, were it viable, would reduce the overall cost of the programme (when including fisher contributions to buying and maintaining equipment) as a much more cost-effective solution can be sought through leveraging the national bargaining power. In addition, cost recovery and reduction mechanisms can be incorporated in the REM programme through engaging directly with the vendor, these may include but are not limited to:

- Onboard data processing (including capture and storage) and priority reporting (reducing the analysis costs);

- Integrated and dedicated video and data review software;
- Licencing (Master licence availability) for video review software;
- Leasing of hardware or whole-sale mechanisms for Defra/MMO/vessel owners; and
- Integration of additional or existing technologies.

Ultimately, who purchases the cameras / services determines the most appropriate designs for integrated packages with the Vendors – therefore there is much to be gained through national scale bargaining. Consideration will need to be given to the approach to REM and how this will be trialled and rolled out across different ownership methodologies. In addition, voluntary or mandated approaches to REM will include numerous complications in determining the best design to finance and implement a REM programme nationally. This would be a substantial project in its own right and has not been included here. However, at a cursory level such approaches could include:

- National purchase (government ownership) and leasing approach to vessel operators;
- National purchase (government ownership) and cost recovery options through vessel licences;
- Operator purchase (ownership) and grant based investment schemes; and,
- Operator purchase (ownership) and an agreed short-list of approved vendors with fixed (low cost) rates.

Each of the above approaches have their merits and drawbacks. Therefore, it would be worth investing in determining which of these approaches best works for English fisheries management, and ultimately fulfils national fisheries policy objectives.

8. Summary

To achieve good environmental status in UK marine environment, the UK government and Devolved Administrations established commitments in the UK Marine Strategy Regulations of 2010, taking an ecosystems-based approach to meet the biodiversity targets set to protect marine habitats and species by the end of 2020. As identified in the UK Marine Strategy Part One report (Defra, 2019) commercial fishing was the most significant pressure preventing the achievement of GES in English seas. In response to missing this target of GES in the marine environment by 2020, the UK Government has committed to achieving GES for English seas by 2024; and explicitly linked the delivery of GES to the Ecosystem Objective as set out within the Fisheries Act 2020.

Remote electronic monitoring (REM) is a tool which can be applied to strengthen English fisheries management, and enable fisheries managers, regulators, and scientists to take precautions against fishing impacts on the marine environment. Defra's (2018) Fisheries White Paper identified REM as both a useful tool to promote compliance at sea for all vessels fishing in UK waters; as well as a mechanism to improve data gathering to strengthen Defra's scientific evidence base.

While REM does not reduce the impact of fishing on the environment directly, nor does it reduce the risk that a fishing vessel may present against achieving GES it does provide the means for fishing effort to be accurately and independently accounted for, audited, and validated. In this way, managers, scientists, and regulators are able to take an evidence-based approach to better manage the risk of fishing pressures impacting GES, and account for fishing impact with a high degree of accuracy across all fishing vessels nationally.

There is an opportunity now for the UK Government to develop new policies that incorporates REM systems on a risk-based approach that will:

(i) help promote compliance;
(ii) collect data for data-poor fisheries;
(iii) protect sensitive species; and
(iv) contribute to achieving GES.

This will help achieve the UK Government's ambitions as set out in the objectives within the Fisheries Act including:

i. to manage fish activities using an ecosystem-based approach to ensure that their negative impacts on marine ecosystem are minimised and where possible, reversed;
ii. to avoid and reduce discards of commercial species and other bycatch;
iii. to ensure all catches are recorded; and
iv. to minimise and eliminate bycatch of sensitive species.

As identified in the delivery of this project, and the production of the modular framework, it is practically and financially feasible to take a nation-wide approach to implementing REM on all English fishing vessels, with a multitude of benefits available to English fisheries stakeholders, in addition to the recognised contributions toward fulfilling objectives on GES and fisheries management. Immediate implementation and data gathering through REM should be a priority for the highest risk vessels. This will enable appropriate fisheries management measures and regulation to be put in place, leading to the most significant progress in minimising impacts on the marine environment and contributing to the commitment for GES in English seas by 2024. REM will need to be implemented taking a fleet-wide approach to ensure that fisheries impact on the environment are correctly accounted for. Therefore, recommendations have been put forward to guide Defra’s approach to rolling out a national REM programme.

