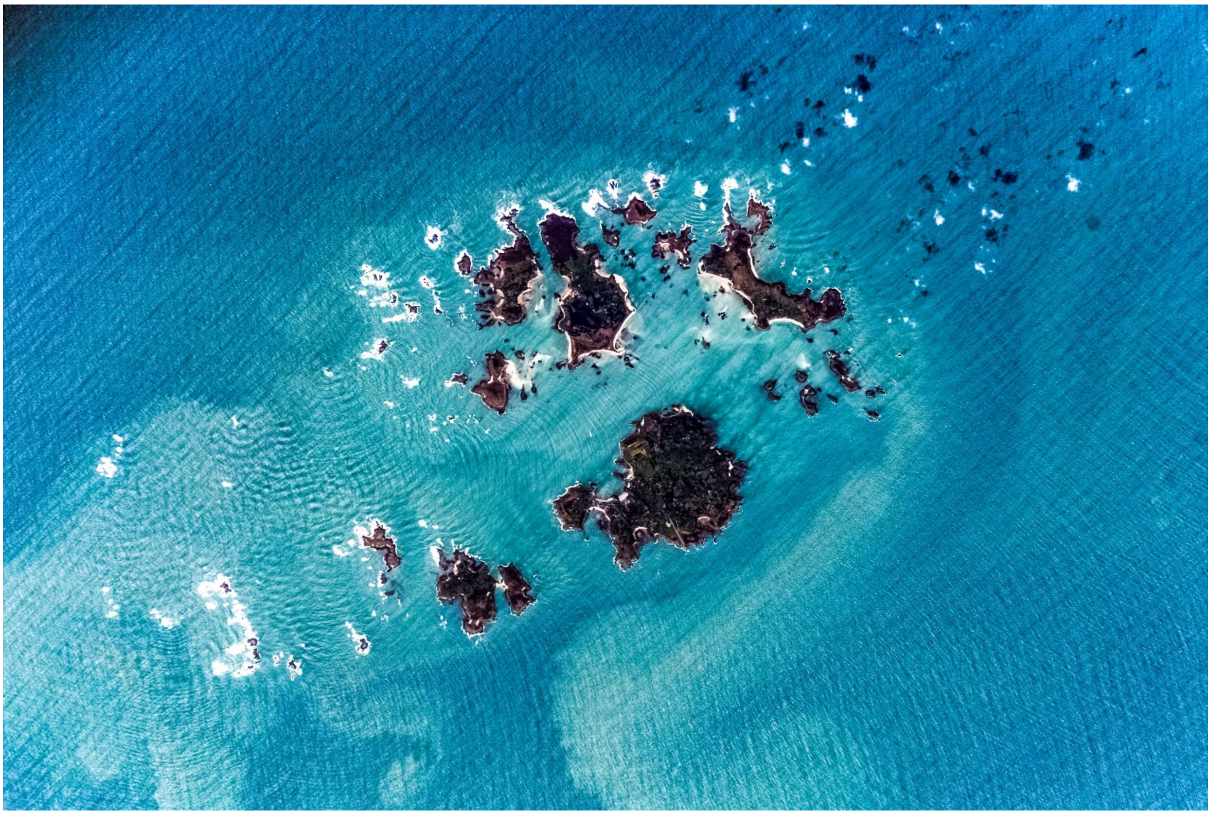
SWEEP

UNIVERSITY OF PLYMOUTH
Marine Institute

Isles of Scilly
Natural Capital Asset and Risk Register to Inform Management of Isles of Scilly Fisheries Resources



Photograph credit: Image from rawpixel.com NASA (Source) (Flickr creative commons https://creativecommons.org/licenses/by-nd/2.0/)

Author and affiliation: Matthew Ashley[1], Siân Rees[1], Tom Mullier[1] Bethany Reed[1], Amy Cartwright[1], Luke Holmes[1], Emma Sheehan[1]

[1] School of Biological and Marine Science, University of Plymouth.

This report has been compiled by staff at The Marine Institute, School of Biological and Marine Science, University of Plymouth.

Contact Details:

Dr Matthew Ashley / Dr Siân Rees
School of Biological and Marine Science,
Marine Institute
Marine Building
Level 3
University of Plymouth.
Drake Circus
Plymouth
PL4 8AA
Tel 00 44 (0) 1752 584732
Web: http://www.plymouth.ac.uk/marine

Suggested citation for this report:

Ashley, M., Rees, S., Mullier, T., Reed, B., Cartwright, A., Holmes, L., Sheehan, E., 2020. Isles of Scilly Natural Capital Asset and Risk Register to Inform Management of Isles of Scilly Fisheries Resources. A report by research staff the Marine Institute at the University of Plymouth

Acknowledgements:
This report was funded by EMFF and NERC- SWEEP NE/P011217/1.The authors would like to thank staff from the Isles of Scilly IFCA, Plymouth Marine Laboratory, The Marine Management Organisation, for assistance with data and advice and all fishers who contributed their time and knowledge.

List of abbreviations

CPUE Catch per Unit Effort

DEFRA Department for Environment, Food & Rural Affairs

ES Ecosystem Service

EUNIS European Nature Information System

GES Good Environmental Status

ICES International Council for the Exploration of the Sea

IFCA Inshore Fisheries and Conservation Authority

iVMS Inshore Vessel Monitoring System

JNCC Joint Nature Conservation Committee

LRC Likely Relative Condition

MarESA Marine Evidenced Based Sensitivity Assessment

MCAA Marine and Coastal Access Act 2009

MCZ Marine Conservation Zone

MESH Marine European Seabed Habitats

MPA Marine Protected Area

MSC Marine Stewardship Council

MSFD Marine Strategy Framework Directive

MSY Maximum Sustainable Yield

NCC Natural Capital Committee

IOS Isles of Scilly

SAC Special Area of Conservation

SSB Spawning Stock Biomass

TAC Total Allowable Catch

iVMS Inshore Vessel Monitoring System

WFD Water Framework Directive

Contents

1 Summary

Inshore Fisheries and Conservation Authorities (IFCAs) aim to manage a sustainable marine environment and inshore fisheries, by successfully securing the right balance between social, environmental and economic benefits to ensure healthy seas, sustainable fisheries and a viable industry (IFCA 2020).

Maintaining the marine environment and inshore fisheries in a condition that provides sustainable fisheries also supports many other benefits people receive from coastal seas. Marine habitats and species populations represent 'natural capital assets', and are of interest to recreational activities and tourism, contribute to climate benefits through capture and storage of carbon, aid maintenance of clean water and sediments, as well as reducing flood and storm impacts on coastal communities. A series of policy commitments from UK Government have been made to mainstream "the value of nature across our society, create a green economy, strengthen the connections between people and nature" (HM Government, 2011). This has included the development of the 'Natural Capital Approach' as a foundational framework of the United Kingdom's 25 Year Plan to Improve the Environment (HM Government, 2018).

The aim of the project is to work with the Isles of Scilly IFCA to develop the underpinning ecological and socio-economic research that supports decision making to ensure that the Isles of Scilly continues to have healthy seas, which support a wide range of benefits including a sustainable and viable fishing industry. Spatial habitat and activity data were integrated into a mapping tool, which enabled implications of current fishing activity and future scenarios to be evaluated in relation to ecological and economic sustainability.

This study documents the extent (quantity) and condition (quality) of marine habitat and species assets and reviews the benefits derived from them in Isles of Scilly IFCA district. As a part of the study, ecological habitat surveys were undertaken to increase knowledge of the mapped extent and condition of habitats within offshore areas of the IFCA district.

Flow of 'food' benefits from fisheries landings to Isles of Scilly are quantified and interviews with the fishing community are undertaken to understand community identified risks to natural capital assets. Interviews also gathered perceptions of current and future management options to support ecologically and economically sustainable fisheries.

Risk of loss of benefits provided by habitats and species populations in Isles of Scilly IFCA district is assessed by reviewing status of habitat and species extent (quality) and condition against marine

environment policy targets for sustainability. In particular 'Good Environmental Status' under the EU Marine Strategy Framework Directive (MSFD).

Under pressures associated with current fishing activity, habitat and species assets in Isles of Scilly IFCA district are assessed to be achieving, or on course to achieve policy targets for sustainability. Interviews with the Isles of Scilly fishing community identified perceptions that favour sustainable fishing practices, although some respondents also identified a lack of economic opportunity due to current restrictions on diversification to other fishing practices.

Future fishing scenarios were developed with the IFCA to assess the impact of changes in gear types and fishing practice within the IFCA district on sensitive marine habitats and subsequent effect on the flows of benefits. Scenarios focussed on the reintroduction of fishing using dredging gear in the eastern IFCA district and increasing exposure to fishing activity using otter trawl.

All scenarios with an increase in bottom towed fishing activity, in addition to the current potting and netting activity in the IFCA district, resulted in increased risk of loss of ecosystem services benefits (e.g. provision of food or climate regulation). There were also negative impacts on habitats of importance to species that support existing potting and netting commercial fishing activity. Greatest risk to multiple benefits was assessed in relation to scallop dredge activity. Providing access for limited otter trawling activity to lowest sensitivity habitats provided the smallest negative impact on benefits of all scenarios tested. However, in comparison to current activity an increase in otter trawling still had a greater negative effect on ecosystem service benefit provision than current commercial fishing activity. Ecological sustainability targets limiting the proportion of habitat that can be exposed to damaging activities are recognised to be restrictive when assessed over small study areas. Lack of monitoring and evidence of condition and recovery of offshore habitats also limits assessment and forces a precautionary approach which may be further restrictive.

Current commercial fishing activity poses very limited risk to the flows of ecosystem service benefits from habitats within Isles of Scilly IFCA District. Maintaining activities with limited ecological impact, while maximising economic opportunities from marketing and sale of catches may have greatest long-term ecological sustainability benefits. However, this approach needs to be assessed in relation to the level of economic sustainability it provides fishing businesses.

2 Introduction

Marine ecosystems provide a number of essential functions, such as primary production and climate regulation, which underpin life on earth (Millennium Ecosystem Assessment, 2005; United Nations, 2015). Since 2011, a systematic approach has developed in the UK to fully incorporate the role of ecosystems in supporting the delivery of ecosystem services and human well-being into decision making (UK National Ecosystem Assessment, 2011). A series of policy commitments from UK Government have been made to mainstream "the value of nature across our society, create a green economy, strengthen the connections between people and nature" (HM Government, 2011). This has included the development of the 'Natural Capital Approach' as a foundational framework of the United Kingdom's 25 Year Plan to Improve the Environment (HM Government, 2018).

Four key definitions are central to the Natural Capital Approach (Natural Capital Committee, 2017).

- **Natural capital:** The elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions.
- **Assets:** a distinctive component of natural capital as determined by the functions it performs, e.g. soils, freshwater, species.
- **Ecosystem services (ES):** Functions and products from nature that can be turned into benefits with varying degrees of human input.
- **Benefits:** Changes in human welfare (or well-being) that result from the use or consumption of goods, or from the knowledge that something exists.

Assessment and appraisal frameworks aiming to understand the rate and change of natural capital in relation to UK policy or management interventions include tools such as Environmental Impact Assessments, Natural Capital Accounts, Asset and Risk Registers, Regulatory Impact Assessment and Sustainability Appraisal (Hooper *et al.*, 2018). Asset and Risk registers are decision support tools developed within the business and industry sector to identify risks to operations based on an assessment of business assets, plausible risk, likely impacts and ownership of the driver of risk (Leonard, 1995). An asset and risk register in tune with the Natural Capital Approach was first developed by Mace et al (2015). In 2020 the UKs first Marine Natural Capital Asset and Risk Register was developed as a foundational tool to inform routes towards sustainable development and management to underpin the flow of ecosystem services (Ashley et al 2019; Rees et al., 2019). The purpose of this report is to develop the framework of a Natural Capital Asset and Risk Register as a tool for fisheries management.

Across the UK Inshore Fisheries and Conservation Authorities (IFCAs) operate with the vision to:

"Lead, champion and manage a sustainable marine environment and inshore fisheries, by successfully securing the right balance between social, environmental and economic benefits to ensure healthy seas, sustainable fisheries and a viable industry (IFCA 2020)."

Achieving this vision enables goals within the framework of the United Kingdom's 25 Year Plan to Improve the Environment (HM Government, 2018) and supports goals within United Nations (2018) 2030 Agenda for Sustainable Development. Ensuring sustainable use of key species and ensuring seafloor habitats are productive and sufficiently extensive to support healthy, sustainable ecosystems are key to the United Kingdom's 25 Year Plan to Improve the Environment and Sustainable Development Goal #14 (HM Government, 2018b, United Nations, 2018). Sustainable development goal #14(b) also considers enhancing access for small-scale fishers to marine resources and markets, and requires consideration in relation to the overarching goal of conservation and sustainable use of marine reosurces (United Nations, 2018).

3 Aims and Objectives

The aim of the project is to work with the Isles of Scilly IFCA to develop the underpinning ecological and socio-economic research that supports decision making to ensure that the Isles of Scilly continues to have healthy seas which support a wide range of benefits including a sustainable and viable fishing industry. Novel habitat data are collected to improve existing evidence and combined with existing data sets within a mapping tool, to assess the implications of current fishing activity and scenarios for future activity in relation to ecological and economic sustainability. Implications are assessed within the context of enabling provision of ecosystem services and associated benefits. The key objectives are to

- Incorporate novel (primary) and existing data sets to provide a Natural Capital Asset Register for Isles of Scilly IFCA District and assess flows of ES benefits.
- Apply Rees et al.'s (2020) risk register tool to assess risk to provision of ES under current activity and future fisheries management scenarios.
- Assess implications of management scenarios on risk to ES provision and social and economic implications on the fishing industry.

'Best available data' for the Natural Capital Asset and Risk Register was strengthened by primary data (substratum present and epifauna and infauna species community) collected through towed video surveys and benthic grab surveys, conducted by marine ecologists at University of Plymouth (funded by EMFF grant ENG3727). To improve confidence in the Natural Capital Asset Register, local ecological knowledge is also combined with best available evidence of habitat and species asset extent and condition.

3.1 Study Site: Isles of Scilly IFCA District

The Isles of Scilly IFCA District incorporates the waters, up to 6nm around the Isles of Scilly archipelago, 28 miles (45km) south west of the UK mainland. The archipelago's position, isolated from the mainland and the within oceanic water masses contribute to the European and national importance of the habitat features. The Isles of Scilly contains one Special Area of Conservation (SAC), designated under European legislation and 11 marine conservation zones (MCZ), designated under UK legislation (Annex I) (Figure 1). The habitat features within the IFCA district provide important resources supporting shellfish and fish populations targeted by the Isles of Scilly fisheries and multiple other ES benefits to the local and international community.

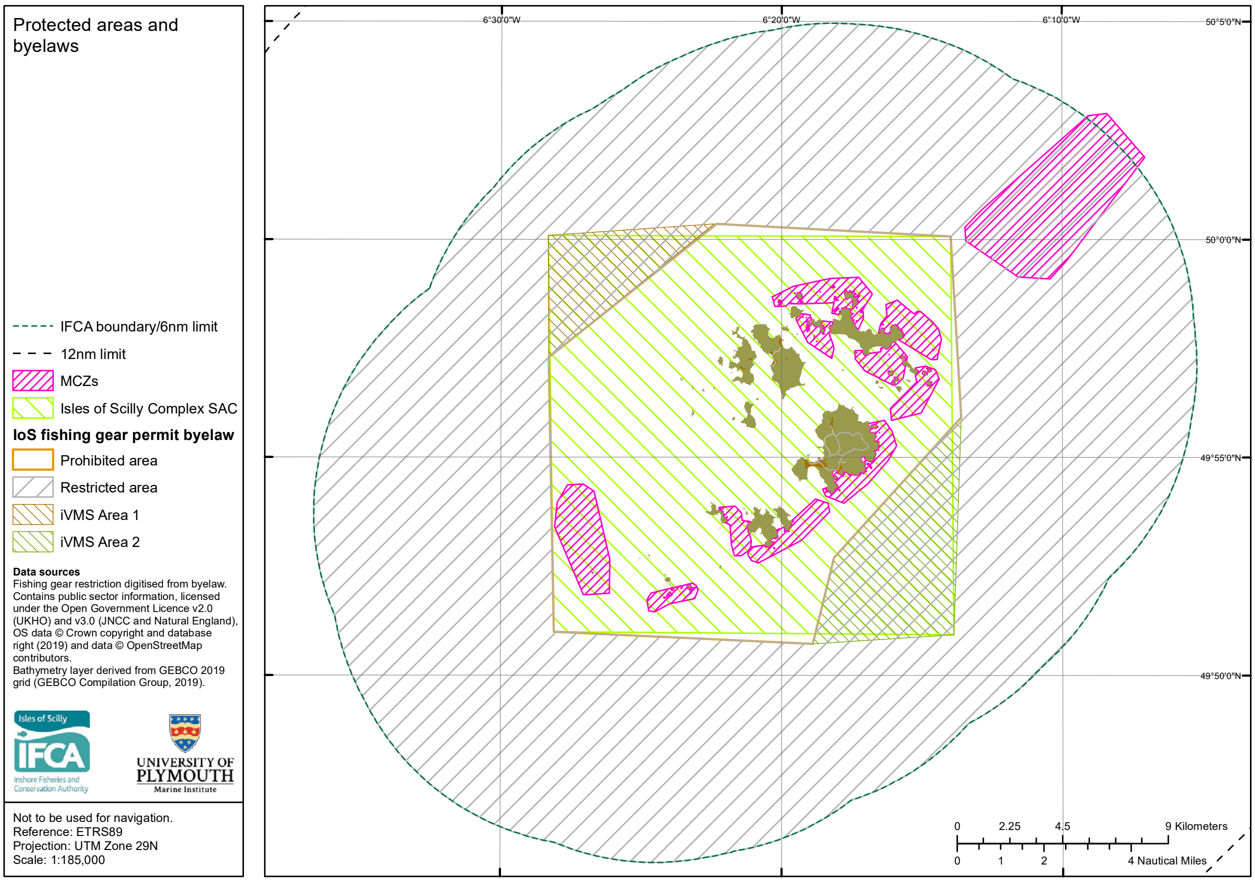


Figure 1 Map of Isles of Scilly including conservation and management boundaries within the IFCA district.

The most important resources, by value, supporting fisheries in the Isles of Scilly are European lobsters *Homarus gammarus* and brown (edible) crabs *Cancer pagurus* that are caught in pots. Crawfish *Palinurus elephas* are the third most valuable species, caught within the district with tangle nets. Sum of landings weight and value for 2018 clearly demonstrate the importance of these species to the fishery (Table 1). Tangle nets are also used to target spiny lobster (crawfish) *P. elephas* and species such as monkfish *Lophius spp.*; gill nets to catch pollack *Pollachius pollachius* and grey mullet *Chelon labrosus, Liza ramada* (Mugilidae); and trammel nets to catch bait to use in lobster and crab pots. Pollack are also caught using hand lines and rods. In 2018 and recent years, there was just one boat that uses a light otter trawl to catch fish such as haddock *Melanogrammus aeglefinus*, dover sole *Solea solea*, megrim *Lepidorhombus whiffiagonis*, plaice *Pleuronectes platessa* and john dory *Zeus faber* (Isles of Scilly IFCA, 2018).

Fishing is seasonal, and primarily takes place between March and November. Working static gear in small boats through the winter in the exposed conditions around Isles of Scilly would be uneconomical (Isles of Scilly IFCA, 2018).

Table 1 Landings to Isles of Scilly (ports) 2018, Species by live weight (high to low) and sum of economic value.

Species	**Sum of Live Weight (tonnes) 2018**	**Sum of Value (£000s)**
Crabs	83.67	167.31
Lobsters	33.35	366.88
Pollock	2.75	9.57
Mullet	2.73	8.57
Crawfish	2.29	68.92
Skates and Rays	0.16	0.27
Monks or Anglers	0.1	0.58
Plaice	0.09	0.53
Turbot	0.07	0.87
Dogfish	0.05	1.33
Sole	0.05	0.36
Megrim	0.04	0.25
Lemon sole	0.04	0.21
Haddock	0.03	0.15
Mackerel	0.02	0
Brill	0.02	0.17
John Dory	0	0

All MPA sites within the IFCA district require the designated habitat or species features they contain to be "recovered" or "maintained" to "favourable condition". Favourable condition is, "… the condition that would be expected in the absence of significant anthropogenic pressures which have an adverse effect" (Carr *et al.*, 2016; JNCC, 2010). For a habitat in an MCZ to be in favourable condition, "… the extent is required to be stable or increasing and its structures and functions, its quality and the composition of its characteristic biological communities are such as to ensure that it remains in a condition which is healthy and not deteriorating" (Carr *et al.*, 2016; JNCC, 2010). Favourable condition in a SAC is assessed as whether "… the natural range and area of a habitat feature is stable or increasing and which are necessary for its long-term maintenance are present and are likely to continue to exist for the foreseeable future" (JNCC, 2017).