Implementation of a national REM programme does come with a number of challenges, primarily surrounding resource, infrastructure and capacity requirements to be able to process and act on the data collected. Significant investment in both infrastructure and human resources will be required to translate the data gathered into actionable information which can be used to strengthen the scientific evidence base for fishing impacts, as well as bolster national fisheries enforcement efforts to combat illegal, unregulated, and unreported fishing.

9. Appendices

Appendix 1 Classification of the top 15 métiers investigated in this project.

Level 1	Level 2	Level 3	Level 4	Number of vessels			
Activity	Gear classes	Gear groups	Gear type	EU	UK >10m	UK <10m	Total
Fishing	Dredges	Dredges	Boat dredge (DRB)	189	141	82	412
	Traps	Traps	Pots and traps (FPO)	115	279	2298	2692
	Nets	Nets	Gillnets (GN)	-	14	406	420
			Drift net (GND)	13	3	58	74
			Set gillnet (GNS)	113	15	120	248
			Trammel net (GTR)	75	2	49	126
	Hooks and Lines	Rods and Lines	Hand and pole lines (LHP)	29	4	335	368
			Hooks and lines (LX)	-	1	113	114
		Longlines	Longlines (LL)	1	6	56	63
			Set longlines (LLS)	101	11	10	122
	Trawls	Bottom trawls	Bottom otter trawl (OTB)	511	357	397	1265
			Multi-rig otter trawl (OTT)	47	65	4	116
			Beam trawl (TBB)	237	88	63	388
			Nephrops trawl (TBN)	-	25	21	46
		Pelagic trawl	Midwater otter trawl (OTM)	110	30	6	146
	Dredges	Dredges	Hand dredges (DRH)	2	-	4	6
			Mechanized dredge (DRM)	2	-	-	2
			Mechanized suction dredge (HMD)	3	4	1	8
	Traps	Traps	Traps (FIX)	-	-	1	1
	Nets	Nets	Encircling gillnets (GNC)	1	1	2	4
			Combined gillnets-trammel nets (GTN)	8	-	-	8
			Surrounding nets without purse lines (LA)	-	1	-	1
			Boat operated lift nets (LNB)	1	-	-	1
	Hooks and Lines	Rods and Lines	Mechanised lines and pole-and-lines (LHM)	2	-	37	39
			Trolling lines (LTL)	4	-	1	5
		Longlines	Drifting longlines (LLD)	25	1	-	26
	Trawls	Bottom trawls	Pair bottom trawl (PTB)	-	27	-	27
			Bottom trawl (TB)	3	-	-	3
			Otter trawls (not specified) (OT)	2	-	-	2
			OTS	-	6	5	11

		Pelagic trawl	Mid-water pair trawl (PTM)	23	5	1	29
		Trawls	TBS	1	-	-	1
			Trawls (TX)	1	-	-	1
	Seines	Surrounding nets	Purse seines (PS)	9	6	1	16
		Seines	Fly shooting seine (SSC)	17	13	2	32
			Beach and boat seine (SV)	3	-	2	5
			Beach seines (SB)	-	-	1	1
			Anchored seine (SDN)	25	4	1	30
			Pair seine (SPR)	4	-	-	4
			Seine nets (not specified) (SX)	1	-	-	1
			Gear (MIS)	-	1	25	26
			No gear (NK)	-	1	24	25
			Sub-total	**1541**	**1041**	**4018**	**6600**
			Grand total	**1678**	**1111**	**4126**	**6915**
			% Of fleet to be assessed	**91.84%**	**93.70%**	**97.38%**	**95.44%**

Appendix 2 National and international distribution of fishing vessels across the classified métiers

Region (classified by)		DRB	FPO	GN	GND	GNS	GTR	LHP	LL	LLS	LX	OTB	OTM	OTT	TBB	TBN	PTM	PTB	Total
EU (flag state)	BEL					2						4			58				64
	DEU		1			2				2		24	2		20				51
	DNK					18						68	11		12				109
	ESP									60		31							91
	FRA	102	72		1	58	73	1	1	28		280	14	36	15		22		703
	IRL	90	52		12	26	2	7				89	65		11	2	1		357
	LTU												2						2
	NLD		2			4		20				13	7	11	121				178
	POL											1	1						2
	PRT		2			3		1		11		8							25
	SWE												8						8
	Total	**192**	**129**	**0**	**13**	**113**	**75**	**29**	**1**	**101**	**0**	**518**	**110**	**47**	**237**	**2**	**23**	**0**	**1590**

		<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	<10m	>10m	Total
England (home port)	Cornwall	7	4	140	15	75	6	6		11	6		2	159	2	5		2		6		24	13	1			1	1	15				2		1	437	67	504
	Devon and Severn	11	25	93	25	37		5		17				56	1	6			1	22		23	17	1	1		5	4	26			1				276	101	377
	Eastern	1	5	81	11	8		9	1	6		2		1		10		3				19	7			1		9	31							150	55	205
	Isles of Scilly			11	1	1				1	1			2								3														18	2	20
	Kent and Essex	6	14	38	2	27	1	21	2	18		9		2		1	1			3		38	3			2		4	1		1					169	25	194
	North Eastern	2	3	105	27	30	1			1		2		1		3	1		1			13	9	1	1		1		4	1	1				8	159	57	216
	North Western		2	14	7	6		6		3	1	2							1			27	13	1				14							1	73	25	98
	Northumberland			56	9	12	1			1	3	1		1			1		3			22	18				2		1	3	2					96	40	136
	Southern	25	2	69	6	33	1			10		2		6		6				23		28	1	1												203	10	213
	Sussex	1	4	57	9	48	1	7		10		21		7		5				16		34	4					7	4							213	22	235
	Sub-total	**53**	**59**	**664**	**112**	**277**	**11**	**54**	**3**	**78**	**11**	**39**	**2**	**235**	**3**	**36**	**3**	**5**	**6**	**70**	**0**	**231**	**85**	**5**	**2**	**3**	**9**	**39**	**82**	**4**	**4**	**1**	**2**	**0**	**10**	**1794**	**404**	**2198**
	Total	**112**		**776**		**288**		**57**		**89**		**41**		**238**		**39**		**11**		**70**		**316**		**7**		**12**		**121**		**8**		**3**		**10**				**2198**
UK (home port)	Scotland	8	49	831	78	25	1			8	3			36		2	1	2	5			61	142	1	20		34	9	2	7	13		1		17	990	366	1356
	Wales	3	4	171	17	35		4		27		7		24		8		2		24		23	4					7	3				2			335	30	365
	Northern Ireland	5	11	136	8	3				1		1				1						22	62		6		1	1		2	5					172	93	265
	Channel Islands	1		100	10	7	1			1				9		5	2			8		6	5		1								1			137	20	157
	Sub-total	**17**	**64**	**1238**	**113**	**70**	**2**	**4**	**0**	**37**	**3**	**8**	**0**	**69**	**0**	**16**	**3**	**4**	**5**	**32**	**0**	**112**	**213**	**1**	**27**	**0**	**35**	**17**	**5**	**9**	**18**	**1**	**3**	**0**	**17**	**1635**	**508**	**2143**
	Total	**81**		**1351**		**72**		**4**		**40**		**8**		**69**		**19**		**9**		**32**		**325**		**28**		**35**		**22**		**27**		**3**		**17**				**2143**
?	Unknown	11	16	387	49	59	1			5	1	2		31	1	4		1		11	1	51	54		2	1	21	7	1	7	2					577	149	726
	Total	**27**		**436**		**60**		**0**		**6**		**2**		**32**		**4**		**1**		**12**		**105**		**2**		**22**		**8**		**9**		**0**		**0**				**726**
	Grand total	**412**		**2692**		**420**		**74**		**248**		**126**		**368**		**63**		**122**		**114**		**1264**		**147**		**116**		**388**		**46**		**29**		**27**				**6657**

# of vessels	1 - 10	▨
	11 - 20	▨
	21 - 50	▨
	51 - 100	▨
	101 - 200	▨
	200+	▨

Table 113. Distribution of DRB vessels

Region		DRB	
EU	FRA	102	
	IRL	90	
	Total	**192**	
		<10m	>10m
England	Cornwall	7	4
	Devon and Severn	11	25
	Eastern	1	5
	Kent and Essex	6	14
	North-Eastern	2	3
	North-Western	-	2
	Southern	25	2
	Sussex	1	4
	Sub-total	**53**	**59**
	Total	**112**	
UK	Scotland	8	49
	Wales	3	4
	Northern Ireland	5	11
	Channel Islands	1	-
	Sub-total	**17**	**64**
	Total	**81**	
?	Unknown	11	16
	Total	**27**	
	Grand total	**412**	