Under the Marine and Coastal Access Act 2009, the Marine Management Organisation (MMO) are responsible for the management of MCZs and EMSs. Between 0-6 miles, Inshore Fisheries and Conservation Authorities (IFCAs) are the lead regulators for fisheries within their Districts. They have duties under the MCAA (s.154) to 'further the conservation objectives of MCZs' and the Conservation of Habitats and Species (Amendment) Regulations 2012 which requires the competent authority (e.g. IFCAs) to exercise their functions which are relevant to nature conservation, including marine conservation, so as to secure compliance with the requirements of the Directives. The MMO and IFCAs coordinate enforcement roles.

Condition assessments are undertaken by Natural England to identify if features within SACs and MCZs are in favourable condition and a conservation objective of 'maintain' can be applied. If the feature is in unfavourable condition a conservation objective of 'recover' (to favourable condition) is applied.

Management of fisheries within MPAs is based on the level of risk that a fishing activity presents to protected features, either habitat or species, to conserve important habitats and species in line with the EU Habitats and Birds Directives (Marine Management Organisation, 2014). Assessments of impact of each fishing activity on features of MCZs in the Isles of Scilly IFCA District have been undertaken by the Isles of Scilly IFCA, in coordination with advice from Natural England, to identify where management measures are required. Across the IFCA district there are minimum landing size byelaws and restrictions on size and length of vessels. There is a prohibition on the use of towed gear within Isles of Scilly Complex SAC, apart from iVMS areas I and II (where there is currently permission for 1 otter trawler to operate) (Figure 1). Outside the SAC, but within the IFCA district there are currently restrictions under the Fishing Gear Permit Byelaw, based on gear designs.

IFCA byelaws active in 2018/19, in Isles of Scilly district include:

- Lobster Minimum Landing Size Byelaw
- Fishing Gear Permit Byelaw, which includes restrictions on:
  - Vessel Size (length and weight), Size restrictions (10 tonnes) and length restrictions (11 metres).
  - Restrictions on the use of Towed Fishing Gear
  - Permit conditions relating to dredges

- Permit conditions relating to towed nets
- Permit conditions relating to Inshore Vessel Monitoring System.

(Isles of Scilly IFCA, 2019) Details on IFCA byelaws are available at https://www.scillyifca.gov.uk/

4 Section 1: Natural Capital Asset Register

4.1 Methods

4.1.1 Isles of Scilly: Asset – benefit relationship

Asset-benefit relationships represent the relationship between the condition of the natural capital asset and the ecosystem service flows that benefit people. Three types of natural capital assets were identified for this study. These comprise:

- Habitat Assets - All EUNIS level 3 habitats (or above where data exists) that provide a moderate or significant contribution to an ecosystem service benefit
- Species Assets- commercial species (fish and shellfish) with and without quota; migratory species (salmon and seatrout) and;
- The Water Column - water bodies, bathing waters, shellfish waters.

Ecosystem Services and linked benefits were defined in line with the goods and benefits defined in the United Kingdom National Ecosystem Assessment Follow On (Turner *et al.*, 2014). Links between habitats and benefits built on previous matrices assessing level of provision of ecosystem services from UK marine habitats (Fletcher *et al.*, 2012; Fletcher, Saunders & Herbert, 2011; Potts *et al.*, 2014; Saunders *et al.*, 2015). To update the matrix approach, literature between 2014 and 2017 on provision of ecosystem services from marine and coastal habitats were reviewed to identify any updated evidence for supply from marine habitats (*See Supplementary Material 1 Tab 1*). A further matrix approach was undertaken for fish species and links to habitats during essential life history stages (*Supplementary Material 1 Tab 2*).

4.1.2 Habitat and Species Asset Status

Asset Status

The natural capital asset register provides the foundation for the risk register in Section 2. The asset register provides a method to document the extent and condition of the natural capital within the area being assessed (Natural Capital Committee, 2017). Risk register methods developed by Mace *et al.* (2015) then record degradation of natural capital in the asset and risk register in relation to the degree to which it will lead to loss of well-being in present and future generations (Asset Status). Three dimensions of asset status are identified that help resolve how much benefits are affected by deterioration in the condition of assets. These measure the: i) quantity (extent), ii) quality (condition) and iii) spatial configuration of the assets in relation to the benefits (links to extent and condition).

Habitat Quantity (extent)

A composite habitat map below mean high water was generated that combined spatial data sets. Existing data were accessed through two sources 1) A Natural England external habitats dataset, compiled from best available survey maps and; 2) Modelled data from the European Marine Observation and Data Network (EMODnet)/EUSeaMap (EMODnet/EUSeaMap, 2019). In offshore areas, there was known to be a paucity of habitat data, limiting effective decision making in the Isles of Scilly IFCA district. To increase knowledge of habitat presence and extent, primary survey data were collected as part of this study, and habitat classification undertaken to add to the exiting spatial data.

- Primary data collection and analysis methods

Habitat classification from primary data collection was undertaken through collection and analysis of towed video and benthic grab survey data conducted by University of Plymouth. Primary survey data combined with existing data sets were used to inform the mapping tool developed in this study, to form the basis of the asset register and risk register assessment. Full methods for data collection, analysis and attributing EUNIS codes to classify habitats from primary survey data are provided in the ecological survey methods document (Annex III, Annex IV) and summarised below.

Data were collected at locations where site identification side-scan sonar surveys had previously identified sites which would cover a range of habitats present in the offshore study area. These surveys were carried out from the 19th - 21st of May 2019, aboard the Cornwall IFCA's Research Vessel (R/V) Tiger Lily VI.

Epifaunal biodiversity present were sampled using a towed video camera array. The minimum contact with the seabed due to the buoyancy of the array makes this method a cost effective and non-destructive method of sampling the epibenthic biodiversity (Sheehan *et al.*, 2010; 2016).

Species present in the towed array videos were identified to the highest taxonomic level possible. Video analysis methods followed those described in detail in Stevens et al. (2013), which allow for the quantification of densities of fauna through analysis of individual frames as well as analysis of the entire transect for infrequently occurring sessile fauna or mobile fauna. To classify the habitats present in the survey, each transect was given a dominant habitat type; defined as the habitat type which covered more than 50% of the transect length. The habitat categories were formed of two parts, the epifauna type and the substrate type.

Infaunal sample collection was also carried out from 4th-18th of June 2019. Samples were collected using a Shipek grab (0.04m^2 area). Once collected, the volume of the sample and a description of the type of sediment was recorded. Samples were sieved through 2mm, 1mm and 0.5mm Endecott sieves. Organisms were identified to a minimum of family level; polychaetes were identified to family level as this has been found to be a high enough resolution to identify community changes and reduces the time required for analysis (Gray *et al*., 1990; Chapman, 1998; Sanchez-Jerez *et al*., 2018). The procedure was carried out in line with NMBAQC's Processing Requirements Protocol for marine invertebrate samples (Worsfold and Hall, 2010) (Annex III).

- Assigning Eunis biotopes to epifauna towed video and infauna grab samples

Dominant habitat type, defined as the habitat type across each towed video survey, which covered more than 50% of the transect length, was first related to the relevant EUNIS level L2/3 code (A4 circalittoral rock or A5 sublittoral sediment). Epifauna species presence (A4 habitat) and / or infauna species presence (A5 habitat) were then used to identify all relevant biotopes present at >Eunis L3. As towed video surveys in particular passed over multiple biotopes, all relevant biotopes were selected per transect. As a precautionary measure for later assessment of risk from pressures associated with fishing activities, the most sensitive biotope to pressures associated with trawl or dredge fishing activities were attributed across the whole transect or sample site. Biotope assignment was sense checked by reviewing towed video recordings with members of the ecology project team (AC, BR), to limit error (Annex IV).

Primary survey data were entered into the spatial mapping tool, as Eunis L3 biotopes. The Biotopes identified at >Eunis L3 were applied to later assessment of sensitivity to pressures associated with fishing activity (Annex IV).

- Assigning habitat classification where data sets overlap

Where overlap in data sets occurred within the mapping tool, a compilation method was undertaken in ArcGIS 10.3. 'Best available data', were retained on the basis of Mapping European Seabed Habitats project (MESH) confidence scores (MESH Accuracy & Confidence Working Group, 2007) and age of the data. Survey data was prioritised over modelled data where available. Wherever possible, the composite habitat map aims to provide habitat data at the European Nature Information System (EUNIS) classification level 3 and the corresponding EUNIS habitat was consistently identified for areas where habitat attributes were labelled under different designations. Finally, for areas where spatial overlap of habitat features from surveys occurred (from overlapping data of equal confidence or ambiguous classification by map creators/interpreters), the ecosystem service provision from each habitat was reviewed using matrix data based on Potts et al. (2014) and Saunders et al. (2015)

on supply of ecosystem services from habitats. The habitat with the highest provision across ecosystem services was retained. The total extent (km^2) of each habitat occurring within IoS was calculated from the composite habitat map using ArcGIS. The extent (km^2) of habitat within Marine Protected Areas was also calculated along with the extent (km^2) of each habitat with an associated management measure (i.e. habitat extent in an MPA with a byelaw, such as bottom towed fishing gear restrictions).

- Gathering local ecological knowledge on habitat distribution from resource users

Resource user interviews were conducted with Isles of Scilly fishers and diving tour operators to gather local ecological knowledge on extent and condition of habitats and species (*Supplementary Material 3*). The interviews contained a participatory mapping element where participants reviewed a habitat map containing all evidence apart from the University of Plymouth survey data, and provided annotations on inconsistencies for the seabed substratum they were aware of in areas they had knowledge of.

Habitat Quality (Condition)

Two methods were applied to assess habitat quality (condition). For habitats within MPAs quality (condition) is inferred through conservation objectives assigned to each habitat feature in Conservation Advice packages produced by the UK Statutory Agency Natural England for each site. (Natural England, 2017). To compile this data a literature review was undertaken of Conservation Advice Packages available for sites in the case study area (Annex I).

As condition assessments of benthic habitats are limited to the purpose of Conservation Advice Packages they apply to the extent of designated sites only and to the designated features of interest within them. There are also limitations on the level of activity (pressure) information and regularity of Conservation Advice updates. For habitats outside of MPAs there is no data on habitat condition therefore a proxy method was applied based on habitat sensitivity to pressures.

The habitat quality (condition) proxy data layer was constructed as follows: Sensitivity information by EUNIS habitat was extracted from the Marine Evidence-based Sensitivity Assessment (MarESA) database (Tyler-Walters *et al.*, 2019). MarESA compiles sensitivity information through a detailed literature review process of available evidence on the effects of pressures arising from human activities on marine habitats (Tyler-Walters *et al.*, 2018). The assessments assign scores for habitat sensitivity as a combination of resistance and resilience to particular pressures. The scores allocated are: Not Sensitive (NS), Low (L), Medium (M), High (H) and Not relevant (NR). MarESA assessments also include semi-quantitative assessments of the quality of evidence, applicability of evidence and the degree of agreement between evidence sources (Tyler-Walters *et al.*, 2018). These were coded numerically and linked to the composite habitat map through a series of iterative joins, linking sensitivity information based on the most detailed habitat class information available (EUNIS levels 5 and 6), up to EUNIS level 3. At the higher EUNIS levels (3 and 4), MarESA assessments were aggregated, taking advantage of EUNIS' hierarchical structure and following a precautionary approach to assign the most sensitive score of all 'child' classes from existing MarESA assessments to their 'parent' class. Primary towed video survey data and existing survey data were used to identify the potential highest sensitivity habitat present. Using survey data also prevented sensitivity for habitats that are not present in IoS being attributed, as would occur if all EUNIS parent classes were used.

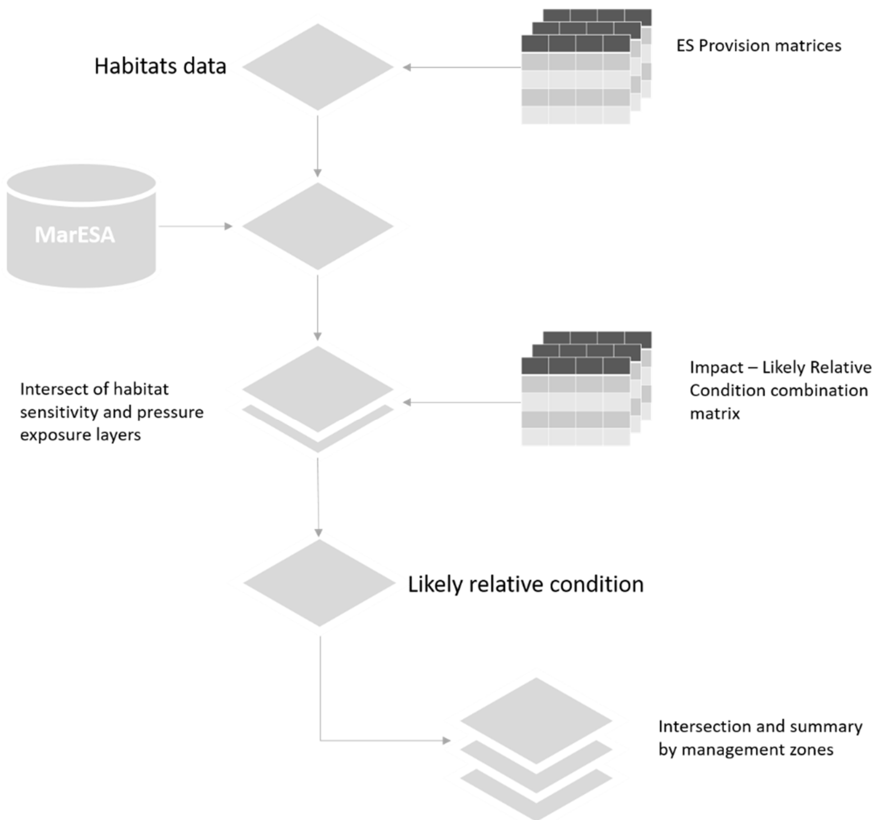


Figure 2 - Diagram overview of process to assess 'Likely Relative Condition'

This habitat- sensitivity data layer was then intersected with data on fishing intensity. The fishing data used was an amalgamated product combining spatial information on smaller fishing vessels. Data were amalgamated from a recent participatory mapping exercises with Isles of Scilly fishermen, undertaken by Gierhart (2019) and Perry (2019) (potting activity), Olex position data provided by fishermen and data collected through a participatory mapping exercise with fishers in 2019 (all gear types) (*Supplementary Material 3*). Evidence was reviewed on impacts of each fishing activity on marine habitats to identify threshold levels of effort, that would cause pressures the habitat was identified to be sensitive to (Annex II). In line with (Rees, 2018), potting intensity was categorised into low (0 to < 15 pots/0.25km^2), moderate (15 to < 30 pots/0.25km^2) and high (>= 30 pots/0.25km^2) with effort > moderate identified as the threshold (Annex II). Otter trawling activity from Olex data was classified as high where ground was towed multiple times in a year (more than twice in a year), based on reviewed evidence (Tyler Waters et al. 2018; 2019; Heinz et al., 2009; Kaiser et al, 2006; Sewell, 2005) (Annex II). Results are reported on a scale of 'Likely Relative Condition' (LRC) of the seabed habitat where 1 indicates poor LRC and 5 indicates a good LRC. LRC of 3 or below indicate the habitat is likely to be degraded and function is impaired and level of delivery of ES benefits reduced. Finally, the LRC layer was intersected with spatial boundaries of management measures (MPAs and fishery byelaws) and areas aggregated by broad ecosystem services classes to examine extent and condition under management. It must be noted that the 1-5 scale does not take into account the historical condition of the seabed and therefore 5 represents a shifted baseline (Klein & Thurstan, 2016). Options for recovery, restoration and renewal of the seabed must still be considered. Results are summarised in the report, following tables designed in Hooper et al., (2020), with trend analysis and full tables provided in *Supplementary Material 2, Tab 2, Tab 3.*

Habitat Spatial Configuration

Where Conservation Advice Packages for Features of Conservation Interest included an assessment of spatial distribution e.g. change in spatial distribution of species communities, this was included in assessment of condition and the risk assessment. Changes to the spatial distribution of communities across the feature are identified as an indicator that could highlight changes to the condition and function of the overall feature, and so ecosystem service provision (JNCC, 2004).

Species Assets (quantity and quality)

Abundance of commercial species populations (population size or biomass), spawning stock biomass (SSB) and recruitment were identified as indicators of species asset quantity and quality. Where available, ICES assessments of SSB and total allowable catch (TAC) for ICES areas intersecting with the Isles of Scilly IFCA district were used for commercial species to assess quantity and quality of stocks for the baseline year, and trend. Landings of non-quota shellfish over time provided the best available data linked to asset quantity (Cefas, 2012). Quality of non-quota shellfish species assets were assessed from south west UK regional assessment of stocks (Cefas, 2012; Cefas, 2017a; Cefas, 2017b) (*Supplementary Material 2, Tab 4*).

It is recognised that spatial scales of ICES areas and south west UK regional stock assessments of brown crab and European lobster are too broad scale for some commercially targeted species. To provide evidence at IFCA district scale, resource user surveys asked participants to comment on the condition of the local stocks of the species they targeted (*Supplementary Material 3*).

The Water Column Quantity (quantity and quantity)

In line with UK commitments under the Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD) data is collected by government agencies that can be applied in the natural capital context as indicators of the condition of water body assets. Water body status, in reference to WFD targets, for water bodies was assessed for the water body intersecting Isles of Scilly IFCA district. Data on water body statuses was accessed from HM Government online resources (Environment Agency, 2018) (*Supplementary Material 2, Tab 5*).

Trend analysis

Where possible all data were assessed for the baseline year (2018 or next closest year data are available) and the trend since 2010 (increase or decrease) was analysed using annual data for 2010-2018 where available. Indicator metric data resources and physical data have been recorded and stored in linked excel spreadsheets provided as supplementary material *(Supplementary Material 2*).

Where data were available for multiple years the trends (positive, negative or no change) between the earliest years data and the baseline year (2018) were assessed. Values such as fisheries landings for a species may rise and fall between years and do not necessarily provide a linear trend over time (increase or decrease concurrently and at a constant rate). Therefore, to visually identify if a trend over time occurred, annual data (e.g. 2010-2018) were first plotted in line charts in excel to observe inter-year changes. To statistically test for the presence of a trend, Kendall's tau-b statistical tests were calculated in SPSS to test for presence of a monotonic relationship between indicator data and time (2010-2018). The test provides a non-parametric form of monotonic trend regression analysis (Meals *et al.*, 2011). Monotonic trends occur when the variables (indicator over time) tend to move in the same relative direction, but not necessarily at a constant rate. A significant positive or negative trend was assessed at the 95% confidence limit (>0.05).

Moving averages (3year) were also compared where possible, to identify a change in average values between the most recent 3 year period and the three year period previous to it (e.g was there an increase, decrease or no change in the moving (3 year average) between 2010-2012, and 2013-2015). This provided a summary of changes in the most recent years data, and provided consideration for inter annual variation which was common in data such as fisheries landings.

4.2 Results

Habitat Assets

All intertidal habitats occur within Isles of Scilly Complex SAC and Isles of Scilly MCZs. Conservation objectives assigned to each intertidal habitat feature in Conservation Advice packages produced by the UK Statutory Agency Natural England identified these habitats to be in favourable condition with a conservation objective of 'maintain' (Table 2) (Annex I) (*Supplementary Material 2, Tab 2*). Infralittoral rock features also occurred within Isles of Scilly Complex SAC and Isles of Scilly MCZs with a conservation objective of 'maintain' (Table 2) (Annex I) (*Supplementary Material 2, Tab 2*). Sublittoral macrophyte dominated sediment (eelgrass *Zostera marina* beds) were assigned a conservation objective of 'maintain', however more recent annual monitoring suggests a decrease in extent at 4 out of 5 sample sites and increased frequency of wasting disease at some sites in (Bull and Kenyon, 2016). As a precaution, sublittoral macrophyte dominated sediment was assessed as declining in extent and condition (Table 2) (Annex I) (*Supplementary Material 2, Tab 2*).