Table 114. Distribution of FPO vessels

Region		DRB	
EU	DEU	1	
	FRA	72	
	IRL	52	
	NLD	2	
	PRT	2	
	Total	**129**	
		<10m	>10m
England	Cornwall	140	15
	Devon and Severn	93	25
	Eastern	81	11
	Isles of Scilly	11	1
	Kent and Essex	38	2
	North-Eastern	105	27
	North-Western	14	7
	Northumberland	56	9
	Southern	69	6
	Sussex	57	9
	Sub-total	**664**	**112**
	Total	**776**	
UK	Scotland	831	78
	Wales	171	17
	Northern Ireland	136	8
	Channel Islands	100	10
	Sub-total	**1238**	**113**
	Total	**1351**	
?	Unknown	387	49
	Total	**436**	
Grand total		**2692**	

Table 115 Distribution of GN and GNS vessels

Region		GN		GNS	
EU	BEL	-		2	
	DEU	-		2	
	DNK	-		18	
	FRA	-		58	
	IRL	-		26	
	NLD	-		4	
	PRT	-		3	
	Total	**0**		**113**	
		<10m	>10m	<10m	>10m
England	Cornwall	75	6	11	6
	Devon and Severn	37		17	
	Eastern	8		6	
	Isles of Scilly	1		1	1
	Kent and Essex	27	1	18	
	North-Eastern	30	1	1	
	North-Western	6		3	1
	Northumberland	12	1	1	3
	Southern	33	1	10	
	Sussex	48	1	10	
	Sub-total	**277**	**11**	**78**	**11**
	Total	**288**		**89**	
UK	Scotland	25	1	8	3
	Wales	35		27	
	Northern Ireland	3		1	
	Channel Islands	7	1	1	
	Sub-total	**70**	**2**	**37**	**3**
	Total	**72**		**40**	
?	Unknown	59	1	5	1
	Total	**60**		**6**	
Grand total		**420**		**248**	

Table 116 Distribution of GND vessels

Region		GND	
EU	FRA	1	
	IRL	12	
	Total	**13**	
		<10m	>10m
England	Cornwall	6	-
	Devon and Severn	5	-
	Eastern	9	1
	Isles of Scilly		
	Kent and Essex	21	2
	North-Western	6	-
	Sussex	7	-
	Sub-total	**54**	**3**
	Total	**57**	
UK	Wales	4	-
	Sub-total	**4**	**0**
	Total	**4**	
Grand total		**74**	

Table 117 Distribution of GTR vessels

Region		GTR	
EU	FRA	73	
	IRL	2	
	Total	**75**	
		<10m	>10m
England	Cornwall	-	2
	Eastern	2	-
	Kent and Essex	9	-
	North-Eastern	2	-
	North-Western	2	-
	Northumberland	1	-
	Southern	2	-
	Sussex	21	-
	Sub-total	**39**	**2**
	Total	**41**	
UK	Wales	7	-
	Northern Ireland	1	-
	Sub-total	**8**	**0**
	Total	**8**	
?	Unknown	2	-
	Total	**2**	
Grand total		**126**	

Table 118 Distribution of LHP vessels

Region		LHP	
EU	FRA	1	
	IRL	7	
	NLD	20	
	PRT	1	
	Total	**29**	
		<10m	>10m
England	Cornwall	159	2
	Devon and Severn	56	1
	Eastern	1	-
	Isles of Scilly	2	-
	Kent and Essex	2	-
	North-Eastern	1	-
	Northumberland	1	-
	Southern	6	-
	Sussex	7	-
	Sub-total	**235**	**3**
	Total	**238**	
UK	Scotland	36	-
	Wales	24	-
	Channel Islands	9	-
	Sub-total	**69**	**0**
	Total	**69**	
?	Unknown	31	1
	Total	**32**	
Grand total		**368**	

Table 119 Distribution of LX vessels

Region		LX	
EU	-	-	
	Total	**0**	
		<10m	>10m
England	Cornwall	6	-
	Devon and Severn	22	-
	Kent and Essex	3	-
	Southern	23	-
	Sussex	16	-
	Sub-total	**70**	**0**
	Total	**70**	
UK	Wales	24	-
	Channel Islands	8	-
	Sub-total	**32**	**0**
	Total	**32**	
?	Unknown	11	1
	Total	**12**	
Grand total		**114**	