Smaller extents (across entire IFCA district) of deeper circalittoral rock and subtidal sediment habitats occurred within MPAs. Evidence was limited on extent and condition of these assets outside MPAs. Within Bristows to the Stones MCZ circalittoral rock features were assessed to be unfavourable/maintain ($17km^2$ (4.6% of all circalittoral rock extent, 10% of extent within MPAs)). An additional $3.1km^2$ of circalittoral reef habitat had interacted with activities that led to a reduction in modelled condition (LRC <L3). This brought the total area of cicalittoral rock habitat in degraded condition to $20.1 km^2$, (5.4% of total extent within IoS IFCA district) (Table 2) (Annex I) (*Supplementary Material 2, Tab 2, Tab 3*).

Primary towed video survey data identified circalittoral reef habitats in the eastern area of IoS IFCA district to be colonised with rich sponge, anemone and bryozoan communities in good condition. Evidence of increased extent of circalittoral rock was identified through towed video surveys than previous modelled data suggested. Habitat extents that previous modelled data recorded as soft substratum were identified by towed video data to be colonised by reef associated bryozoan species and hydroid species. Such species require hard substratum to attach to, and towed video data showed a thin veneer of sediment over underlying circalittoral rock habitat. Limited evidence of condition of deeper sublittoral soft substratum and poor confidence in extent from modelled habitat data, prevented accurate assessment of extent and condition of sublittoral soft substratum assets (Table 2) (Annex I) (*Supplementary Material 2, Tab 3*).

Table 2 Extent and condition of marine habitat assets in Isles of Scilly IFCA district including summary of 10 year trend (where data available) (table adapted from Hooper et al., 2020).

Broad Habitat	**Detail (with Eunis code)**	**Extent (km^2)**	**Extent trend**	**Condition**	**Condition trend**
Marine inlets and transitional waters					
Intertidal reef	A1: Littoral rock and other hard substrata	**1.1**			
Intertidal sediments	A2.1 Littoral coarse sediment	**0.70**			
	A2.2: Littoral sand and muddy sand	**0.02**			
	A2.3: Littoral mud	**0.01**			
	A2.4: Littoral mixed sediment	**0.00**			
Sublittoral habitats					
Subtidal reef	A3: Infralittoral rock and other hard substrata	**48.35**			
	A4: Circalittoral rock and other hard substrata	**372.51**			
Subtidal sediment	A5.1: Sublittoral coarse sediment	**306.67**			
	A5.2: Sublittoral sand	**223.53**			
	A5.4: Sublittoral mixed sediments	**11.07**			
	A5.5: Sublittoral macrophyte dominated sediment	**5.38**			

Key:					
Trend	*Positive*	*Stable*	*Negative*		*Insufficient data*
Condition	*Good*	*Acceptable*	*Of concern*		

- Resource user assessment of habitat condition

Habitat condition was identified to generally be good by participants of resource user interview surveys, although past activities were reported to have impacted reef habitats. Historical scallop dredging was reported by 3 respondents (25% of participants) to have 'flattened' rocky pinnacles and removed corals and sponges, and an area of good crawfish *P. elephas* abundance was lost when this occurred (Figure 3). Environmental pressures from storms were also considered to contribute to reduction in extent in seagrass habitats *Zostera marina* habitats over winter by one respondent, although they expected the habitat would recover (Figure 3).

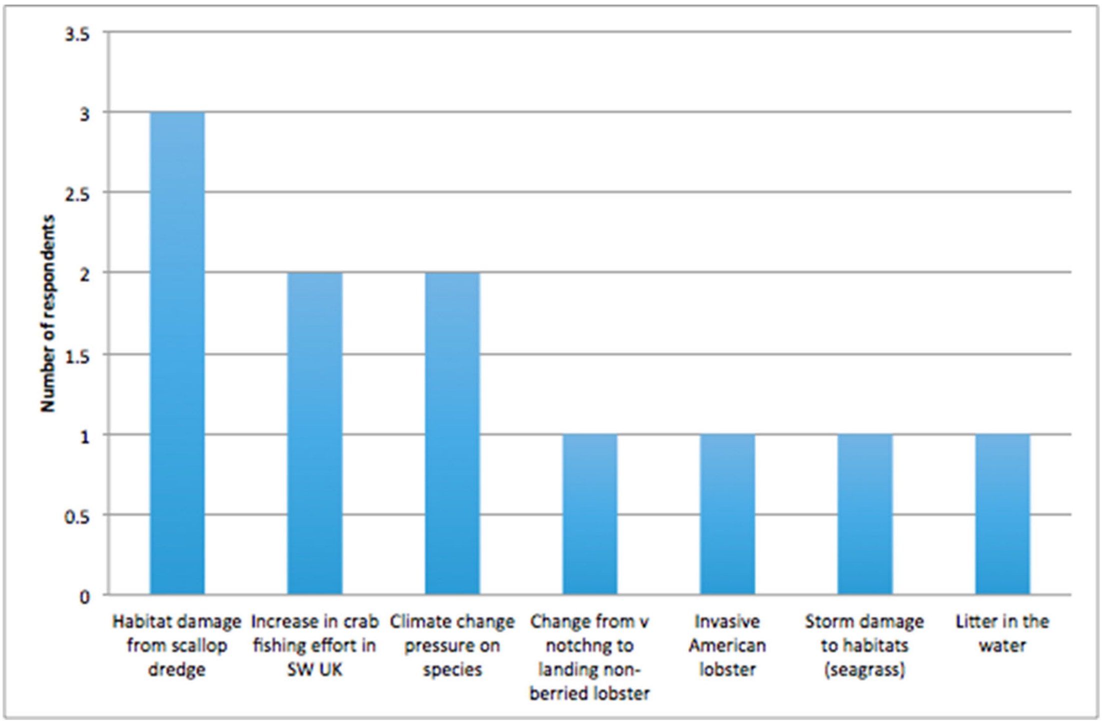


Figure 3 Current and recent historical pressures identified to impact condition of habitat and species assets in interviews with Isles of Scilly fishing community

Species Assets

Spawning stock biomass (SSB) calculations for ICES area 7e (or next most relevant spatial scale) displayed a positive trend for plaice *Pleuronectes platessa*, sole *Solea solea* and monkfish *Lophius spp.* and a stable or small decrease for mackeral *Scomber scombrus*. Limited ICES reports on SSB of commercially targeted species prevented assessment of extent (quantity) of 8 species. (Table 3) (*Supplementary Material 2*). SSB calculations consider stocks at much larger spatial extents than Isles of Scilly IFCA district and should be interpreted with caution, especially for species that may have a more limited range.

Crab *Cancer pagurus* and lobster *Homarus gammarus* do not have comprehensive stock assessment data but condition is assessed in relation to harvest pressure at south west UK scale. Although the spatial scale of the assessment provides limited confidence of Isles of Scilly stocks, crab *Cancer pagurus* were assessed to be harvested within sustainable limits. Lobster *Homarus gammarus* stocks were assessed to be above critical levels and harvests were not yet at the maximum sustainable yield (MSY) (Table 3) (*Supplementary Material 2*). There is limited or no assessment of spiny lobster/crawfish *Palinurus elephas* stocks. Across the South West UK, populations of spiny lobster *P. elephas*, also known as crawfish, are viewed as being depleted, and have a conservation objective ‘recover’ across South West MPAs, including the Isles of Scilly MCZs.

Total allowable catch (TAC) assessments were available for 6 species, although there was insufficient data available for ICES to provide confidence in TAC calculated for Pollack *Pollachius pollachius.* TAC calculated for plaice *Pleuronectes platessa*, sole *Solea solea* and monkfish *Lophius spp* have displayed a positive trend over the time series (Table *3*, *Supplementary Material 2*). Between 2010-2018 landings weight (kg) from UK vessels for commercial species to Isles of Scilly ports have displayed a positive monotonic trend for Crab *Cancer pagurus,* Lobster *Homarus gammarus*, Spiny lobster/crawfish *Palinurus elephas,* Grey mullet *Mugilidae spp,* plaice *Pleuronectes platessa,* sole *Solea solea.* Landings have remained stable for Pollack *Pollachius pollachius* and displayed a negative trend for monkfish *Lophius spp.* and skates and rays *Raja spp.* between 2010-2018 (Table 3) (*Supplementary Material 2*).

Table 3 Extent, condition and benefit flow of commercially targeted fish and shellfish species assets in Isles of Scilly IFCA district including summary of 10 year trend (where data available).

Scientific name	Common name	Quantity	Quantity unit	Quantity trend	Condition	Condition unit	Condition trend	ES Food Benefit (Quantity)	Benefit unit	Benefit trend
Commercially targeted fish and shellfish										
Cancer pagurus	Crab	no data			Sustainable	MSY		83.67	t/yr	
Homarus gammarus	Lobster	no data			Above critical	MSY		33.35	t/yr	
Palinurus elephas	Spiny lobster/crawfish	no data						2.29	t/yr	
Pollachius pollachius	Pollack	no data			3,360	(t) advised TAC ICES Area 7		2.75	t/yr	
Mugilidae spp.	Grey mullet	no data			no data			2.73	t/yr	
Pleuronectes platessa	Plaice	2,200	(t) SSB ICES Area 7e		10,360	(t) advised TAC ICES Area 7d+e		0.09	t/yr	
Solea solea	Sole	3,974	(t) SSB ICES Area 7d+e		1,202	(t) advised TAC ICES Area 7e		0.05	t/yr	
Lophius spp.	Monkfish	59,751	(t) SSB ICES Area 7		42,496	(t) advised TAC ICES Area 7		0.1	t/yr	
Raja clavata	Thornback ray	no data			no data			no data		
Raja spp.	Skates and rays	no data			no data			0.16	t/yr	
Scophthalmus maximus	Turbot	no data			no data			no data		
Scomber scombrus	Mackerel	4,186,496.00	(t) SSB ICES All areas		1,194,000	(t) advised TAC ICES all Areas		no data		

Key:					
	Trend	*Positive*	*Stable*	*Negative*	*Insufficient data*
	Condition	*Good*	*Acceptable*	*Of concern*	

- Resource user assessment of species condition

Species stocks were generally identified by respondents to be in good condition although environmental and anthropogenic pressures were identified. An increase in potting effort outside of the 6nm limit, was raised as a possible pressure that could lead to decrease in crab *C. pagurus* stocks that were shared with Isles of Scilly fisheries by 2 participants (17%) (Figure 3). Lobster *H. gammarus* populations were perceived to be in good condition, with good catches and abundant juveniles being seen in pots. Historical v-notching was identified to have been beneficial to supporting the population and a byelaw preventing landing berried female lobster to be less effective, as a breeding female may still be landed if not berried (Figure 3). Crawfish *P. elephas* abundance was also reported to have been increasing but one respondent suggested that some individual *P.elephas* shells appeared weaker. Environmental pressures were considered responsible, with respondents suggesting that this is due to climate change effects on ocean chemistry (preventing *P.elephas* building up calcium for shell development, and also mentioned in relation to condition of crab *C. pagurus*). Wider climate change pressure on health and distribution of stocks were also a raised as a concern of one other participant (Figure 3).

Water body asset condition

Water body status targets have been met for Isles of Scilly waterbodies. Ecological status, chemical status and overall water body status is assessed as 'good' in the latest Environment Agency data assessing Water Framework Directive targets (Table 4) (*Supplementary Material 2, Tab 5*). Actions were identified to review and update waste management practices on the islands to reduce pressures from hazardous substances and specific pollutants (nitrates) (Environment Agency 2009). These actions have been undertaken (South West Water pers. comm. 2020).

Table 4 Extent and condition of water body assets in Isles of Scilly IFCA district

Water Body	Status based on Water Framework Directive Targets	Condition	Condition trend
Isles of Scilly	***Overall Waterbody Status***		
	Component status		
	Ecological status		
	Chemical status		
	Hydromorpholoy status		

Key:					
Trend	*Positive*	*Stable*	*Negative*		*Insufficient data*
Condition	*Good*	*Acceptable*	*Of concern*		

4.3 Summary

Asset extent and condition status is overall good in Isles of Scilly IFCA district. Although condition of a moderate extent of circalittoral rock habitat within MPAs (10% of extent in MPAs) is assessed as degraded, this is due to historic pressures from fishing activity and the habitat is expected to be in recovery. Outside MPAs a very small proportion of the overall extent of circalittoral rock habitat across the IFCA district (<1%) was assessed to be degraded by interaction with pressures related to current fishing activity and level of effort (Table 2) (*Supplementary Material 2, Tab 3*).

Much of the extent of deeper cicalittoral soft substratum habitats is only evidenced by modelled data with poor confidence in true extent. Condition is unknown but there has been limited interaction in recent years, up to 2018/2019, with activities that the habitats are sensitive to (Tyler-Waters et al., 2018; 2019). Lack of reliable survey data for these habitats currently limits confidence in assessment, particularly asset condition. Therefore, an insufficient data category was selected (Table 2).

Spiny lobster/crawfish *P. elephas* provide an important economic resource to fishers on Isles of Scilly. However, monitoring of Isles of Scilly stocks between 2013-2015 suggested a low number of juvenile, from records of individual *P. elephas* caught in tangle nets and parlour pots by local vessels (Kelly-Fletcher and Holt 2015). Continued monitoring is required (as had started in 2019) to understand stock levels in IOS IFCA district. Modelling by Whormersley et al., (2018) identified *P. elephas* larvae from south coasts of Cornwall and Devon, and more distant areas, such as north-west France were more likely to be transported to Isles of Scilly waters, than larvae originating from Isles of Scilly (Whomersley et al. 2018). Although respondents to resource user interviews identified that

P.elephas stocks were in good condition in IoS IFCA district, joined up management over large spatial scales is required to continue to support the fishery. Current byelaws implemented to protect stocks across the UK MCZ network are beneficial to the *P.elephas* stock, but continued monitoring of stocks would aid condition assessment.

Conflicting evidence of condition of sublittoral macrophyte dominated sediment (eelgrass *Zostera marina* beds) between the existing conservation objective of 'maintain', and reduced extent and condition in annual monitoring (Bull and Kenyon, 2016) has led to the habitat asset condition being assessed as 'of concern'. Eelgrass *Zostera marina* beds in Isles of Scilly are still identified as some of the most extensive and best-developed eelgrass *Zostera marina* beds in southern England (Hocking & Tompsett 2001; Jones and Unsworth, 2016). Further monitoring would aid evidence to confidently assess condition.

5 Section 2: Risk Register

5.1 Methods

Policy Targets

Within a risk register, it is necessary to define the nature and the severity of the risk to the asset-benefit relationship. Mace *et al.* (2015) categorise risk according to the performance of the asset-benefit relationship to relevant policy targets. Policy targets in this context are considered to be societal aspirations for the asset-benefit relationship and, as such, form a threshold target against which risk can be defined. Policy targets applied within this Risk Register are outlined in the Supplementary Materials linked to Convention on Biological Diversity Aichi Target 11, UN Sustainable Development Goal 14, The Marine Strategy Framework Directive Descriptor 6 and 3, and The Water Framework Directive (*Supplementary Material 4, Tab 1*).

Risk register under current activity and 10 year trend (baseline conditions).

A natural capital asset and risk register (and additional assessment of risk to commercial species habitat requirements) was completed and results summarised for current status and 10 year trend.

Risk Assessment

Following the process defined by (Mace *et al.*, 2015) and applied by Rees, Ashley and Cameron (2019), each asset – benefit relationship was assessed against the evidence in the asset register according to the identified policy targets (*Supplementary Material 4, Tab 1*). A precautionary approach was applied to identify risk, adapted from Mace et al. (2015). In instances where the status of benefit is below target and the trend negative we apply an adapted amber risk rating with an asterisk to highlight those asset benefit relationships that are at risk of tipping over to a red risk rating (Figure 4). Each risk scoring was assessed for the strength of evidence and agreement between evidence sources, assessed for on a scale of 1-4 for both status and trend (*Supplementary Material 4, Tab 2*). The confidence score is the sum of confidence scores for 'status' and 'trend', if both scores relate to limited evidence (confidence score 4) and low agreement between sources (confidence score 4) the total score presented in the risk assessment was 8 (Figure 4). Mace et al. (2015) presented total scores of <4 as high confidence (low uncertainty), and scores of >5 as low confidence in the evidence and so high uncertainty. In this study we have applied a precautionary approach and clarified this scoring with total scores of between 1 to 3 regarded as high confidence (low uncertainty) and total scores of ≥4 regarded as low confidence (high uncertainty). Cells in the risk matrix output where there was high confidence (low uncertainty) in the evidence the assessment was based on, appear in bold colour. The cells with low confidence (high uncertainty) in the evidence were shaded in a lighter shade of the colour (Figure 4).

		Status		
		Above, at or just below target	Below target	Substantially below target
Trend	Positive or not discernible	Low	Medium	Medium
	Negative	Medium	Medium*	High
	Strongly negative	High	High	High

a)

		Agreement	
		High	Low
Robustness	Significant evidence	1	3
	Limited evidence	2	4

b)

	High confidence	Low confidence
Total Score	1 to 3	≥ 4

Figure 4 Matrix to assess asset status against asset trend. a) Matrix to assess the robustness and agreement of the evidence used to assess the risk category and b) provide a final confidence score in available evidence

Risk to fish and shellfish resources supporting Isles of Scilly fisheries

Risk assessment indicators for quota species and non-quota species used SSB, TAC or stock assessment for wider ICES areas or the entire south west UK region. However, commercial species utilise habitats for shelter and food resources within the spatial scale of the IFCA district to support both adult and juvenile life stages (*Supplementary Material 1, Tab 2*). Degradation of IoS habitats supporting life stages of commercially targeted species is likely to negatively impact level of contribution to ES 'Food' within Isles of Scilly, and negatively impact quantity and quality (extent and condition) of stocks supporting IoS fisheries. To investigate potential implications of changes in habitat extent and condition on the species that utilise those habitats, reviewed evidence on importance of each habitat to life history stages of fish and shell fish species (*Supplementary Material 1, Tab 2*) was combined with level of risk identified for each habitat in the risk register.

Risk from degradation of habitat assets, to the species that rely on those assets to support life history stages was assessed through adapting methods developed by Hooper *et al.* (2017). The risk rating of each habitat asset 'quality/condition' component (Figure 4) was assessed in relation to the importance of that habitat to adult and juvenile life stages of the species being considered (*Supplementary Material 1, Tab 2*) (Figure 5).

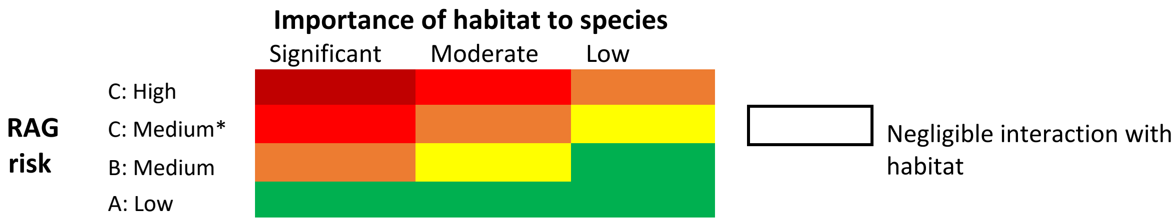


Figure 5 Matrix to assess species habitat – condition linkages in relation to assessment in the risk register for ES benefit 'Food' (adapted from Hooper et al., 2018).

Resource user community identified risks

Resource user interview responses on current and recent historical pressures that had affected condition of habitats and species within Isles of Scilly IFCA district, were applied in both the asset and risk register. Responses were coded within themes and number (and %) of participants identifying each risk theme were reported.

The top 3 future risks to the condition (health) of habitats and species within Isles of Scilly IFCA district, identified by interview participants are also applied in the risk register section. Replies were coded within themes and weighted according to the prioritization provided by the respondent (Top or No. 1 risk = 3, 2nd risk = 2, 3rd highest =1). Total weighted responses within themes were presented in a chart.

Participants were also asked for perceptions of current management actions, and future management needs (*Supplementary Material 3*).

Participants were asked to provide their agreement on a scale between 0 (not at all) and 10 (totally agree) to what extent they believed each of the current and upcoming IFCA byelaws and management actions have benefitted (or will benefit) their fishing activity/the fishery in Isles of Scilly. Participants were also asked to what extent they believed developing further market opportunities for Isles of Scilly caught fish would benefit fisheries in the Isles of Scilly. Mean agreement (and standard error) was calculated across the sample group and presented in a chart.

Finally, participants were asked for their (open ended) responses of future management options they believe will benefit fisheries in the Isles of Scilly (their own activity or others to aid a sustainable and viable fishery in the Isles of Scilly). Replies were coded within themes and number (and %) or participants identifying each risk theme were reported.

Consent was sought for information to be used in the study and all data anonymised, ethical approval for the interview survey was sought and approved under University of Plymouth research ethics policy.

Summary of environmental and economic implications: Costs, opportunities and limitations

Implications of the risk register were summarised in relation to i) implications on ES provision, ii) implications for fishing industry and iii) Implications for species habitat (and sustainable resource use).

5.2 Results

Risk Register: current risk to the asset-benefit relationship

Of the initial 214 potential relationships between the 5 ecosystem service benefits and the quantity, quality and spatial configuration of 11 EUNIS level 3 habitats, as well as water bodies and stocks of quota fish species and non-quota fish/shellfish species, 106 priority relationships were assessed in the risk register (Figure 6) (*Supplementary Material 4, Tab 3*). 108 relationships were judged to be of lower significance for either contribution to ecosystem service benefits or management reasons, or could not be assessed due to lack of available data to assess status or trend (*Supplementary Material 4, Tab 3*). As examples, the quantity or spatial configuration of water bodies within the Isles of Scilly study area could not be altered, or managed, to enhance or reduce benefits derived from the marine and coastal environment. For fish species, there was limited data available on spatial abundance and also spatial configuration of populations in relation to habitats within the IoS IFCA district.

No asset-benefit relationships were allocated a high-risk component for the assessments of the asset status (quantity, quality, spatial configuration). Medium risk components (amber) were identified for 43 assessments of the asset status (either quantity, quality, or spatial configuration), principally for deeper subtidal habitats. Of those in medium (amber) risk, 23 displayed declining trends (either quantity, quality or spatial extent) and were assigned medium – high risk (amber, C*). Low risk was identified across 63 components, including all intertidal (littoral) habitats, infralittoral reef and quota fish species (Figure 6).

Species - habitat linkages identified moderate to high risk of loss from degraded quality/condition of circalittoral reef habitats and subtidal seagrass to juvenile and adult habitat requirements of 3 shellfish species and 4 fish species (Figure 7). Lack of evidence of extent and condition of subtidal soft substratum led to precautionary medium risk being identified to juvenile habitat of lobster and feeding grounds of brown crab and 4 fish species (Figure 7).

These risks to the delivery of ES benefits are summarised as:

- Food (wild food fish and shellfish) is amber (medium) risk as >5% of circalittorral reef within MPAs has the condition assessment of 'recover' and is therefore above threshold levels for impaired quality (condition) (*Supplementary Material 4, Tab 3*). Negative trend in extent and condition of seagrass habitat also impairs flow of ES benefits. As a precautionary interpretation, due to the lack of evidence of habitat extent, quality and spatial configuration in offshore areas, potential delivery of ES from subtidal soft substratum habitats may also be impaired.
- Habitat contribution to healthy climate benefits is at amber (medium) risk due to the decreased extent and degraded quality of the subtidal seagrass habitat.
- Sea defence services provided by subtidal seagrass habitat are also at amber (medium) risk due to decreased extent and quality of the habitat.
- Recreation and tourism is at amber (medium) risk as a precautionary measure due to degraded habitats supporting habitats and species of interest.
- Clean water and sediments supported by the ecological functions and processes in the subtidal sediment habitats are considered to be at amber (medium) risk of loss, as a precautionary measure, due to lack of evidence on the extent, quality (condition) and spatial configuration of deeper soft substratum species communities.

Risk to species-habitat linkages

In terms of the commercial species - 10% of circalittoral reef has a condition assessment of 'recover'. This is identified as being above threshold levels for impaired quality (condition) (*Supplementary Material 4, Tab 3*). This therefore has the potential for high negative impact on habitat availability for commercially targeted shellfish species and some fish species (Pollack) that utilise the circalittoral reef habitats for shelter and/or finding prey (Figure 7). Impaired condition/quality of circalittoral reefs also has negative impacts on fish species such as plaice, monkfish and thornback ray which use this habitat during key life history stages (Figure 7).

Species that utilize **subtidal seagrass habitats**, particularly during juvenile life stages (pollack, mullet, sole, plaice and skates and rays) are negatively impacted by the decreased extent and degraded quality of the subtidal seagrass habitat (Figure 7).

The amber precautionary risk of loss of the asset-benefit relationship linked to **subtidal soft substratum** habitats is also identified as having a moderate impact on presence of suitable habitat and food resources for commercially targeted flatfish, skates and rays as well as crab and juvenile lobster (Figure 7).

Intertidal (littoral) soft substratum habitats, reef and shallow (infralittoral) reef in IoS IFCA district are likely to be providing all expected resources to the fish and shellfish species targeted by IoS fisheries (Figure 7).

	Littoral rock			Littoral coarse sediments			Littoral sand and muddy sand			Littoral mud			Littoral mixed sediments			Sublittoral Seagrass			Infralittoral rock			Circalittoral rock			Sublittoral coarse sediment			Sublittoral sand			Sublittoral mixed sediments			Water bodies			Fish (quota species)			Fish (non-quota species)		
	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.
Food (Wild Food - fish and shellfish).	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	C (4)	C (4)	C (8)	A (4)	A (4)	A (4)	C (4)	C (4)	C (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)		A (2)		A (4)	A (4)		A (4)	Lob B (4) Crab A (4) Craw C (4)	
Healthy climate (carbon sequestration).										A (4)	A (4)	A (4)				C (4)	C (4)	C (8)	A (4)	A (4)	A (4)														A (2)							
Sea defence. (natural hazard regulation / flood prevention).	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)				A (4)	A (4)	A (4)	C (4)	C (4)	C (8)	A (4)	A (4)	A (4)																					
Tourism / nature watching.				A (4)	A (4)	A (4)	A (4)	A (4)	A (4)							C (4)	C (4)	C (8)	A (4)	A (4)	A (4)	C (4)	C (4)	C (4)											A (2)		A (4)	A (4)		A (4)	Lob B (4) Crab A (4) Craw C (4)	
Clean water and sediments.										A (4)	A (4)	A (4)				C (4)	C (4)	C (8)							B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)		A (2)							

Figure 6 Priority relationships assessed in the risk register. The assets are columns and the benefits in rows. For each ES the top row is risk assessed through analysis of indicator data in relation to policy targets, the lower row for each benefit is risk assessed in relation to (local) community based knowledge of risk. The colour of the cell shows the risk rating for the asset status quantity (Qun), quality (Qul), spatial configuration (Sp) based on the scoring matrix. Red indicates it is at high risk, amber at medium risk (*amber cells with an asterisk, indicate asset status is below target and the trend in status is declining, suggesting risk rating is close to moving to the high risk category), green risk ratings are at low risk. Lighter shaded, red, amber or green cells indicates RAG risk rating where there is less confidence (greater uncertainty) in the risk rating, due to limited evidence and/or limited agreement between evidence sources (e.g. modelled habitat data). The light shading for commercial fish species indicates a RAG assessment based on an assessment of data at a spatial scale greater than the case study area. The grey cells indicate asset- benefit relationships, which did not provide a significant or moderate supply of ecosystem service benefit or there was no information to make an assessment.

Current activity	Marine																							
Natural Capital Asset	**Intertidal reef**		**Subtidal reef**						**Intertidal sediments**								**Subtidal sediment**							
	A1: Littoral rock and other hard substrata		A3: Infralittoral rock and other hard substrata		A4: Circalittoral reef fauna colonised rock		A4: Circalittoral reef fauna colonised veneer		A2.1 Littoral Coarse sediment		A2.2: Littoral sand and muddy sand		A2.3: Littoral mud		A2.4: Littoral mixed sediment		A5.1: Sublittoral coarse sediment		A5.2: Sublittoral sand		A5.4: Sublittoral mixed sediments		A5.5: Sublittoral macrophyte dominated sediment	
	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult
Lobster																								
Crawfish																								
Crab																								
Pollack																								
Mullet																								
Turbot																	spawning							
Monks																								
Sole, Plaice				plaice		plaice		plaice														sole		
Skates and Rays																								

Figure 7 Species - habitat condition linkages in relation to assessment in the risk register for ES benefit ‘Food’ under existing conditions in IoS IFCA district (Figure 6)

Risk identified in resource user interviews

Resource user perceptions of habitat condition identified historic and current pressures that had increased risk to asset-benefit relationships. Historic habitat damage from scallop dredge and rock hopper trawls, pressure on crab stocks from increased effort outside the 6 nautical mile IoS IFCA district boundary and climate change related pressures were identified most frequently (Figure 8).

When asked to identify the top 3 future risks to the condition (health) of habitats or stocks that support their fishing activity, participants' responses reflected the historical and current pressures identified during interviews. Pollution from passing shipping, such as an oil spill, was identified as a priority risk (weighted score, 14, Figure 8). Fishers also prioritised potential risk to the sustainability of current fishing activity if scallop dredging or rock hopper trawl activity returned at historical levels (weighted score 12, Figure 8). Intense rock-hopper trawl and dredge activity was identified to damage reef and mixed ground habitats that supported the crawfish *P. elephas* fishery. As well as damage to habitat, participants' identified there would be risk of gear conflict if larger dredge or trawl vessels returned, with resulting risk to income if pots had to be replaced (Figure 8). Fishers were also aware of pressure on crab *C. pagurus* stocks from outside the 6nm limit. Demand from Chinese markets for crab *C.pagurus* and owners of large beam trawlers switching to offshore potting was considered to increase risk to the sustainability of crab *C.pagurus* stocks that moved into Isles of Scilly waters from offshore areas. Climate change impacts on species distribution and health were also perceived as environmental pressures that would potentially increase risk to health of stocks and abundance within Isles of Scilly in the future (Figure 8).

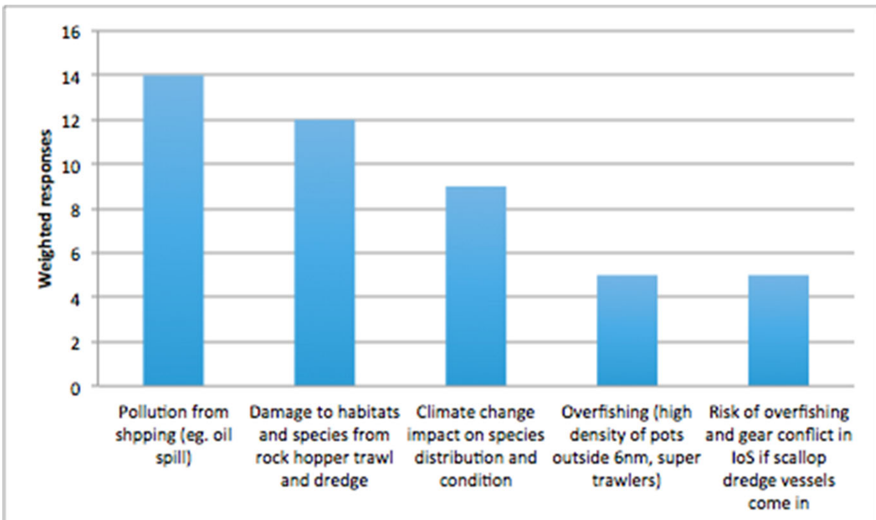


Figure 8 Future risks to habitat and species assets supporting fisheries in the Isles of Scilly, identified in interviews with Isles of Scilly fishing community, weighted by level of priority (high, medium, low) identified by individual respondents.

Resource user open responses around future management needs

66% of participants (8) identified risk from future pressures from newer designs of vessels that could meet the existing vessel size and weight restrictions, but still have engine power to carry a lot of pots, lengths of net, or, if permitted dredges and trawls (Figure 9). To prevent over fishing of resources, or damage to habitats from local or visiting vessels, responses suggested limiting engine power of vessels. Permitting otter trawling with power restrictions was suggested by 6 respondents (50%). The ageing population of Isles of Scilly fishers needing a less physically demanding fishing method, the need for bait for crab and lobster pots and need to provide diversification opportunities to encourage younger generation to enter, or remain in the industry was raised by respondents in regard to permitting greater numbers of otter trawl licenses (Figure 9). In relation to diversification options, and encouraging opportunities for an Isles of Scilly fishery to continue, 3 respondents mentioned simplifying processes for licensing, including passing on licenses to other individuals would be beneficial (25%). Changes to landing restrictions were raised, to aid sustainability, 2 respondents suggested pollack landing size could be increased further and banning landing of hen lobster and crawfish would also benefit the fishery (Figure 9). There was interest in promoting the sustainability of the Isles of Scilly crab fishery and building market opportunities, such as through MSC accreditation or similar approaches (Figure 9).

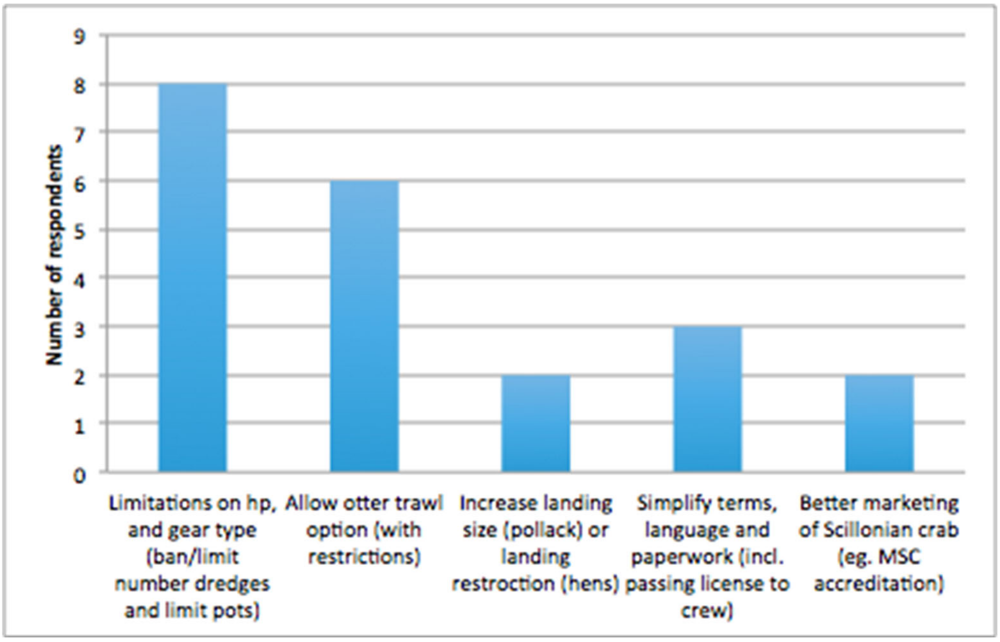


Figure 9 Resource user open responses around future management needs

Resource user perceptions of benefit of current management

There was high support for all current management actions that supported sustainable fishing activities in the Isles of Scilly (Crawfish minimum landing size bylaw 9.8 SE ± 0.4, V notching of egg bearing female lobsters 9.1 SE ± 1.4, vessel limit under 10 tonnes and 11 metres 8.3 SE ± 2.1, introduction of hatchery reared juvenile lobsters 7.8 SE ± 2) . On average, respondent's level of agreement that the hobby potting byelaw was benefitting fisheries in the Isles of Scilly was moderate (7.0 SE ± 2.4, Figure 10). Respondents indicating lower support recognised the byelaw reduced excessive resource use, but may also prevent opportunities for younger generations to gain interest and enter the industry. There was interest in future opportunities to develop markets or sales of fish and shellfish in Isles of Scilly (8.7 SE ± 2.2) (Figure 10), although participants recognised limitations due to seasonal fishery and weather limitations to provide constant supply to orders.

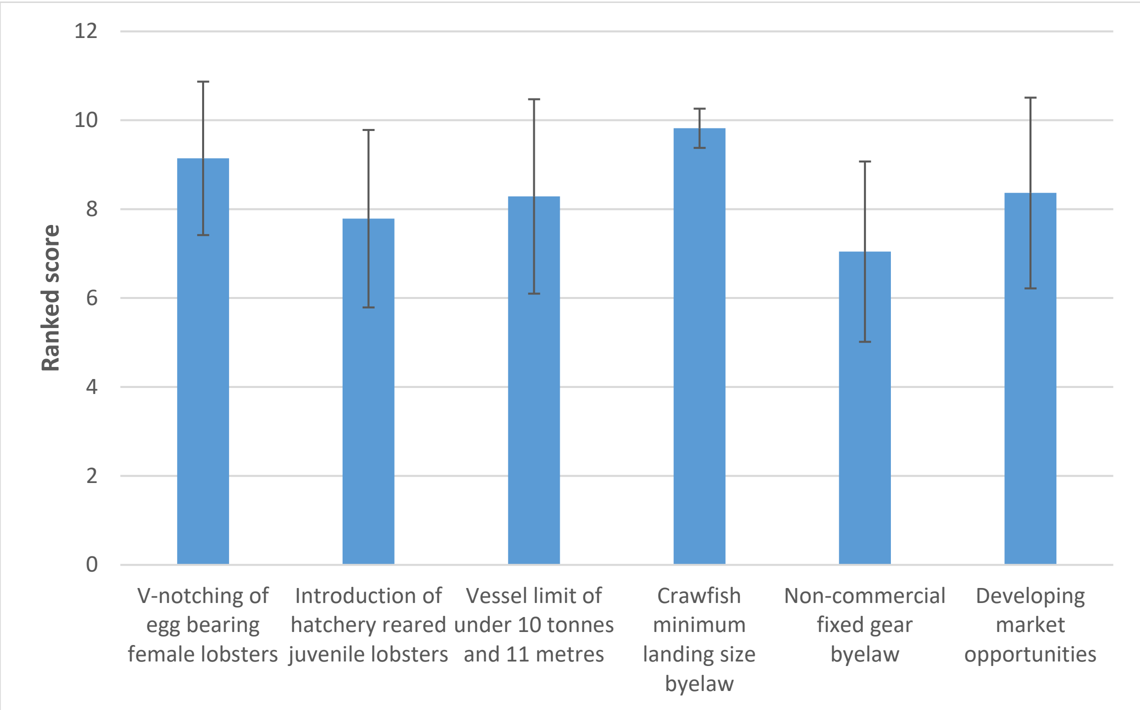


Figure 10 Resource user perceptions of benefit of current and incoming management mean agreement and SE, ranked score refers to sum of weighted rank (highest (no.1) priority = score 3, 2nd highest = 2, 3rd highest = 1).

Summary of environmental and economic implications: costs, opportunities and limitations

There is strong interest from Isles of Scilly fishers participating in the interview survey to continue to fish within sustainable limits, while allowing opportunities for diversification and marketing catches. Economic risks from limited opportunity to diversify, such as using different gear types were raised by respondents as challenges to recruiting younger generations into the industry. There was high support for all existing management actions that supported a sustainable fishery and prevented historical damage to habitats from larger, powerful visiting trawlers and scallop dredgers (Figure 8, Figure 9, Figure 10). Solutions presented to limit risks to sustainability were to allow a limited number of licenses (50% respondents (Figure 9)) and to limit power of vessels for all gear types to reduce impact on habitats and species (67% respondents (Figure 9)).

Table 5 Implications of current activity and management on ES provision, fishing industry economic sustainability and implications on species – habitat linkages.

Current activity		
Implication for ES provision	Implication for fishing industry	Implication for habitats and species
• Historical pressure and current low pressure to deeper subtidal habitats results in increased risk to provision of ES 'food', 'Tourism and nature watching', 'Clean water and sediments'. • Under current activity/pressures, subtidal habitats are expected to be recovering from historical impact.	• Limited diversification options for Isles of Scilly fishers. • Negligible to no economic opportunity for other UK fishers. • Seasonal fishery limits full time employment opportunities. • Currently sustainable resource use with low or recovering risk to ES provision, and species stocks. • Isles of Scilly industry is sustainable and will continue to support current effort.	• Historical impacts to habitat supporting species and risk to ES flows are recovering under current activity and associated pressures. • In comparison to other UK locations habitat is in a condition that is, sustainably supporting existing low impact resource use. • Contributing to GES and achievement of sustainability goals for UK.