Table 120 Distribution of LL and LLS vessels

Region		LL		LLS	
EU	DEU	-		2	
	ESP	-		60	
	FRA	1		28	
	PRT	-		11	
	Total	**1**		**101**	
		<10m	**>10m**	**<10m**	**>10m**
England	Cornwall	5	-	2	-
	Devon and Severn	6	-	-	1
	Eastern	10	-	3	-
	Kent and Essex	1	1	-	-
	North-Eastern	3	1	-	1
	North-Western	-	-	-	1
	Northumberland	-	1	-	3
	Southern	6	-	-	-
	Sussex	5	-	-	-
	Sub-total	**36**	**3**	**5**	**6**
	Total	**39**		**11**	
UK	Scotland	2	1	2	5
	Wales	8	-	2	-
	Northern Ireland	1	-	-	-
	Channel Islands	5	2	-	-
	Sub-total	**16**	**3**	**4**	**5**
	Total	**19**		**9**	
?	Unknown	4	-	1	-
	Total	**4**		**1**	
	Grand total	**63**		**122**	

Table 121 Distribution of bottom otter trawl (OTB) and multi-rig otter trawls (OTT) vessels

Region		OTB		OTT	
EU	BEL	4		-	
	DEU	24		-	
	DNK	68		-	
	ESP	31		-	
	FRA	280		36	
	IRL	89		-	
	NLD	13		11	
	POL	1		-	
	PRT	8		-	
	Total	**518**		**47**	
		<10m	**>10m**	**<10m**	**>10m**
England	Cornwall	24	13	-	1
	Devon and Severn	23	17	-	5
	Eastern	19	7	1	-
	Isles of Scilly	3	-	-	-
	Kent and Essex	38	3	2	-
	North-Eastern	13	9	-	1
	North-Western	27	13	-	-
	Northumberland	22	18	-	2
	Southern	28	1	-	-
	Sussex	34	4	-	-
	Sub-total	**231**	**85**	**3**	**9**
	Total	**316**		**12**	
UK	Scotland	61	142	-	34
	Wales	23	4	-	-
	Northern Ireland	22	62	-	1
	Channel Islands	6	5	-	-
	Sub-total	**112**	**213**	**-**	**35**
	Total	**325**		**35**	
?	Unknown	51	54	1	21
	Total	**105**		**22**	
	Grand Total	**1264**		**116**	

Table 122 Distribution of OTM and PTM vessels

		OTM		PTM	
EU	DEU	2		-	
	DNK	11		-	
	FRA	14		22	
	IRL	65		1	
	LTU	2		-	
	NLD	7		-	
	POL	1		-	
	SWE	8		-	
	Total	**110**		**23**	
		<10m	**>10m**	**<10m**	**>10m**
England	Cornwall	1	-	-	2
	Devon and Severn	1	1	1	-
	North-Eastern	1	1	-	-
	North-Western	1	-	-	-
	Southern	1	-	-	-
	Sub-total	**5**	**2**	**1**	**2**
	Total	**7**		**3**	
UK	Scotland	1	20	-	1
	Northern Ireland	-	6	-	2
	Channel Islands	-	1	-	-
	Sub-total	**1**	**27**	**0**	**3**
	Total	**28**		**3**	
?	Unknown	-	2	-	-
	Total	**2**		**0**	
	Grand total	**147**		**29**	

Table 123 Distribution of TBB and PTB vessels

		TBB		PTB	
EU	BEL	58		-	
	DEU	20		-	
	DNK	12		-	
	FRA	15		-	
	IRL	11		-	
	NLD	121		-	
		237		**0**	
		<10m	>10m	<10m	>10m
England	Cornwall	1	15	-	1
	Devon and Severn	4	26	-	-
	Eastern	9	31	-	-
	Kent and Essex	4	1	-	-
	North-Eastern	-	4	-	8
	North-Western	14	-	-	1
	Northumberland	-	1	-	-
	Sussex	7	4	-	-
		39	**82**	**-**	**10**
		121		**10**	
UK	Scotland	9	2	-	17
	Wales	7	3	-	-
	Northern Ireland	1	-	-	-
		17	**5**	**0**	**17**
		22		**17**	
	Unknown	7	1	-	-
		8		**0**	
		388		**27**	

Table 124 Distribution of TBN vessels

		TBN
EU	IRL	2
		2

		<10m	>10m
England	Kent and Essex	-	1
	North-Eastern	1	1
	Northumberland	3	2
		4	**4**
		8	

UK	Scotland	7	13
	Northern Ireland	2	5
		9	**18**
		27	

?	Unknown	7	2
		9	

	46

Appendix 3 Search terminology used in the Objective 1 literature review.

Item	Search term(s)
Descriptor 1. **Biodiversity is maintained**	‘Biodiversity’ AND ‘Mortality rate’ AND ‘Population abundance’ AND ‘Habitat’
Descriptor 3. **The population of commercial fish species is healthy**	‘Stock status’ AND ‘MSY’ AND ‘Mortality rate’ AND ‘Age and size distribution’
Descriptor 4. **Elements of food webs ensure long-term abundance and reproduction**	‘Food-web’ AND ‘abundance’ AND ‘Reproduction’ AND ‘trophic’
Descriptor 6. **The sea floor integrity ensures functioning of the ecosystem**	‘Seafloor integrity’ AND ‘benthic habitat’ AND ‘physical disturbance’
Descriptor 10. **Marine litter does not cause harm**	‘Marine litter’ OR ‘ALDFG’ OR ‘ghost gear’ OR ‘Marine plastics’
Descriptor 11. **Introduction of energy (including underwater noise) does not adversely affect the ecosystem**	‘Underwater noise’ OR ‘noise pollution’
Additional risk factor 1. **Commercial fish bycatch (Discards + choke species)**	‘Discards’ AND ‘choke species’
Additional risk factor 2. **Protected (ETP) species bycatch**	‘Protected species’ OR ‘ETP’ AND ‘bycatch’
Additional risk factor 3. **Non-compliance against minimum landing size and quota species (e.g., misreporting)**	‘non-compliance’ OR ‘IUU’ AND ‘quota’ AND ‘minimum landing size’ OR ‘Minimum conservation reference size’
Additional risk factor 4. **Non-compliance against area restrictions e.g., gear type / marine protected areas**	‘non-compliance’ OR ‘IUU’ AND ‘Area restriction’ OR ‘Marine protected areas’ OR ‘MPA’ OR ‘protected features’
Additional risk factor 5. **Essential fish habitat**	‘Essential fish habitat’ AND ‘nursery’ AND ‘spawning’
Additional risk factor 6. **Displacement of fishing activity due to presence of offshore wind farm**	‘Displacement’ AND ‘Windfarm’ AND ‘Cables’ AND ‘co-existence’ AND ‘offshore renewables’
Boat dredge (DRB)	‘Boat dredge’ AND ‘Molluscs’
Pots and traps (FPO)	‘Pots and Traps AND ‘Crustaceans’
Gillnets (GN)	‘Gillnets’ AND ‘Demersal fish’ AND ‘Pelagic fish’
Drift net (GND)	‘Driftnet’ AND ‘Pelagic fish’
Set gillnet (GNS)	‘Set gillnet’ AND ‘Demersal fish’ AND ‘Pelagic fish’
Trammel net (GTR)	‘Trammel net’ AND ‘Demersal fish’
Hand and pole lines (LHP)	‘Hand and pole lines’ AND ‘finfish’
Hooks and lines (LX)	‘Hooks and lines’ AND ‘Demersal fish’ AND ‘Pelagic fish’
Longlines (LL)	‘Longlines’ AND ‘Demersal fish’
Set longlines (LLS)	‘Set longlines’ AND ‘Demersal fish’
Bottom otter trawl (OTB)	‘Bottom otter trawl’ AND ‘Demersal fish’ AND ‘Crustaceans’ AND ‘Molluscs’
Multi-rig otter trawl (OTT)	‘Multi-rig otter trawl’ AND ‘Demersal fish’ AND ‘Crustaceans’ AND ‘Molluscs’

Beam trawl (TBB)	‘Beam trawl’ AND ‘Demersal fish’ AND ‘Cephalopods’
Nephrops trawl (TBN)	‘Nephrops trawl’ AND ‘Crustaceans’
Midwater otter trawl (OTM)	‘Midwater trawl’ AND ‘Pelagic fish’

Appendix 4 Complete list of questions and sub-questions used in the survey.