The current limitations on bottom towed fishing activities contribute to meeting recovery objectives within Isles of Scilly MPAs. As a result MSFD 'good environmental status' targets can be met under current management.

The current limitations on fishing activities in the district present a challenge to meeting perceived benefits of increasing otter trawl and diversification opportunities shared by a proportion of interview respondents (Figure 9, Table 5). In respect to the current iVMS areas, there is currently very little to no activity. However, increased activity in iVMS zones I and II may degrade circalittoral reef and reef/veneer habitat and further limit recovery and increase risk to flows of ES.

Through methods applied in Mace et al., (2015) and Rees et al., (2019), 59% of natural capital asset – ES components in Isles of Scilly IFCA district were assessed to be at low risk of loss, under baseline conditions. Low risk assets were contributing to ES provision as expected from reviewed evidence.

Medium risk was assessed to be occurring for 19% of asset components and medium - high risk (medium status with declining trend) for 22%. No components were assessed to be at high risk in relation to contribution to ES provision. It is important to note components in medium to medium high risk associated with sublittoral seagrass and sublittoral soft substratum received precautionary assessments due to limited or conflicting evidence. In addition, current medium-high risk in relation to circalittoral rock contribution to ES is potentially lower risk as bottom towed fishing activity has declined in the district.

Assessment of risk to species-habitat linkages identified species at specific risk. Due to degraded quantity and quality of reef and sublittoral seagrass habitat features. A high risk of negative impact occurred for 11 interactions of habitat components that are of importance to adult and juvenile life stages of species supporting Isles of Scilly fisheries. Limited evidence of extent and condition (quantity and quality) of deeper sublittoral habitats contributed to precautionary assessments of habitat asset risk and so may exacerbate risk to species-habitat linkages. Despite precautionary measures, current assessments returned no interactions in the significant risk category for habitats that are of importance to adult and juvenile life stages of species.

6 Section 3: Risk Register under future management scenarios

6.1 Methods

Three scenarios were selected through consultation with Isles of Scilly IFCA on fishing methods to be included. For example scenarios of interest to vessel operators in Isles of Scilly and/or vessel operators from other UK ports that had expressed interest in fishing in the district (Figure 11). The spatial area selected for scenarios was based on areas of greatest interest to both groups of vessel operators (Isles of Scilly based and wider UK port based), and areas with greatest confidence in habitat and infauna and epifauna species communities across the area selected in the scenario.

Impacts on quantity, quality and spatial consideration of natural capital habitat assets were assessed based on interaction of proposed activities with natural capital habitat assets and the level of sensitivity of habitats to pressures associated with those new or changed activities. Sensitivity of habitats to associated pressures were assessed as in methods for assessment of LRC (*Habitat Quality (Condition) - outside MPAs*), using evidence assessed by Tyler-Walters et al., (2018; 2019). Full detail on thresholds for each fishing activity and the associated pressures identified to use in sensitivity assessments are contained in Annex II.

Scenario 1: Scallop dredging activity occurring across the eastern Isles of Scilly IFCA, excluding the Isles of Scilly Complex SAC (Figure 11). Scenario 1 assessed the implications for risk to ES flows as a result of exposing 172km ^{2} of deeper offshore habitats in the eastern area of IoS IFCA district to bottom towed fishing activity, using gears that penetrate the surface to cause pressures sub-surface disturbance and habitat structure change under high levels of activity (Tyler-Waters et al., 2018; 2019) (Annex II).

Scenario 2: Otter trawl effort and intense potting effort increasing in low sensitivity habitats to abrasion (Figure 11). The scenario assesses exposure of low sensitivity habitat to the pressure 'abrasion' in relation to intensive potting and otter trawling activity (over 231 km^2 of seabed) (Tyler-Waters et al., 2018; 2019) (Annex II).

Scenario 3: Otter trawl activity increases in iVMS area 2 (south eastern) and the eastern IFCA district outside SAC (Figure 11). Scenario 3 assessed the implications for risk to ES provision of increased otter trawl activity in iVMS area 2 (south eastern) and the eastern IFCA district outside the SAC (Figure 11). The activity would interact with 76.7km^2 of circalittoral reef and reef veneer, 101.5km^2

of circalittoral coarse sediment, 21.7km² of sublittoral sand and 4.4km² of sublittoral mixed sediment and relates to the pressure 'abrasion' (Tyler-Waters et al., 2018) (Annex II).

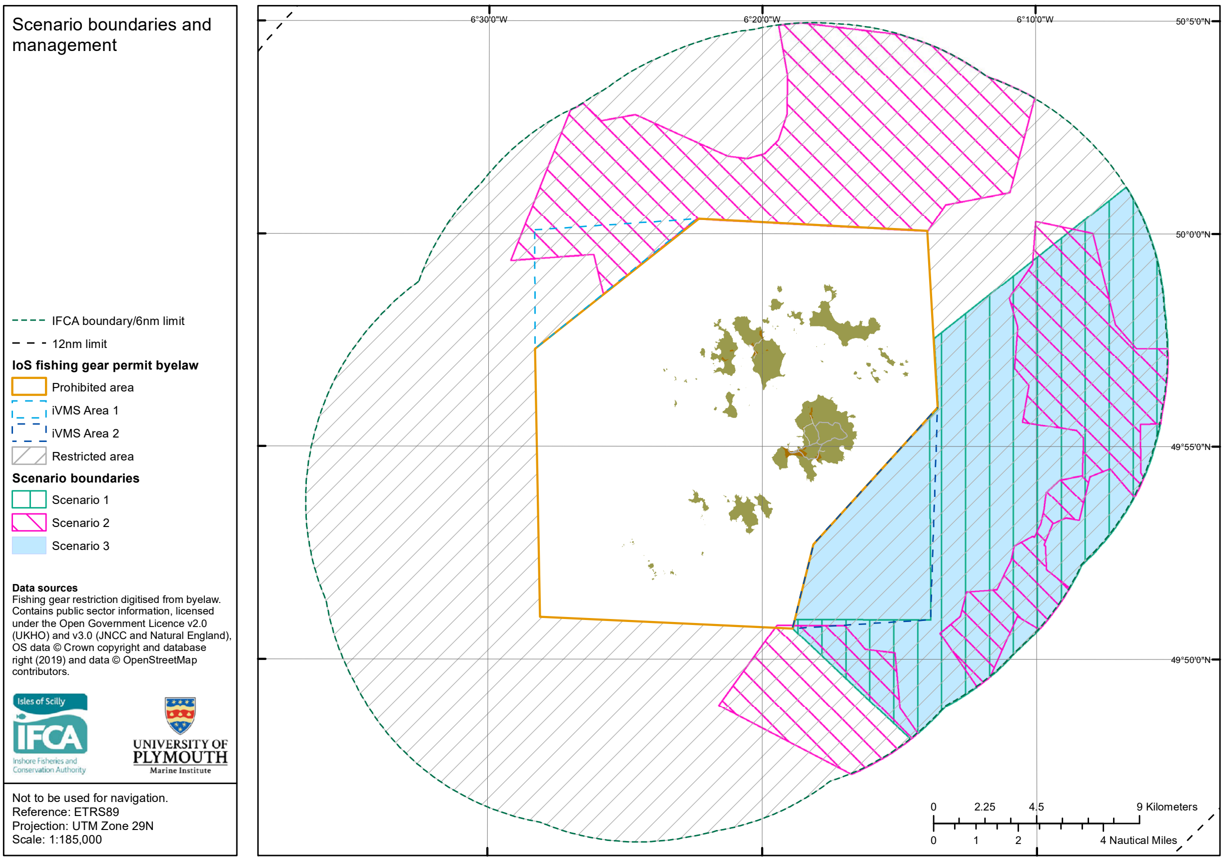


Figure 11 Map displaying scenario spatial areas in relation to existing management. Scenario I increase in scallop dredge activity within boundary. Scenario 2 increase in otter trawl activity over ow sensitivity habitats. Scenario 3 Increase in otter trawl activity over all habitats within spatial boundary.

Scenario outputs are intended to focus discussion with resource users on risk and implications associated with management options. Monitoring of habitat response to interactions with fishing activity would be required to assess actual impacts under any given scenario, if it were to progress to being applied in IoS IFCA District.

6.2 Results

Under current (baseline) activity and existing fisheries management, no (zero) asset-benefit relationships were allocated a high risk component for the assessments of the asset status (quantity, quality, spatial configuration). In Scenario 1, 14 components were assessed as high risk of loss of the asset- benefit relationship (red), under scenario 2, 4 components were assessed as high risk and under scenario 3, 8 components were assessed as high risk (Table 6).

Table 6 Components in risk assessment category under each scenario.

Risk to ES provision	**Current activity**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Red: High	0	14	4	8
Amber (C): Medium - High	23	19	23	21
Amber (B): Medium	20	10	16	14
Green (A): Low	63	63	63	63
Total in High and Medium-High Risk	**23**	**33**	**27**	**29**

Under current activity habitat assets are either within policy targets identified by the risk register or recovering to meet targets. All scenarios that assessed implications of an increase in fishing activity (either scallop dredge or otter trawl activity or increased potting intensity) identified a reduction in the ability of habitats and associated species communities to recover to meet targets. As a result there were limitations on the provision of ES, in particular, ES: Food, Tourism/Nature Watching and Clean Water and Sediments. All scenarios increased risk to habitats that supported important species-habitat linkages for essential life stages of commercially targeted fish and shellfish that contributed to ES of 'Food' (Table *7*).

Table 7 Risk to species – habitat linkages (sum of species - habitat linkage components within each risk category) with species grouped within the gear types/fishery practice that targets them.

		Current				Scenario 1				Scenario 2				Scenario 3			
		Potting	Tangle net	Handline	Potting	Potting	Tangle net	Handline	Mixed fish	Potting	Tangle net	Handline	Mixed fish	Potting	Tangle net	Handline	Mixed fish
Risk	Significant	0	0	0	0	**6**	**2**	**2**	**6**	2	0	0	4	4	2	2	0
	High	**2**	**3**	**3**	**3**	**3**	**4**	**1**	**16**	**3**	**4**	**3**	**7**	**2**	**2**	**1**	**11**
	Moderate	8	0	0	23	3	0	0	7	6	0	0	19	4	0	0	16
	Low-Moderate	2	3	0	4	1	1	0	1	1	2	0	2	2	2	0	3
	Low	7	2	3	10	7	2	3	10	7	2	3	10	7	2	3	10
	Total in Significant and High risk	**2**	**3**	**3**	**3**	**9**	**6**	**3**	**22**	**5**	**4**	**3**	**11**	**6**	**4**	**3**	**11**

Scenario 1

In scenario 1, scallop dredging was permitted within 172km² of the offshore area of the eastern IFCA district, across reef, reef/veneer and soft substratum habitats (Figure 11, Figure 12). Interaction with 100km² of medium or high sensitivity habitats and 72km² of low sensitivity habitat to pressures associated with scallop dredging activity (Tyler-Waters et al., 2018; 2019), resulted in a 43% increase in number of asset components assessed to be in high and medium-high risk categories in relation to contribution to ES provision (Table 6). Food, tourism and nature watching and clean water and sediments would be the ES benefits impacted by degraded habitat quality under scenario 1. Due to increased risk associated with quantity and quality of habitat features, high or significant risk of negative impact occurred for 40 interactions of habitat components that are of importance to adult and juvenile life stages of species supporting Isles of Scilly fisheries (Table *7*). An increase of 35 interactions compared to baseline conditions.

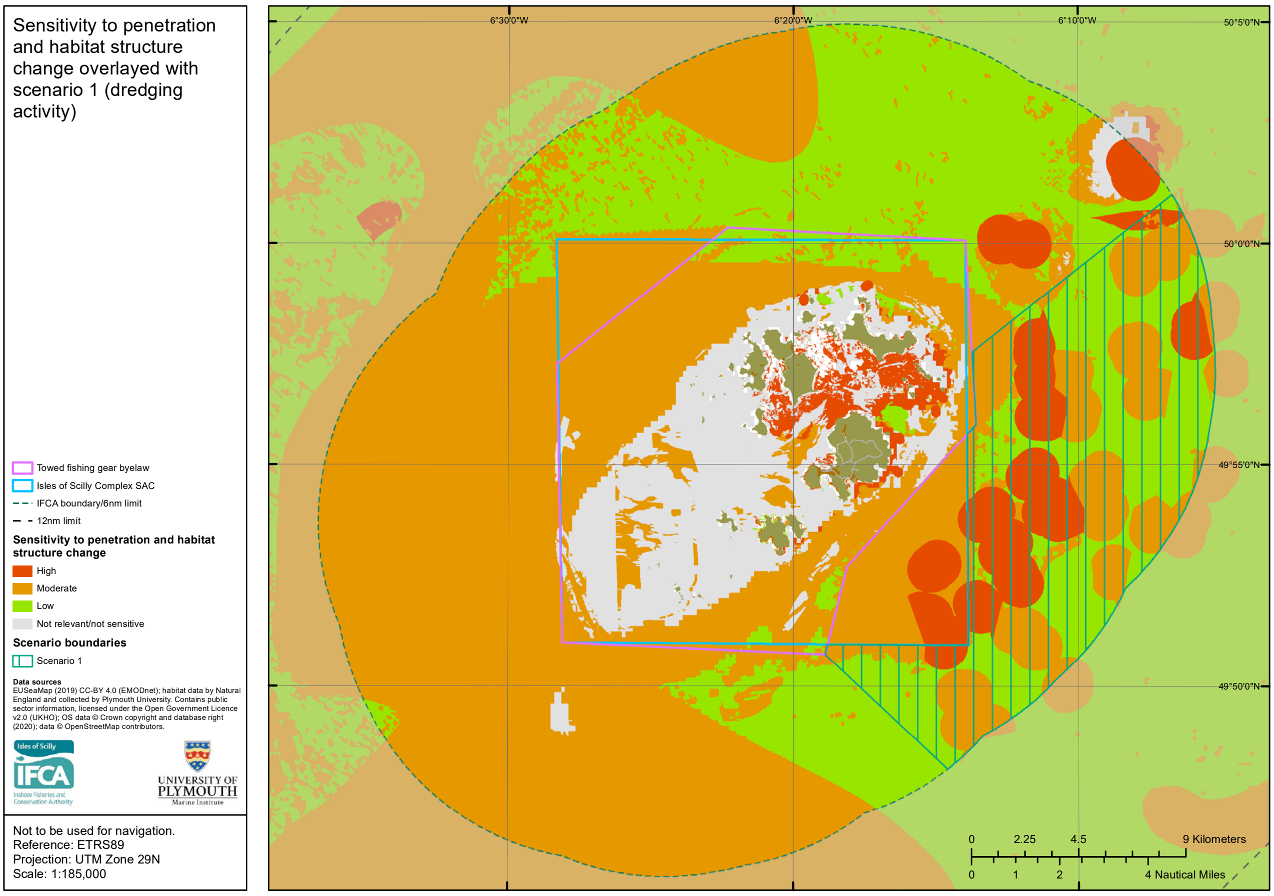


Figure 12 Interaction of habitats with high, medium and low sensitivity to pressures associated with scallop dredging within spatial extent of scenario 1

Impact on the asset-benefit relationship (Ecosystem Services)

In Scenario 1, 14 components were assessed as high risk of loss of the asset- benefit relationship (red) (Figure 13). Medium risk components (amber) were identified for 29 assessments of the asset status (either quantity, quality, or spatial configuration), of which 19 exhibited a declining trend and so increased risk to the medium – high category (C*) (Figure 13). Low risk was identified across 63 components, including all intertidal (littoral) habitats, infralittoral reef and quota fish species (Figure *13*). Habitat asset components assessed as low risk under existing activity, did not interact with the activity in the 188km^2 zone used in the scenario (Figure 12). In Scenario 1:

- Risk to the provisioning ES 'Food' is raised from medium to red (high) risk as an additional 100km^2 of habitat that has medium or high sensitivity to sub surface disturbance is impacted by activities. This increases the % of circalittoral reef outside MPAs with LRC below 3, from 1.4% to 16.6% and this creates a strong negative trend. Potential delivery of ES benefits from subtidal soft substratum habitat species communities are further impaired by exposure to sub-surface disturbance, due to risk category increasing from B (medium) to

C*(medium/high). Negative trend in extent and condition of seagrass habitat also continues to impair flow of ES benefits, but does not interact with activities in scenario 1.

- The Contribution of natural capital assets to ES of healthy climate and sea defence are unchanged at amber (medium) risk due to the spatial scale of scenario 1 not interacting with subtidal seagrass habitat.
- The ES benefit of a 'healthy climate' may also be impacted by degraded condition of subtidal soft substratum, as a small amount of plankton reaching the seafloor becomes buried in sediments (Howard et al., 2017). Contribution is low, so not included in the matrix, but potentially extends over large extents of IFCA district.
- The risk to the ES of 'recreation and tourism' increases to an amber (C* medium/high) risk due to potential degradation of habitats supporting species of interest to the recreation and tourist industry.
- The ES benefit of 'clean water and sediments', supported by the ecological functions and processes in the subtidal sediments, are at greater risk (red (high)) under Scenario 1. Initial assessment was as a precautionary measure, due to lack of evidence on the extent, quality (condition) and spatial configuration of deeper soft substratum species communities. However, species communities within these habitats are likely to be negatively impacted by activities in scenario 1. As a result, the functions performed by healthy ecological communities such as burial and release of pollutants, will be impaired.

Impact on the asset-benefit relationship (Commercial fish and shellfish)

Under scenario 1 a baseline moderate or high risk to species – habitat linkages increased to high or significant risk of loss for 8 species, due to further degraded quality/condition of circalittoral reef habitats, under activities in scenario 1 (Figure 14). Increased risk to the quality of soft substratum habitats were also assessed to have a high to significant impact on food and shelter resources for all commercially targeted species other than pollack (Figure 14).

	Littoral rock			Littoral coarse sediments			Littoral sand and muddy sand			Littoral mud			Littoral mixed sediments		
	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.
Food (Wild Food - fish and shellfish).	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)
Healthy climate (carbon sequestration).										A (4)	A (4)	A (4)			
Sea defence. (natural hazard regulation / flood prevention).	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)				A (4)	A (4)	A (4)
Tourism / nature watching.				A (4)	A (4)	A (4)	A (4)	A (4)	A (4)						
Clean water and sediments.										A (4)	A (4)	A (4)			

	Sublittoral Seagrass			Infralittoral rock			Circalittoral rock			Sublittoral coarse sediment			Sublittoral sand		
	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.
Food (Wild Food - fish and shellfish).	C (4)	C (4)	C (8)	A (4)	A (4)	A (4)	C (4)	C (4)	C (4)	B (4)	C (4)	C (4)	B (4)	B(4)	B (4)
Healthy climate (carbon sequestration).	C (4)	C (4)	C (8)	A (4)	A (4)	A (4)									
Sea defence. (natural hazard regulation / flood prevention).	C (4)	C (4)	C (8)	A (4)	A (4)	A (4)									
Tourism / nature watching.	C (4)	C (4)	C (8)	A (4)	A (4)	A (4)	C (4)	C (4)	C (4)						
Clean water and sediments.	C (4)	C (4)	C (8)							B (4)	C (4)	C (4)	B (4)	B (4)	B (4)

	Sublittoral mixed sediments			Water bodies			Fish (quota species)			Fish (non-quota species)		
	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.
Food (Wild Food - fish and shellfish).	C (4)	C (4)	C (4)		A (2)		A (4)	A (4)		A (4)	Lob B (4) Crab A (4) Craw C (4)	
Healthy climate (carbon sequestration).					A (2)							
Sea defence. (natural hazard regulation / flood prevention).												
Tourism / nature watching.					A (2)		A (4)	A (4)		A (4)	Lob B (4) Crab A (4) Craw C (4)	
Clean water and sediments.	C (4)	C (4)	C (4)		A (2)							

Figure 13 Priority relationships assessed in the risk register under scenario of 172km² of IoS IFCA district being exposed to activities that cause the pressure ‘sub surface disturbance’. The assets are columns and the benefits in rows. For each ES the top row is risk assessed through analysis of indicator data in relation to policy targets, the lower row for each benefit is risk assessed in relation to (local) community based knowledge of risk. The colour of the cell shows the risk rating for the asset status quantity (Qun), quality (Qul), spatial configuration (Sp) based on the scoring matrix. Red indicates it is at high risk, amber at medium risk (*amber cells with an asterisk, indicate asset status is below target and the trend in status is declining, suggesting risk rating is close to moving to the high risk category), green risk ratings are at low risk. Lighter shaded, red, amber or green cells indicates RAG risk rating where there is less confidence (greater uncertainty) in the risk rating, due to limited evidence and/or limited agreement between evidence sources (e.g. modelled habitat data). The light shading for commercial fish species indicates a RAG assessment based on an assessment of data at a spatial scale greater than the case study area. The grey cells indicate asset- benefit relationships, which did not provide a significant or moderate supply of ecosystem service benefit or there was no information to make an assessment.