Question
Q4. How would you rank the importance of the following descriptors for determining fishing impact in the UK marine environment (highest impact to lowest)? • *Descriptor 1. Biodiversity is maintained,* • *Descriptor 3. The population of commercial fish species is healthy,* • *Descriptor 4. Elements of food webs ensure long-term abundance and reproduction,* • *Descriptor 6. The sea floor integrity ensures functioning of the ecosystem,* • *Descriptor 10. Marine litter does not cause harm,* • *Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem*
Q5. Which of the following potential uses of REM technology would you consider most important within the fishing industry? Rank these in order of importance. • *Determining where vessels operate* • *Identifying (video identification) of what has been caught* • *Documenting malpractice for enforcement purposes* • *Strengthening scientific (biological) data collection for sustainable stock management* • *Maximising data value* • *Improving fisher safety and maximising fisher benefits*
Q6. Which of the following factors would you consider most important in determining the risk posed by fishing activity? Rank these in order of importance. • *Assessing the fishing métiers by number and size of vessel* • *Assessing the vulnerability of marine habitats and fishing grounds* • *Assessing the impact of the different fishing gear types to the marine environment* • *Assessing the impact of fishing practices (i.e., bycatch and discards) on stocks* • *Assessing the impact of English fishing vessels operating in the English inshore (sub 12nm area)* • *Assessing the impact of devolved nation and foreign fleets operating in the English inshore (sub 12nm area)*
Q7. Please indicate how you would preference the below application of REM. Please score each sub question as - 1 = very important or 5= least important. • *Minimal impact to fishermen* • *Maximising benefits to fishers* • *Maximising benefits to fisheries managers / enforcement / regulators* • *Maximising scientific data collection*
Q8. Please use this text box to include any other stipulations you would want to see considered, additionally, you may use this space to provide comment and include your thinking.
Q10. Based on your own experiences, please feel free to use the below text box to provide us with anecdotal information about the fisheries you are particularly concerned about. *We are specifically looking to collate information on concerns regarding discarding, ETP species bycatch, misreporting and non-compliance with fisheries regulations. We will use this information to inform the risk assessment where possible. Please note, all responses will remain confidential and will only be used in informing the risk assessment process.*

Question
Q12. Please indicate which technologies you feel should be applied to each métier (Select which apply to meet your priorities), for vessels under 10m in length. • *Above Surface Data Capture - Gear Sensors* • *Below Surface Data Capture - Gear Sensors* • *Bycatch mitigation technologies sensors* • *Cameras* • *RFID Tagging* • *Unsure / no answer* • *VMS / AIS / GPS* • *Weight Scales - biological data collection*
Q13. Please select which of the following technology capabilities should be included with each Métier, for vessels under 10m in length. • *Independent of vessel systems* • *Live reporting capabilities* • *Remote access to cameras / control box* • *Remote data storage* • *Ruggedised, secure and encrypted* • *Sufficient internal storage capacity for days / weeks* • *Supports AI / machine learning software* • *Uninterruptable power supply* • *Unsure / no answer*
Q14. We value your inputs, if you feel something has been missed off this list, then please include any additional thoughts or comments on Q12&13 in this long free text box.
Q15. Please indicate which technologies you feel should be applied to each métier (Select which apply to meet your priorities), for vessels over 10m in length. • *Above Surface Data Capture - Gear Sensors* • *Below Surface Data Capture - Gear Sensors* • *Bycatch mitigation technologies Sensors* • *Cameras* • *RFID Tagging* • *Unsure / no answer* • *VMS / AIS / GPS* • *Weight Scales - biological data collection*
Q16. Please select which technology capabilities should be included with each Métier, for vessels over 10m in length. • *Independent of vessel systems* • *Live reporting capabilities* • *Remote access to cameras / control box* • *Remote data storage* • *Ruggedised, secure and encrypted* • *Sufficient internal storage capacity for days / weeks* • *Supports AI / machine learning software* • *Uninterruptable power supply* • *Unsure / no answer*
Q17. We value your inputs, if you feel something has been missed off of this list, then please include any additional thoughts or comments on Q15&16 in this long free text box.
Q18. Please indicate which type of connection you think will work best in the English inshore fisheries. Please score each sub question as - 1 = very important or 5= least important. • *Satellite uplink*