Scenario 1	Marine																							
Natural Capital Asset	Intertidal reef		Subtidal reef						Intertidal sediments								Subtidal sediment							
	A1: Littoral rock and other hard substrata		A3: Infralittoral rock and other hard substrata		A4: Circalittoral reef fauna colonised rock		A4: Circalittoral reef fauna colonised veneer		A2.1 Littoral Coarse sediment		A2.2: Littoral sand and muddy sand		A2.3: Littoral mud		A2.4: Littoral mixed sediment		A5.1: Sublittoral coarse sediment		A5.2: Sublittoral sand		A5.4: Sublittoral mixed sediments		A5.5: Sublittoral macrophyte dominated sediment	
	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult
Lobster						↑		↑									↑	↑			↑	↑		
Crawfish						↑		↑										↑			↑	↑		
Crab						↑		↑										↑				↑		
Pollack						↑		↑																
Mullet																		↑				↑		
Turbot																	↑spawning	↑				↑		
Monks						↑		↑										↑				↑		
Sole, Plaice				plaice		↑ plaice		plaice										↑				↑ sole		
Skates and Rays						↑		↑										↑				↑		

Figure 14 Species - habitat linkages in relation to assessment in the risk register for ES benefit 'Food' under scenario 1 (Figure 13) ↑ indicates an increase in risk, ↓ indicates a decrease in risk compared to current baseline activity .

Scenario 2

Impact on the asset-benefit relationship (Ecosystem Services)

Assessments under scenario 2, resulted in a 17% increase from the baseline, in the number of asset components assessed to be in high and medium-high risk categories in relation to contribution to ES flows (Table *6*). In scenario 2, habitat with low sensitivity to activities that cause the pressure 'abrasion' (in relation to intensive potting and otter trawling activity) within Isles of Scilly IFCA district are exposed to those activities (Figure 15). Although risk to ES contribution from asset components was lower than for scenario 1, risk increased, from medium to high for 4 asset benefit components under scenario 2. Sublittoral coarse sediment contribution to ES benefits 'Food' and 'Clean Water and sediments' was at high risk, due to the large extent of habitat interacting with pressures associated with the activity in scenario 2 (Figure 15, Figure 16).

Compared to current activity, scenario 2 presents a higher risk to ES flows for 4 asset-benefit components where 'abrasion' of habitats linked to the use of otter trawls and pots has a potential to degrade the quality of subtidal coarse sediment. (Figure 15, Figure 16). Low risk of loss of the asset-benefit relationship was identified across 63 components, including all intertidal (littoral) habitats, infralittoral reef and quota fish species (Figure 15, Figure 16). Habitat asset components assessed as low risk under existing activity, did not interact with the activity in the offshore zone considered in the scenario (Figure 15, Figure 16). In summary:

- The provisioning ES benefit of 'food' (wild food fish and shellfish) is negatively impacted due to loss of essential fish habitat that supports the commercial fishing industry in IoS.
- The ES benefit of 'tourism and nature watching' are also at increasing risk due to potential impact of fishing gear on species of interest to diving and recreational fishing.
- The ES benefit of 'clean water and sediments' are impacted due to reduced structure and functioning of faunal communities within soft substratum habitats.
- The ES benefit of 'healthy climate' is potentially impacted if structure and functioning of faunal communities within soft substratum habitats is reduced. Evidence is limited but plankton reaching the seabed and not consumed is likely to be buried in soft substratum habitats (Howard *et al.*, 2017). Level of contribution through this process is low, so not included in the matrix. However, although carbon storage is low through burial of plankton in soft substratum habitats, these habitats, including coarse sediment habitats cover large extents within the IFCA district.

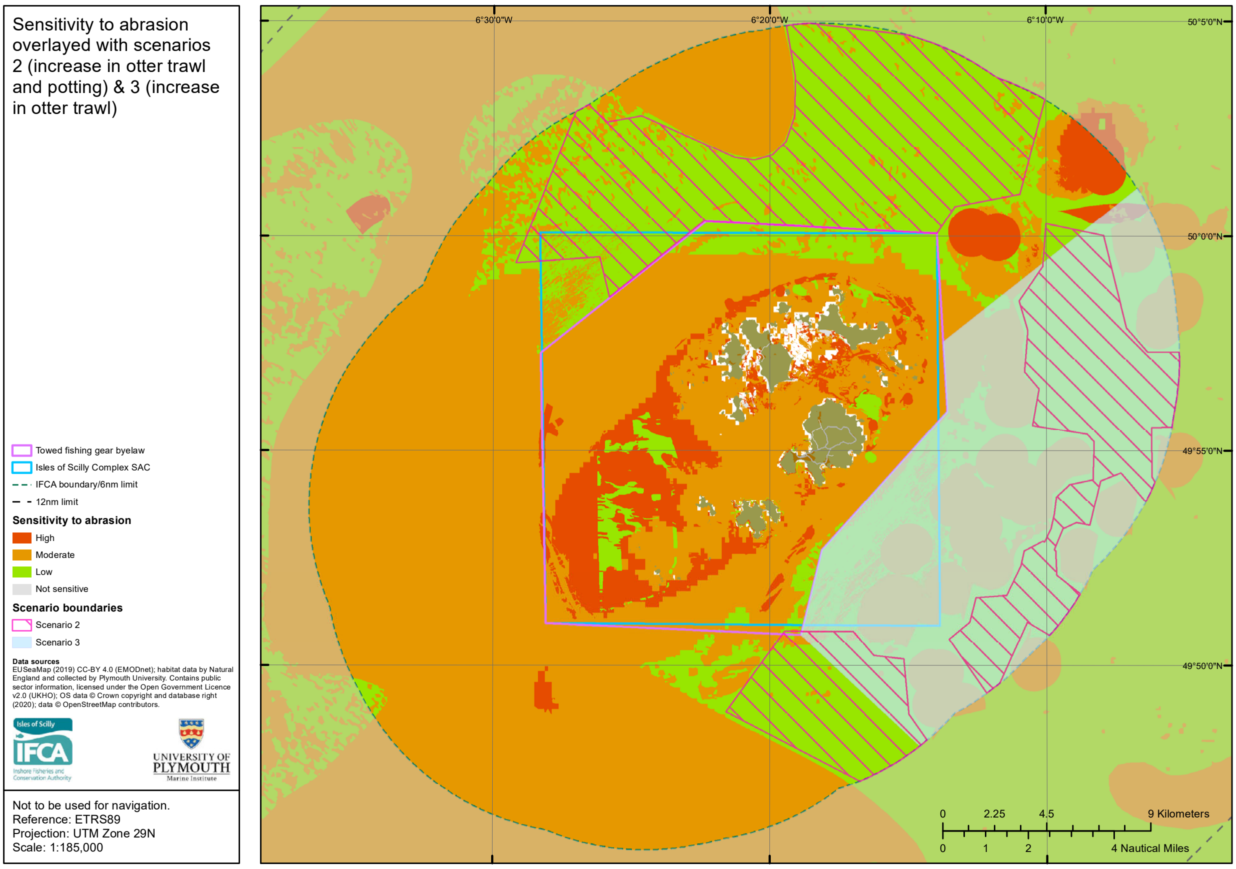


Figure 15 Spatial distribution of interaction of habitats with low sensitivity to pressures associated with increased otter trawl and potting activity within spatial extent of scenario 2 and scenario 3.

Impact on the asset-benefit relationship (Commercial fish and shellfish)

The degraded state of sublittoral soft substratum habitats under scenario 2 was linked to a high risk of negative impact for interactions of habitat components that are of importance to adult or juvenile life stages of 9 species supporting Isles of Scilly fisheries (Figure 16, Figure 17). An increase of 10 interactions in comparison to current (baseline) conditions (Figure 17). Components moved from medium to high risk for adult and juvenile life stages of lobster and turbot, and adult life stages of crab, monkfish, sole, skates and ray. Risk increased for habitat components supporting mullet and crawfish from low to moderate categories (Figure 17). There was significant impact in relation to habitat-species linkages for 5 species due to degradation of subtidal coarse sediment under activity in scenario 2.

	Littoral rock			Littoral coarse sediments			Littoral sand and muddy sand			Littoral mud			Littoral mixed sediments			Sublittoral Seagrass			Infralittoral rock			Circalittoral rock			Sublittoral coarse sediment			Sublittoral sand			Sublittoral mixed sediments			Water bodies			Fish (quota species)			Fish (non-quota species)		
	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.
Food (Wild Food - fish and shellfish).	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	C (4)	C (4)	C (8)	A (4)	A (4)	A (4)	C (4)	C (4)	C (4)	B (4)	C (4)	C (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)		A (2)		A (4)	A (4)		A (4)	Lob B (4) Crab A (4) Craw C (4)	
Healthy climate (carbon sequestration).										A (4)	A (4)	A (4)				C (4)	C (4)	C (8)	A (4)	A (4)	A (4)														A (2)							
Sea defence. (natural hazard regulation / flood prevention).	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)				A (4)	A (4)	A (4)	C (4)	C (4)	C (8)	A (4)	A (4)	A (4)																					
Tourism / nature watching.				A (4)	A (4)	A (4)	A (4)	A (4)	A (4)							C (4)	C (4)	C (8)	A (4)	A (4)	A (4)	C (4)	C (4)	C (4)											A (2)		A (4)	A (4)		A (4)	Lob B (4) Crab A (4) Craw C (4)	
Clean water and sediments.										A (4)	A (4)	A (4)				C (4)	C (4)	C (8)							B (4)	C (4)	C (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)		A (2)							

Figure 16 Priority relationships assessed in the risk register under scenario of low sensitivity habitat of IoS IFCA district being exposed to activities that cause the 'abrasion' to intensive potting and otter trawling. The assets are columns and the benefits in rows. For each ES the top row is risk assessed through analysis of indicator data in relation to policy targets, the lower row for each benefit is risk assessed in relation to (local) community based knowledge of risk. The colour of the cell shows the risk rating for the asset status quantity (Qun), quality (Qul), spatial configuration (Sp) based on the scoring matrix. Red indicates it is at high risk, amber at medium risk (*amber cells with an asterisk, indicate asset status is below target and the trend in status is declining, suggesting risk rating is close to moving to the high risk category), green risk ratings are at low risk. Lighter shaded, red, amber or green cells indicates RAG risk rating where there is less confidence (greater uncertainty) in the risk rating, due to limited evidence and/or limited agreement between evidence sources (e.g. modelled habitat data). The light shading for commercial fish species indicates a RAG assessment based on an assessment of data at a spatial scale greater than the case study area. The grey cells indicate asset- benefit relationships, which did not provide a significant or moderate supply of ecosystem service benefit or there was no information to make an assessment.

Scenario 2	Marine																							
Natural Capital Asset	**Intertidal reef**		**Subtidal reef**						**Intertidal sediments**								**Subtidal sediment**							
	A1: Littoral rock and other hard substrata		A3: Infralittoral rock and other hard substrata		A4: Circalittoral reef fauna colonised rock		A4: Circalittoral reef fauna colonised veneer		A2.1 Littoral Coarse sediment		A2.2: Littoral sand and muddy sand		A2.3: Littoral mud		A2.4: Littoral mixed sediment		A5.1: Sublittoral coarse sediment		A5.2: Sublittoral sand		A5.4: Sublittoral mixed sediments		A5.5: Sublittoral macrophyte dominated sediment	
	juv.	adult	juv.	adult	juv.	Adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult
Lobster																	↑	↑						
Crawfish																		↑						
Crab																		↑						
Pollack																								
Mullet																		↑						
Turbot																	↑spawning	↑						
Monks																		↑						
Sole, Plaice				plaice		Plaice		plaice										↑				sole		
Skates and Rays																		↑						

Figure 17 Species – habitat linkages in relation to assessment in the risk register for ES benefit 'Food' under scenario 2 ↑ indicates an increase in risk, ↓ indicates a decrease in risk compared to current activity

Scenario 3.

Scenario 3 assessed the implications for risk to ES provision of increased otter trawl activity in iVMS area 2 (south eastern) and the eastern IFCA district outside the SAC (Figure 15).

Impact on the asset-benefit relationship (Ecosystem Services)

Risk Assessment under scenario 3, resulted in a 26% increase from the baseline, in number of asset components assessed to be in high and medium-high risk categories in relation to contribution to ES flows (Table 6). A greater proportion of asset-benefit components are assessed at high risk of loss of ES in comparison to scenario 2. The scenario results in an additional 101.5km² of circalittoral reef habitat interacting with the pressure 'abrasion' from otter trawl activity. Due to the sensitivity of the habitat to the pressure 'abrasion' associated with otter trawling, there is a significant decline in the asset status in relation to targets. 8 components across all asset-benefit component statuses were assessed as increasing to high risk (red) under this scenario (Figure 18). A further medium-high risk of loss were identified for 21 components (amber C*) (Figure 18). Medium risk components (amber) were identified for 14 assessments of the asset status (either quantity, quality, or spatial configuration) (Figure 18). Low risk was identified across 63 components of asset status, including all intertidal (littoral) habitats, infralittoral reef and quota fish species (Figure 18). Habitat asset components assessed as low risk under existing activity, did not interact with the activity in the zone used in the scenario (Figure 15). In Summary:

- The ES benefit of Food is negatively impacted due to degraded fauna communities that are sensitive to the activity/pressure abrasion, and resulting loss of food and shelter required by adult and juvenile life stages of lobster and adult life stages of all other commercially targeted species.
- The ES benefit of tourism and nature watching is assessed as negatively affected as a precautionary measure due to impact on species of interest to diving and recreational fishing.
- The ES benefit of clean water and sediments is impacted due to reduced structure and functioning of faunal communities within sublittoral mixed soft substratum habitats.
- The ES benefit of Healthy climate is potentially impacted if structure and functioning of faunal communities within sublittoral mixed soft substratum habitats is reduced. Evidence is limited but plankton reaching the seabed and not consumed is likely to be buried in soft substratum habitats (Howard et al., 2017). Level of contribution through this process is low, so not included in the matrix, and likely to be focused in sand and coarse sediment habitats.

Impact on the asset-benefit relationship (Commercial fish and shellfish)

Risk to species – habitat linkages for all commercially targeted species increase under scenario 3. Where risk was high to species – habitat linkages under existing activity, this increased to significant risk for interaction between three species, lobster, crawfish and pollack and circalittoral reef or reef veneer. Habitat linkages increased from medium to high risk for 4 further species (crab, monkfish, plaice, skates and rays) under activities in scenario 3 (Figure 19). The degraded quality of subtidal rock and mixed substratum habitats under scenario 3 changed species habitat linkage risk from medium risk to high risk for 5 species, and low risk to medium for 2 species (Figure 19).

	Littoral rock			Littoral coarse sediments			Littoral sand and muddy sand			Littoral mud			Littoral mixed sediments			Sublittoral Seagrass			Infralittoral rock			Circalittoral rock			Sublittoral coarse sediment			Sublittoral sand			Sublittoral mixed sediments			Water bodies			Fish (quota species)			Fish (non-quota species)		
	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.	Qun	Qal	Sp.
Food (Wild Food - fish and shellfish).	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	C (4)	C (4)	C (8)	A (4)	A (4)	A (4)	C (4)	C (4)	C (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	C (4)	C (4)	C (4)		A (2)		A (4)	A (4)		A (4)	Lob B (4) Crab A (4) Craw C (4)	
Healthy climate (carbon sequestration).										A (4)	A (4)	A (4)				C (4)	C (4)	C (8)	A (4)	A (4)	A (4)														A (2)							
Sea defence. (natural hazard regulation / flood prevention).	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)	A (4)				A (4)	A (4)	A (4)	C (4)	C (4)	C (8)	A (4)	A (4)	A (4)																					
Tourism / nature watching.				A (4)	A (4)	A (4)	A (4)	A (4)	A (4)							C (4)	C (4)	C (8)	A (4)	A (4)	A (4)	C (4)	C (4)	C (4)											A (2)		A (4)	A (4)		A (4)	Lob B (4) Crab A (4) Craw C (4)	
Clean water and sediments.										A (4)	A (4)	A (4)				C (4)	C (4)	C (8)							B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	C (4)	C (4)	C (4)		A (2)							

Figure 18 Priority relationships assessed in the risk register under scenario of otter trawling effort increasing in iVMS Area II and across eastern offshore IFCA district. The assets are columns and the benefits in rows. For each ES the top row is risk assessed through analysis of indicator data in relation to policy targets, the lower row for each benefit is risk assessed in relation to (local) community based knowledge of risk. The colour of the cell shows the risk rating for the asset status quantity (Qun), quality (Qul), spatial configuration (Sp) based on the scoring matrix. Red indicates it is at high risk, amber at medium risk (*amber cells with an asterisk, indicate asset status is below target and the trend in status is declining, suggesting risk rating is close to moving to the high risk category), green risk ratings are at low risk. Lighter shaded, red, amber or green cells indicates RAG risk rating where there is less confidence (greater uncertainty) in the risk rating, due to limited evidence and/or limited agreement between evidence sources (e.g. modelled habitat data). The light shading for commercial fish species indicates a RAG assessment based on an assessment of data at a spatial scale greater than the case study area. The grey cells indicate asset- benefit relationships, which did not provide a significant or moderate supply of ecosystem service benefit or there was no information to make an assessment.

Scenario 3	Marine																							
Natural Capital Asset	**Intertidal reef**		**Subtidal reef**						**Intertidal sediments**								**Subtidal sediment**							
	A1: Littoral rock and other hard substrata		A3: Infralittoral rock and other hard substrata		A4: Circalittoral reef fauna colonised rock		A4: Circalittoral reef fauna colonised veneer		A2.1 Littoral Coarse sediment		A2.2: Littoral sand and muddy sand		A2.3: Littoral mud		A2.4: Littoral mixed sediment		A5.1: Sublittoral coarse sediment		A5.2: Sublittoral sand		A5.4: Sublittoral mixed sediments		A5.5: Sublittoral macrophyte dominated sediment	
	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult	juv.	adult
Lobster						↑		↑														↑		
Crawfish						↑		↑														↑		
Crab						↑		↑														↑		
Pollack						↑		↑																
Mullet																						↑		
Turbot																	spawning					↑		
Monks						↑		↑														↑		
Sole, Plaice				plaice		↑ plaice		↑ plaice														↑ sole		
Skates and Rays						↑		↑														↑		

Figure 19 Species - habitat condition linkages in relation to assessment in the risk register for ES benefit ‘Food’ under scenario 3 (Figure 18) ↑ indicates an increase in risk, ↓ indicates a decrease in risk compared to current activity

6.3 Summary of environmental and economic implications: costs, opportunities and limitations

Scenario 1

Costs, opportunities and limitations

Table 8 Implications for ES provision, benefits to the fishing industry and implications to species habitat under scenario 1

Scenario 1. Otter trawl activity increases and dredge permitted across 172km² habitat mosaic of high to low sensitivity habitats to 'abrasion' and 'sub-surface disturbance' (removal of reef fauna community).		
Implication for ES provision	Implication for fishing industry	Implication for species habitat
• Increased pressure to deeper subtidal habitats results in increased risk to provision of ES 'food', 'Tourism and nature watching', 'Clean water and sediments'. • Potential risk to ES 'healthy climate' from impacts to benthic infauna. • Spatial extent of 'reef' unknown and even within 'sand' habitat reef species occur in video tows, thereby negative impact could be greater. • Recovery time to reinstate the habitat and therefore ES function is 20 years for high sensitivity habitats.	• 172km² of seabed available for scallop dredging or comparable activity. • Diversification options for Isles of Scilly fishers. • Economic opportunity for UK fishers. • Potential for gear conflict. • Negative impact on potting and tangle net fishery. • Negative impact on fishers using vessels and methods that have limited range (and so alternative fishing options). • Loss of ground for tangle net and potting fisheries if reef, veneer and mixed ground dredged.	• Significant risk of negative impact to habitat that is of importance for adult and juvenile life stages of lobster and crawfish. • Significant risk of negative impact to habitat that is of importance to adult life stages of crab, turbot, skates and rays. • Significant risk of negative impact to habitat that is of importance to adult life stages of monkfish and plaice and moderate risk to habitat of importance to mullet.

Even though fishing effort would be undertaken outside the SAC in scenario 1 and the Conservation objectives to 'recover' would be on course to be met within IoS MPAs, 'good environmental status' targets would not be met under scenario 1, due to impact on habitats outside the SAC (*Supplementary Material 4, Tab 4*). ES flows from the assets related to the habitat quality of circalittoral reef and mixed substratum communities would also be heavily impacted. For highly sensitive benthic communities, recovery to pre-impact communities providing levels of Ecological function and ES delivery may take up to 20 years (Tyler-Walter et al., 2018; 2019).

Degradation of habitats is related to sensitivity to bottom trawl and dredge activity, identified in MarESA assessments (Tyler-Walter et al., 2018; 2019). For instance, areas of sponge and hydroid communities on reef and boulder habitat were recorded in comparable areas to be greatly reduced, and boulders even completely removed where scallop dredging activity has been undertaken (Hinz *et al.*, 2011; Picton & Goodwin, 2007). Recovery of sensitive habitats, with slow growing species characterising communities was reviewed to take up to 20 years (Tyler-Walters et al., 2018, 2019).

In Lyme Bay, UK habitat structural complexity, supporting functional restoration of ES such as food provision and tourism and nature watching, displayed positive responses within 3 years following the cessation of towed demersal fishing (Sheehan et al., 2013). However, definitive evidence of recovery was only noted for species richness and three of the 13 indicator taxa in the study (Sheehan *et al.*, 2013). Recovery for habitat asset extents impacted in scenario 1 would require cessation of activity, and repeated activity in the scenario would not allow this. Alleviating negative impacts on species – habitat linkages would also require recovery of supporting habitat.

Recovery of European lobster *H. gammurus*, with increases in catch per unit effort have followed full protection of marine habitats, combined with restocking, similar to restocking programs in Isles of Scilly, within 2 years (Cau *et al.*, 2019). If activity was permitted and later ceased, an increase of ES provision within 2-3 years may occur, but full contribution to expected level of delivery of ES, considering recovering beyond the shifted baseline, will take longer (Klein and Thurstan, 2016; Rees et al., 2019).

When interpreting the scenario it is important to be aware that the interaction of spatial fishing effort with habitats extends over all habitats in the scenario. Low powered vessels using scallop dredges may be unlikely to be capable of towing through hard substratum, and fishers are likely to be unwilling to damage equipment. As such, impact on circalittoral rock habitat, that is not veneer or boulder habitat, may be lower than predicted. Low sensitivity habitat to the pressures of sub-surface penetration and habitat change are present in the spatial extent of scenario 1 (Figure 12). Repeated activity is likely to still have a negative impact on condition and potential contribution to ES delivery from these habitat, although less so than for more sensitive habitats (recovery if activity ceases ~<2 years (Tyler-Walters et al., 2018; 2019). There is also limited extent for vessels to operate in, within these predominantly sand and coarse sediment habitats (Figure 12).

Scenario 1 addresses challenges to meet a proportion of fisher's perceived socio-economic benefits from having a more diverse fishery (Figure 9), but at the added risk of increasing conflict between static and mobile gear fisheries and reducing sustainability (Table 8).

Fishers were not asked to provide financial data as part of interview surveys in this study. Comparable fisheries in an inshore region of south west UK (Lyme Bay), demonstrated income inequality between inshore static gear fisheries and bottom towed gear fisheries (Rees et al., 2016). Estimated average profit for respondents fishing from ports within Lyme Bay using static gears was

£15,000 and ranged from respondents just covering costs to others making £20-30,000 profit (Rees et al., 2016). There was large disparity between estimated profit values provided by respondents from Lyme Bay ports using bottom towed gears. Estimated average profit of £22,500 was suggested by one group of respondents using bottom towed gears and much greater profit, in excess of £100,000 was returned by another group that included operators of larger, more powerful vessels with greater range (Rees et al., 2016).

It is evident that increasing opportunity for bottom towed gear fisheries provides potential greater profit from fisheries in Isles of Scilly. However, the increase in profit is likely to be smaller for inshore vessels with lower power and range, than the profit available for larger more powerful vessels with greater range entering the fishery.

Of the bottom towed gear fisheries in the UK the scallop fishery has been under increasing pressure due to loss of grounds (e.g. through restrictions within MPAs, permits and potting separation agreements) (Cappell *et al.*, 2018). Conflict within the fishery between larger nomadic vessels operating within the scallop fishery and smaller vessels with limited range using scallop dredges in UK regions has increased, particularly in English waters (Defra, 2011).

It is recognised that increasing grounds available to smaller vessels would reduce conflict within the scallop fishery and increase economic sustainability for smaller vessels in the sector. Spatial management however, also needs to take into account the negative impacts of increasing scallop dredge fishing activity on habitat condition as well as loss of resources supporting static gear fisheries. There are also negative implications on range of other ES benefits. Increasing mobile towed gear activity will also potentially increase conflict between mobile and static gear fisheries within the district.

Scenario 2

Costs, opportunities and limitations

Table 9 Implications for ES provision, benefits to the fishing industry and implications to species habitat under scenario 2

Scenario 2. Otter trawl and potting >15 pots per .25km² increase effort in locations with 'low' sensitivity to 'abrasion' outside SAC.		
Implication for ES provision	Implication for fishing industry	Implication for species habitat
• Increased risk to provision of ES 'food', 'Tourism and nature watching', 'Clean water and sediments'.	• 231 km² of seabed available for otter trawling. • Diversification options for Isles of Scilly fishers. • Economic opportunity for UK fishers.	• Moderate risk of impact to habitat that is of importance for adult and juvenile life stages of lobster and crawfish.

• Potential risk to ES ‘healthy climate’ from impacts to benthic infauna. • Recovery time to pre-existing species communities is up to 2 years for low sensitivity habitats. • Recovery time would increase with increased effort frequency and intensity. • Spatial extent of ‘reef’ unknown and even within low sensitivity ‘sand fauna’ habitat, reef species occur in video tows, thereby risk may be greater than predicted.	• Bait available for IoS fishery. • Potential for more reliable service to hotels and restaurants. • Potential for land based business opportunities. • Potential for gear conflict. • Negative impact on potting and tangle net fishery from increased otter trawl activity. • Negative impact on fishers using vessels and methods that have limited range (and so alternative fishing options).	• Moderate risk of impact to habitat that is of importance to adult life stages of crab, turbot, skates and rays, sole, monkfish and plaice. • Low risk of negative impact to habitat that is of importance to mullet. • Does not interact with reef habitat of importance to pollack. • Potential to attract scavenging species to trawl tracks.

As with scenario 1, even when effort would be undertaken outside the SAC in scenario 2 and conservation objectives to ‘recover’ would be on course to be met within MPAs, ‘good environmental status’ targets under MSFD Descriptor 6 outside MPAs will be negatively impacted (Cefas, 2012) (*Supplementary Material 4, Tab 1, Tab 5*) (Figure 16). Targets in relation to sublittoral coarse sediments would be below target under scenario 2. ES flows related to habitat quality of sublittoral coarse sediments would, thereby, be impacted.

Recovery to communities providing reviewed levels of ES delivery may take up to 10 years, and repeated activity is likely to prevent full recovery to a state where ES provision is at reviewed levels under un-impacted conditions (Tyler-Walter et al., 2018; 2019; Klein and Thurstan, 2016; Rees et. al., 2019). It is noted that there may be short term benefits from availability of scavenging fish and shellfish species that are attracted to previously trawled locations, due to presence of killed or damaged prey organisms. This behaviour of scavenging species has been related to the observation of trawlers turning through 180 degrees to return to a trawl line (Kaiser & Spencer, 1994; Mills *et al.*, 2006; Rijnsdorp *et al.*, 2000). Long term recoverability of the benthic fauna within the soft substratum habitats and long-term sustainability of stocks, however, also needs to be taken into account. In addition, longer term impacts to ES not associated with fishing catches, such as clean water and sediment and tourism and nature watching need to be considered as any loss in benefits linked to these ES would have economic impacts for the recreation and tourism sector.

Scenario 2 provides diversification options that could provide income from otter trawling, bait to potters, and landings that could support any new market initiatives in Isles of Scilly (Figure 9, Table 9). There is risk of increasing conflict between static and mobile gear fisheries if mobile gear effort increased in, as identified by a large proportion of the Isles of Scilly fishers interviewed (Figure 8, Figure 9), especially if activity is undertaken intensively over large spatial scales.

Scenario 3

Under scenario 3 increased otter trawl activity interacted with a variety of habitats. Interaction with circalittoral reef biotopes assessed to have medium or greater sensitivity to abrasion, led to a significant negative impact on level of contribution to multiple ES (Tyler Walters et al., 2018; 2019). It is recognised however, degradation of circalittoral reef habitat may be overestimated as skippers of low powered otter trawl vessels are believed to avoid known reef areas to avoid gear entanglement. Mixed boulder and veneer ground, identified in towed video surveys, may, however still be impacted in this scenario.

Costs, opportunities and limitations

Table 10 Implications for ES provision, benefits to the fishing industry and implications to species habitat under scenario 3

Scenario 3. Otter trawl effort increases in iVMS area and eastern area of district (204km² habitat mosaic of high to low sensitivity habitats)		
Implication for ES provision	Implication for fishing industry	Implication for species habitat
• Increased risk to provision of ES 'food', 'Tourism and nature watching', 'Clean water and sediments'. • Potential risk to ES 'healthy climate' from impacts to benthic infauna. • Recovery time to reinstate ES provision is 2 years for low sensitivity habitats. • Recovery time would significantly increase with increased effort frequency and intensity. • Spatial extent of 'reef' unknown and even within low sensitivity 'sand fauna' habitat, reef species occur in video tows, thereby risk may be greater than predicted.	• 204km² of seabed available for otter trawl effort. • Diversification options for Isles of Scilly fishers. • Economic opportunity for UK fishers. • Potential for gear conflict. • Negative impact on potting and tangle net fishery. • Negative impact on fishers using vessels and methods that have limited range (and so alternative fishing options).	• Significant risk of impact to habitat that is of importance for adult life stages of lobster, crawfish and pollack. • High risk of impact to habitat that is of importance to adult and juvenile life stages of lobster and turbot, and adult life stages of crab, monkfish, plaice, sole, skates and rays.

Under scenario 3 there was not as large a negative impact on risk to ES provision and risk to species-habitat linkages as dredging activity across the same region in scenario 1. There are, however, negative impacts to the 3 species that support the highest economic value related to current Isles of Scilly fisheries, in comparison to risk under current activity (Table 10). Fishers potting near reef habitat for lobster and tangle netting for crawfish and potting for crab in coarse, mixed and sand substratum habitats in the zone considered in scenario 3, are also likely to encounter gear conflict if number of trawling vessels and effort increases. As Isles of Scilly boats have size and length restrictions, opportunity to travel further to alternative grounds to avoid conflict is limited, especially as the zone in scenario 3 is a sheltered region in relation to prevailing south-westerly winds. Safety risks would be increased if potting and netting effort is displaced (Rees et al., 2016). Increasing otter trawl activity within Isles of Scilly IFCA district, would however, potentially provide cheaper and locally sourced bait for potting and diversification options for older and younger Isles of Scilly fishers (Table 10, Figure 9).

7 Synthesis

Assessment in this study is aimed to provide evidence of risk to Ecosystem Services and habitat supporting fish and shellfish of importance to commercial activity. Risk was assessed under current activity, and proposed scenarios for future fishing activity.

It is recognised that scenarios need to be interpreted with caution and scallop dredge and otter trawl activity is likely to avoid, where possible, circalittoral rock habitat in scenario zones, especially if vessels have limited engine power. However, large extents of reef/sand veneer, mixed substratum and areas of coarse substratum that include outcroppings of reef habitat communities may still interact with pressures associated with these activities. It is also noted that MSFD goals for seafloor integrity are defined as 'no human impact' for 85% -95% of a habitat extent outside an MPA within timescale for habitat recovery (Cefas, 2012). This MSFD target has been generated as a measure to ensure that the benthic habitats can function effectively to support flows of ecosystem services. However, when fisheries management is required to promote economically sustainable levels of fishing activity (and not all ecosystem services)then it is possible that targets or thresholds become unobtainable (Hopkins, Bailey & Potts, 2018; Rees, Ashley & Cameron, 2019).

Negative impacts to ES's and associated benefits were lower for scenarios that increased spatial effort of otter trawling activity, compared to increased spatial effort of scallop dredge activity. However, all scenarios increased risk or loss of ES from the baseline of current fishing activity. Scenario 2 where otter trawl activity occurred in predominantly low sensitivity habitats resulted in the lowest negative implications for ES benefit provision and risk for species-habitat linkages. However, scenario 2 still resulted in increase in risk of loss of delivery of ES benefit of 'Food' and 'Clean Water and Sediments' due to degradation of sublittoral coarse sediment habitats.

If increasing economic benefits is required to maintain a fishery on Isles of Scilly, to provide diversification options for fishers, increased fish catches for local processors and restaurants and regular bait for the potting fishery, decision making would effectively require consideration of acceptable loss in relation to achieving ecological targets. Greatest risk to ES delivery and species-habitat linkages were assessed in relation to fishing activities where gear penetrates soft substratum, or in the case of boulders, may remove the substratum, such as scallop dredging in Scenario 1. Even if interactions with reef habitat were removed from this scenario, large proportions of coarse sediment and mixed sublittoral habitats within the IFCA district would be degraded, with negative implications for the level of delivery of multiple ES benefits which would potentially impact on other economic interests in the IoS, such as recreation and tourism and clean water and sediment benefits. Providing access for limited otter trawling activity to lowest sensitivity habitats in scenario 2 provided the smallest negative impact on ecological targets of all scenarios, but, still limited ES flows and achievement of GES targets in comparison to current activity.

Lack of evidence on extent and condition of habitats in deeper offshore areas and limited evidence on recovery of habitat communities from past pressures has limited confidence in the risk assessments provided. Further evidence on recovery trajectories is required to inform management to assess impacts of activities, and to address recovery or renewal of natural capital assets across the whole site/district, to ensure security of delivery of ES and the associated benefits (Rees et al., 2019a, Solandt et al., 2019). The precautionary approach has been used throughout assessments, to prevent long term negative implications for ecological sustainability. It is recognised that this approach is restrictive to promoting economic activity, where that activity is recognised to cause pressures on the marine environment. Assessment of ecological sustainability targets for proportion of habitat exposed to pressures is also likely to be more restrictive to permitting damaging activities, when assessed over small study areas compared to larger regions.

Greater evidence is required of extent and condition of marine habitats and associated communities. Improved monitoring of habitat extent and condition, over timescales relevant to habitat recovery would be required to support management under environmental and sustainable development policy targets (Klein and Thurston, 2016; McQuatters-Gollop et al., 2019). Evidence from monitoring would then be available to inform adaptive management to ensure environmental and economic sustainability were maintained, providing access to activities where sustainability targets were not compromised (Addison *et al.*, 2017).

Increasing economic opportunity through permitting activities that also increase pressures on the marine environment will have negative ecological consequences and this must be balanced against short and long-term economic goals. The MSFD targets used in this study are recognised to be stringent and may unrealistically reflect area of seabed that needs to be protected from fishing pressure to maintain the broad scale delivery of ecosystem services. The Risk Assessment is also precautionary based on limited evidence of habitat extent and condition. However, as current activity, even under precautionary assessment is not limiting recovery to these stringent targets, maintaining activities with limited ecological impact, while maximising economic opportunities from marketing and sale of catches may have greatest long-term benefits.

Increasing sales and marketing opportunities and investment in processing or icing facilities has been beneficial in supporting economic wellbeing linked to static gear fisheries in Lyme Bay, UK (Rees *et al.*, 2016). Isles of Scilly fishers also identified benefits from increasing marketing of local fish and sale prices on the Isles of Scilly through gaining sustainability certification (Figure 9). When considering supporting economic sustainability for Isles of Scilly fisheries, these options may be beneficial alongside sustainable management of resources.

8 References

Addison, P. F. E., Collins, D. J., Trebilco, R., Howe, S., Bax, N., Hedge, P., Jones, G., Miloslavich, P., Roelfsema, C., Sams, M., Stuart-Smith, R. D., Scanes, P., von Baumgarten, P. & McQuatters-Gollop, A. (2017) 'A new wave of marine evidence-based management: emerging challenges and solutions to transform monitoring, evaluating, and reporting'. *ICES Journal of Marine Science*, 75 (3), pp. 941-952.

Cappell, R., Huntington, T., Nimmo, F. & MacNab, S. (2018) *The UK Scallop Fishery. Current trends, future management options and recommendations, a report for South Western Fish Producer Organisation Ltd (SWFPO) on behalf of the Scallop Industry Consultation Group (SICG).* Poseidon Aquatic Resource Management. Available at: http://www.nwwac.org/_fileupload/Papers%20and%20Presentations/2019/Madrid_2019/1417%20Poseidon%20UK%20Scallop%20final%20report%2011_10_18.pdf.

Carr, H., Cornthwaite, A., Wright, H. & Davies, J. (2016) *Assessing Progress Towards an Ecologically Coherent MPA Network in Secretary of State Waters in 2016: Methodology.* Peterborough: Joint Nature Conservation Committee. Available.

Cau, A., Bellodi, A., Cannas, R., Fois, M., Guidetti, P., Moccia, D., Porcu, C., Pusceddu, A. & Follesa, M. C. (2019) 'European spiny lobster recovery from overfishing enhanced through active restocking in Fully Protected Areas'. *Scientific Reports*, 9 (1), pp. 13025.

Cefas (2012) *Proposed UK Targets for achieving GES and Cost-Benefit Analysis for the MSFD. Final Report.*

Cefas (2017a) *Edible crab (Cancer Pagarus) Cefas Stock Status Report 2017.* Lowestoft: Cefas. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/722904/Cefas_Crab_Stock_Assessment_2017.pdf (Accessed: July 2018).

Cefas (2017b) *Lobster (Homarus gammarus) Cefas Stock Status Report 2017.* Lowestoft. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/722748/2017_Lobster_assessments.pdf (Accessed: June 2018).

Defra (2011) *Consultation on the evidence base for a proposed new English Scallop Order.* London: Defra. Available at:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/82327/110826-scallops-condoc.pdf.

EMODnet/EUSeaMap (2019) 'European Marine Observation Data Network (EMODnet) Seabed Habitats project, Map Viewer, Download & metadata catalogue'. [Online]. Available at: https://www.emodnet-seabedhabitats.eu/.

Environment Agency (2018) 'WFD Water Body Summary Table - Gov.uk'. [Online]. Available at: https://www.gov.uk/government/uploads/.../wfd_water_body_summary_table.XLS (Accessed: December).

Fletcher, S., Saunders, J., Herbert, R., Roberts, C. & Dawson, K. (2012) *Description of the ecosystem services provided by broad-scale habitats and features of conservation importance that are likely to be protected by Marine Protected Areas in the Marine Conservation Zone Project area.* Available.

Fletcher, S., Saunders, J. & Herbert, R. J. (2011) 'A review of the ecosystem services provided by broad-scale marine habitats in England's MPA network'. *Journal of Coastal Research*, 64 pp. 378-383.

Hinz, H., Tarrant, D., Ridgeway, A., Kaiser, M. J. & Hiddink, J. G. (2011) 'Effects of scallop dredging on temperate reef fauna'. *Marine Ecology Progress Series*, 432 pp. 91-102.

HM Government (2011) *The Natural Choice: securing the value of nature.* Her Majesty's Stationery Office. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228842/8082.pdf.

HM Government (2018) *A Green Future: Our 25 Year Plan to Improve the Environment. London: Department for the Environment Food and Rural Affairs.* Available.

Hooper, T., Ashley, M., Cameron, A., Mullier, T., Rees, S. (2020) 'North Devon Marine Natural Capital Plan. Sustainability Assessment. February 2020. Report prepared for the North Devon Biosphere Reserve as part of the South West Partnership for the Environment and Economic Prosperity (SWEEP) and the Marine Pioneer programme.