Question
• *Cellular/4G* • *Port only (Wi-Fi)* • *Port only (Hard drive exchange)*
Q19. Please use the below free-text box to include your thinking with respect to on Q18, or if you would recommend any alternative methods of connection.
Q20. In your experience, which of the following reporting mechanisms would be the most effective? Please score each sub question as - 1 = very important or 5= least important. • *Fishing Activity (start-end markers)* • *Position Reporting Pings* • *Catch Reporting (species identification, quantification reports)* • *Bycatch Mitigation Reporting (application of bycatch mitigation devices when fishing)* • *Discarding Activity (where identified)* • *Protected species bycatch (where identified)* • *Alerts when fishing within a geofenced area (i.e., closed to certain fishing gears- MPAs)*
Q21. Please use a free-text box below to include your thinking on Q20 or provide any alternative suggestions.
Q22. Assuming cost increases with a higher position reporting frequency, please indicate which position reporting frequency do you think would be most cost-effective for fisheries monitoring? Please include your thinking in the comments box. • *1 min* • *3 mins* • *5 mins* • *10 mins* • *15+ mins* • *Other – please specify.*
Q23. Please indicate the level of risk you believe would be associated with each of the following métiers - for both vessels <10m and >10m in length. • *Very High Risk* • *High Risk* • *Medium Risk* • *Low Risk* • *Very Low Risk* • *Unsure / No answer*
Q24. Please indicate the level of monitoring (% of data review) you believe would be required by identified risk level. For example, if we considered a scallop dredge to be a high-risk métier, what level of data review would you expect to see for that vessel. **Risk Level** • *Very High Risk* • *High Risk* • *Medium Risk* • *Low Risk* • *Very Low Risk* • *No answer* **Monitoring Requirement** • *0* • *5* • *10* • *20* • *50* • *100*

Question
Q25. In which of the following categories could we best improve data gathering through the use of REM technologies? Please score each sub question as - 1 = very important or 5= least important. • *Fishing impact - benthic environment* • *Fishing impact - stock / population* • *Fishing impact - ecosystem and trophic structure* • *Fishing impact - endangered, threatened or protected species* • *Fishing effort (days by area)* • *Compliance monitoring* • *Benthic environment / habitat verification* • *Application of AI and machine learning*
Q26. Please use the below free-text box to include your thinking with respect to Q25, or if you would recommend any alternative data gathering requirements, please specify.
Q27. Please indicate which of the following catch documentation requirements you would like to see achieved through REM. A comments field has been added if you wish to outline your thinking. Can you think of any particular fisheries the application of REM will benefit? Please score each sub question as - 1 = very important or 5= least important. • *Species ID – Catch Verification (using Cameras)* • *Number of Individuals* • *Weight of catch (Kg/Tonnes)* • *Biological data collection (Length-Weight)* • *Biological data collection (Sexing)*
Q28. Please use the below free-text box to include your thinking with respect to Q26, or if you would recommend any alternative catch documentation requirements, please specify.
Q29. Please use this free text box to document any projects with REM your organisation is currently running.
Q30. Please use this free text box to document any experiences with REM your organisation is able to share.
Q31. Any other thoughts or comments?
Q32. Lastly, please use this free text box to document in your own words, the benefits or problems REM on English inshore fisheries presents to your organisation.

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10.1 Objective 1

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11. List of abbreviations

Acronym	**Definition**
AFMA	Australian Fisheries Management Authority
AIS	Automatic Identification System
CCTV	Closed circuit television
CEFAS	Centre for Environment, Fisheries and Aquaculture
EFCA	European Fisheries Control Agency
ETP	Endangered, threatened and protected (see PET)
GES	Good environmental status
ICES	International council for the exploration of the Seas
IFCA	Inshore Fisheries and Conservation Authority
INNS	Invasive non-native species
IUU	Illegal, unreported, and unregulated (fishing)
IVMS	Inshore vessel monitoring system
JNCC	Joint Nature Conservation Committee www.jncc.gov.uk
MCRS	Minimum Conservation Reference Sizes
MMO	Marine Management Organisation
MRAG	MRAG Ltd (United Kingdom)
MSFD	Marine strategy framework directive
MSY	Maximum sustainable yield
NOAA	National Oceanographic and Atmospheric Administration
OSPAR	Oslo and Paris Convention
PET	Protected, endangered, and threatened (species)
RAG	Red, Amber, Green (Traffic light status)
RFID	Radio-frequency identification

Acronym	Definition
RVZ	Redersvereniging voor de Zeevisserij (Netherlands)
SCRS	Standing Committee Research and Statistics (ICCAT)
SFPA	Sea Fisheries Protection Authority (Ireland) www.sfpa.ie
UPS	Uninterruptible power supply
VMP	Vessel Monitoring Plan
VMS	Vessel Monitoring System
WCPFC	Western and Central Pacific Fisheries Commission
WWF	Worldwide Fund for Nature

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