Hooper, T., Ashley, M., Börger, T., Langmead, O., Marcone, O., Rees, S., Rendon, O., Beaumont, N., Attrill, M. & Austen, M. (2018) 'Application of the natural capital approach to the marine environment to aid decision-making. Report prepared for the Department for Environment Food and Rural Affairs (project code ME5115).'. pp. 109.

Hooper, T., Beaumont, N., Griffiths, C., Langmead, O. & Somerfield, P. J. (2017) 'Assessing the sensitivity of ecosystem services to changing pressures'. *Ecosystem Services*, 24 pp. 160-169.

Hopkins, C. R., Bailey, D. M. & Potts, T. (2018) 'Navigating future uncertainty in marine protected area governance: Lessons from the Scottish MPA network'. *Estuarine, Coastal and Shelf Science*, 207 pp. 303-311.

Howard, J., Sutton-Grier, A., Herr, D., Kleypas, J., Landis, E., Mcleod, E., Pidgeon, E. & Simpson, S. (2017) 'Clarifying the role of coastal and marine systems in climate mitigation'. *Frontiers in Ecology and the Environment*, 15 (1), pp. 42-50.

IFCA (2020) 'About us' availale at http://www.association-ifca.org.uk/about-us/ifca-vision

JNCC (2010) *Identifying marine conservation zones a quick reference guide. A report by the Joint Nature Conservation Committee and Natural England 2010.* Peterborough: JNCC. Available.

JNCC (2017) *Special Areas of Conservation: UK SAC/SCI site summary.* Peterborough: JNCC. Available.

JNCC, J. N. C. C. (2004) *Common Standards Monitoring Guidance for Inshore Sublittoral Sediment Habitats. Version August 2004* Peterborough Joint Nature Conservation Committee (JNCC). Available.

Kaiser, M. & Spencer, B. (1994) 'Fish scavenging behaviour in recently trawled areas'. *Marine Ecology Progress Series*, 112 pp. 41.

Klein, E. S. & Thurstan, R. H. (2016) 'Acknowledging Long-Term Ecological Change: The Problem of Shifting Baselines', in Schwerdtner Máñez, K. and Poulsen, B. (eds.) *Perspectives on Oceans Past.* Dordrecht: Springer Netherlands, pp. 11-29.

Leonard, J. B. (1995) 'Assessing risk systematically'. *Risk Management;*, 42 (1), pp. 12.

Mace, G. M., Hails, R. S., Cryle, P., Harlow, J. & Clarke, S. J. (2015) 'REVIEW: Towards a risk register for natural capital'. *Journal of Applied Ecology*, 52 (3), pp. 641-653.

Marine Management Organisation (2014) *Guidance: Revised approach to the management of commercial fisheries in European Marine Sites: overarching policy and delivery.* Defra. 4 pp. Available.

McQuatters-Gollop, A., Mitchell, I., Vina-Herbon, C., Bedford, J., Addison, P.F.E., Lynam, C.P., Geetha, P.N., Vermeulan, E.A., Smit, K., Bayley, D.T.I., Morris-Webb, E., Niner, H., Otto, S., (2019) 'From Science to Evidence – How Biodiversity Indicators Can Be Used for Effective Marine Conservation Policy and Management'. *Frontiers in Marine Science,* 6, 109.

Meals, D., Jean Spooner, Steven A. Dressing & Harcum., J. B. (2011) *Statistical analysis for monotonic trends, Tech Notes 6,.* Tetra Tech, Inc., Fairfax, VA,. Available at: https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-monitoringtechnical-notes (Accessed: August 2018).

MESH Accuracy & Confidence Working Group (2007) *Confidence Assessment Guidelines.* JNCC. 6 pp. Available.

Millennium Ecosystem Assessment (2005) *Ecosystems and human well-being: Synthesis.* Washington, D.C.: World Resources Institute. 155 pp. Available.

Mills, C. M., Townsend, S. E., Jennings, S., Eastwood, P. D. & Houghton, C. A. (2006) 'Estimating high resolution trawl fishing effort from satellite-based vessel monitoring system data'. *ICES Journal of Marine Science*, 64 (2), pp. 248-255.

Natural Capital Committee (2017) *How to do it: a natural capital workbook.* 31 pp. Available.

Natural England (2017) 'Designated Sites View: Natural England Conservation Advice for Marine Protected Areas: Advice on Operations, Supplementary Advice on Conservation Objectives'. Natural England. [Online]. Available at: https://designatedsites.naturalengland.org.uk/.

Picton, B. E. & Goodwin, C. E. (2007) 'Sponge biodiversity of Rathlin Island, Northern Ireland'. *Journal of the Marine Biological Association of the United Kingdom*, 87 (6), pp. 1441-1458.

Potts, T., Burdon, D., Jackson, E., Atkins, J., Saunders, J., Hastings, E. & Langmead, O. (2014) 'Do marine protected areas deliver flows of ecosystem services to support human welfare?'. *Marine Policy*, 44 (0), pp. 139-148.

Rees, S. E., Ashley, M. & Cameron, A. (2019) *North Devon Marine Pioneer Report 2: A Natural Capital Asset and Risk Register A SWEEP/WWF-UK report by research staff the Marine Institute at Plymouth University. .* Available.

Rees, S.E., Sheehan, E.V., Stewart, B.D., Clark, R., Appleby, T., Attrill, M.J., Jones, P.J.S., Johnson, D., Bradshaw, N., Pittman, S., Solandt, J.L. (2019a) 'Emerging themes to support ambitious marine biodiversity conservation'. Marine Policy. https://doi.org/10.1016/j.marpol.2020.103864

Rees, S. E., Ashley, M., Evans, L., Mangi, S., Rodwell, L., Attrill, M., Langmead, O., Sheehan, E., R & Rees, A. (2016) *An evaluation framework to determine the impact of the Lyme Bay Fisheries and Conservation Reserve and the activities of the Lyme Bay Consultative Committee on ecosystem services and human wellbeing. A report to the Blue Marine Foundation by research staff the Marine Institute at Plymouth University, Exeter University and Cefas.* University of Plymouth. Available at: https://pearl.plymouth.ac.uk/handle/10026.1/6742.

Rijnsdorp, A. D., Dol, W., Hoyer, M. & Pastoors, M. A. (2000) 'Effects of fishing power and competitive interactions among vessels on the effort allocation on the trip level of the Dutch beam trawl fleet'. *ICES Journal of Marine Science*, 57 (4), pp. 927-937.

Saunders, J., Potts, T., Jackson, E., Burdon, D., Atkins, J. P., Hastings, E., Langmead, O. & Fletcher, S. (2015) 'Linking Ecosystem Services of Marine Protected Areas to Benefits in Human Wellbeing?', in Turner, R.K. and Schaafsma, M. (eds.) *Coastal Zones Ecosystem Services: From Science to Values and Decision Making.* Cham: Springer International Publishing, pp. 167-190.

Solandt, J.-L., T. Mullier, S. Elliott and E. Sheehan (2019). 'Managing Marine Protected Areas in Europe: Moving from 'feature-based' to 'whole-site' management of sites', Elsevier.

Sheehan, E. V., Stevens, T. F., Gall, S. C., Cousens, S. L. & Attrill, M. J. (2013) 'Recovery of a Temperate Reef Assemblage in a Marine Protected Area following the Exclusion of Towed Demersal Fishing'. *PLoS ONE*, 8 (12), pp. e83883.

Turner, K., Schaafsma, M., Elliott, M., Burdon, D., Atkins, J., Jickells, T., Tett, P., Mee, L., van Leeuwen, S., Barnard, S., Luisetti, T., Paltriguera, L., Palmieri, G. & Andrews, J. (2014) *UK National Ecosystem Assessment Follow-on. Work Package Report 4: Coastal and marine ecosystem services: principles and practice.* UNEP-WCMC, LWEC, UK. Available.

Tyler-Walters, H., Hiscock K. (eds), Tillin, H. M., Stamp, T., Readman, J. A. J., Perry, F., Ashley, M., De-Bastos, E. S. R., D'Avack, E. A. S., Jasper, C., Gibb, N., Mainwaring, K., McQuillan, R. M., Wilson, C. M., Roche, C., Budd, G. C., Hill, J. M., Jackson, A., White, N., Rayment, W. J., Wilding, C. M., Marshall, C. E., Wilson, E., Riley, K., Neal, K. J., Sabatini, M., Durkin, O. C., Ager, O. E. D., Bilewitch, J., Carter, M., Hosie, A. M., Mieszkowska, N. & Lear, D. B. (2019) 'Marine Life Information Network: Biology and Sensitivity Key Information Review Database [on-line]. '. Marine Biological Association of the United Kingdom. [Online]. Available at: www.marlin.ac.uk (Accessed: August 2018).

Tyler-Walters, H., Tillin, H. M., d'Avack, E. A. S., Perry, F. & Stamp, T. (2018) *Marine Evidence-based Sensitivity Assessment (MarESA) – A Guide. Marine Life Information Network (MarLIN).* Plymouth: Marine Biological Association of the UK, . 91 pp. Available at: www.marlin.ac.uk/publications.

UK National Ecosystem Assessment (2011) *The UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge.* Available.

United Nations (2015) *Transforming our world: The 2030 agenda for sustainable development A/RES/70/1.* United Nations. 41 pp. Available.

9 Annex I

Annex I MPA sites designated under European and UK law in Isles of Scilly IFCA District

MPA	Feature	Subfeature	EUNIS	Condition	Management
Isles of Scilly Complex SAC	Sandbanks which are slightly covered by sea water all the time	Subtidal coarse sediment	A5.1	Maintain	Towed gear prohibited, netting effort restrictions
		Subtidal sand	A5.2	Maintain	Towed gear prohibited, netting effort restrictions
		Subtidal mixed sediments	A5.4	Maintain	Towed gear prohibited, netting effort restrictions
		Subtidal seagrass beds	A5.5	Maintain	Towed gear prohibited, netting effort restrictions
	Mudflats and sandflats not covered by seawater at low tide	Intertidal sand and muddy sand	A2.2	Maintain	Towed gear prohibited, netting effort restrictions
	Reefs	Intertidal rock	A1	Maintain	Towed gear prohibited, netting effort restrictions
		Infralittoral rock	A3	Maintain	Towed gear prohibited, netting effort restrictions
		Circalittoral rock	A4	Maintain	Towed gear prohibited, netting effort restrictions
	Grey seal (*Halichoerus grypus*)			Maintain	Towed gear prohibited, netting effort restrictions
Bishop to Crim MCZ	Spiny lobster (*Palinurus elephas*)			**Recover**	Towed gear prohibited, netting effort restrictions
Bristows to the Stones MCZ	Fragile sponge and anthozoan communities on subtidal rocky habitats		A4.13	**Recover**	
	High energy circalittoral rock		A4.1	**Recover**	
	Pink sea-fan (*Eunicella verrucosa*)			**Recover**	
	Spiny lobster (*Palinurus elephas*)			**Recover**	
Isles of Scilly: Gilstone to Gorregan MCZ	High energy intertidal rock		A1.1	Maintain	Towed gear prohibited, netting effort restrictions

	Moderate energy intertidal rock		A1.2	Maintain	Towed gear prohibited, netting effort restrictions
	Spiny lobster (*Palinurus elephas*)			**Recover**	Towed gear prohibited, netting effort restrictions
Isles of Scilly: Hanjague to Deep Ledge MCZ	High energy intertidal rock		A1.1	Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal coarse sediment		A2.1	Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal under boulder communities		A1.2142	Maintain	Towed gear prohibited, netting effort restrictions
	Moderate energy intertidal rock		A2.2	Maintain	Towed gear prohibited, netting effort restrictions
	Spiny lobster (*Palinurus elephas*)			**Recover**	Towed gear prohibited, netting effort restrictions
Isles of Scilly: Higher Town MCZ	Intertidal coarse sediment			Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal sand and muddy sand			Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal under boulder communities			Maintain	Towed gear prohibited, netting effort restrictions
	Low energy intertidal rock			Maintain	Towed gear prohibited, netting effort restrictions
Isles of Scilly: Lower Ridge to Innisvouls MCZ	Moderate energy intertidal rock			Maintain	Towed gear prohibited, netting effort restrictions
	Spiny lobster (*Palinurus elephas*)			**Recover**	Towed gear prohibited, netting effort restrictions
Isles of Scilly: Men a Vaur to White Island MCZ	High energy intertidal rock			Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal coarse sediment			Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal sand and muddy sand			Maintain	Towed gear prohibited, netting effort restrictions

	Intertidal under boulder communities			Maintain	Towed gear prohibited, netting effort restrictions
	Moderate energy intertidal rock			Maintain	Towed gear prohibited, netting effort restrictions
	Spiny lobster (*Palinurus elephas*)			**Recover**	Towed gear prohibited, netting effort restrictions
	Stalked jellyfish (*Calvadosia campanulata*)			Maintain	Towed gear prohibited, netting effort restrictions
Isles of Scilly: Peninnis to Dry Ledge MCZ	Intertidal coarse sediment			Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal mixed sediments			Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal sand and muddy sand			Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal under boulder communities			Maintain	Towed gear prohibited, netting effort restrictions
	Low energy intertidal rock			Maintain	Towed gear prohibited, netting effort restrictions
	Moderate energy intertidal rock			Maintain	Towed gear prohibited, netting effort restrictions
	Spiny lobster (*Palinurus elephas*)			**Recover**	Towed gear prohibited, netting effort restrictions
	Stalked jellyfish (*Haliclystus spp*)			Maintain	Towed gear prohibited, netting effort restrictions
Isles of Scilly: Plympton to Spanish Ledge MCZ	High energy intertidal rock			Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal sand and muddy sand			Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal under boulder communities			Maintain	Towed gear prohibited, netting effort restrictions
	Moderate energy intertidal rock			Maintain	Towed gear prohibited, netting effort restrictions

	Spiny lobster (*Palinurus elephas*)			**Recover**	Towed gear prohibited, netting effort restrictions
Isles of Scilly: Smith Sound Tide Swept Channel MCZ	High energy intertidal rock			Maintain	Towed gear prohibited, netting effort restrictions
	Moderate energy intertidal rock			Maintain	Towed gear prohibited, netting effort restrictions
	Spiny lobster (*Palinurus elephas*)			**Recover**	Towed gear prohibited, netting effort restrictions
Isles of Scilly: Tean MCZ	Intertidal coarse sediment			Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal sand and muddy sand			Maintain	Towed gear prohibited, netting effort restrictions
	Intertidal under boulder communities			Maintain	Towed gear prohibited, netting effort restrictions
	Moderate energy intertidal rock			Maintain	Towed gear prohibited, netting effort restrictions

10 Annex II

Assigning sensitivity of habitats in relation to current fishing activity and scenarios under potential management options.

Assessment of 'likely relative condition' (LRC) of habitats in relation to exposure to pressures associated with different fishing activities was based on the assessment of level of exposure (in relation to threshold spatial intensity) and level of sensitivity of a given habitat to pressures associated with each activity (Tyler-Walters et al., 2018; 2019) (Figure 1, Table 1).

Sensitiv-ity	Exposure			
	None	Low	Moderate	High
NS	None	None	None	None
L	None	Low	Low	Moderate
M	None	Low	Moderate	High
H	None	Moderate	High	Very High

⟹

Sensitivity	Exposure			
	None	Low	Moderate	High
NS	Good	Good	Good	Good
L	Good			↓
M	Good			↓
H	Good	→	→	

Figure 20 Likely relative condition matrix for level of risk in relation to exposure to activity and sensitivity of habitat to pressure related to the activity.

Table 11 MARESA pressures related to each fishing activity, including threshold level of activity to trigger ‘low’ category on LRC scale.

Activity	**Related pressures (MARESA) (Tyler-Walters et al., 2018; 2019)**	**Threshold level of activity to trigger ‘Moderate’ exposure category on LRC scale. (evidence reference)**
Potting	• Abrasion	Spatial intensity: >15 pots per .25km^2 (Rees, 2018)
Tangle net	• Abrasion	Spatial intensity: >1 vessel netting same ground regularly (principle ground) over one season (Sewell, 2005)
Otter trawl	• Abrasion	Spatial intensity: Same ground trawled >1 time over one season (Heinz et al., 2009; Kaiser et al, 2006; Sewell, 2005)
Scallop dredge	• Abrasion • Sub-surface disturbance-penetration • Habitat structure changes - removal of substratum (extraction) • Physical change (to another seabed type)	Spatial intensity: Same ground dredged at least 1 time over one season (Jenkins et al., 2001; Sewell, 2005).

11 Annex III

Primary survey data: collection and analysis of towed video and benthic grab survey data conducted by University of Plymouth

1.1 Site Identification

Side-scan sonar surveys were used to identify sites which would cover a range of habitats present in the outer study area. These surveys were carried out from the 19th - 21st of May 2019, aboard the Cornwall IFCA's Research Vessel (R/V) Tiger Lily VI. The surveys were carried out according to the 'Mapping European Seabed Habitats (MESH) Recommended Operating Guidelines (ROG) for side-scan surveys' (Henriques *et al.*, 2013). Data was collected using an EdgeTech 4200 dual frequency side-scan sonar system and was logged at both 300 and 600 kHz, but only observed at the former. Data was captured using EdgeTech 'Discover 4200-MP' (Version 33.0.1.112) software. The side-scan sonar system was connected to the tow line and data cables on the stern deck of the vessel and towed at a speed of approximately 4-5 knots with a layback position of approximately 115m in water depths of 60-100m. Positional information was logged in WGS84 using a dedicated survey GPS receiver. All times recorded are in UTC from a Furuno GP32 GPS. The surveys involved 8 transects of varying lengths, covering ~120miles of ground, with a 400m acoustic swathe. Line separation was approximately 1000m.

Raw acoustic data (.xtf files) at 300kHz were post-processed using Chesepeake SonarWiz 7 software (v7.04.04) The positional data was adjusted for layback and 100 ping course smoothing applied. An acoustic backscatter mosaic was computed through applying: supervised bottom tracking algorithm and appropriate slant range corrections (assuming a flatbed); Empirical Gain Normalisation (EGN); and a de-striping and nadir filter to best enhance seabed backscatter response and minimize artefacts. The final mosaic was then exported as a floating point GeoTIFF for further processing in ESRI ArcGIS where positional information was transformed from WGS84 into OSGB36 British National Grid (OSTN15 projection). The results of the side-scan sonar surveys were then used to identify sites for the towed camera array transects and sediment grabs of the outer Isles of Scilly area in order to ensure a range of habitats over the entire area were covered.

1.1.2 Towed Camera Array

Fieldwork using the towed camera array was carried out from the 30th September - 4th October 2018 aboard the Morvoren, a <11m Offshore 105 vessel, and 4th - 18th June 2019, aboard the Kestrel, a <11m fishing vessel. The towed flying camera array (see Figure 1), designed to fly above the seabed (described in detail elsewhere; Sheehan *et al.*, 2010; 2016), was used to survey the epifaunal biodiversity present. The minimum contact with the seabed due to the buoyancy of the array makes this method a cost effective and non-destructive method of sampling the epibenthic biodiversity (Sheehan *et al.*, 2010; 2016). The array was attached to the boat and towed (see Figure 2 for the arrangement of deployment) for 20minutes at speeds of ~$0.4ms^{-1}$. The high definition camera was placed at an oblique angle to the seabed, the same angle as two green lasers (wavelength 532nm), placed 300mm apart. This allowed for calibration of the area surveyed in both videos and frames and therefore the quantification of taxa densities. GPS positioning was recorded throughout each day of fieldwork using a Garmin GPS tracker (Garmin Ltd., Southampton, UK) and was used to calculate the length of each transect.

1.1.3 Sediment Grabs

Infaunal sample collection was also carried out from 4th-18th of June 2019 aboard the Kestrel. Samples were collected using a Shipek grab ($0.04m^2$ area). Once collected, the volume of the sample and a description of the type of sediment was recorded. Samples were fixed and stored in 70% Industrial Denatured Alcohol (IDA).

1.2 Data Analysis

1.2.1 Video Analysis

Species present in the towed array videos were identified to the highest taxonomic level possible. While the majority were identified to species, the level to which identification was possible varied due to intra-species similarities which are indiscernible through the current methods; therefore, some groups were identified only to their genus, such as *Aplidium sp., Calliostoma sp., Cerianthus sp., Cellaria sp., Inachus sp., Macropodia sp., Pagurus sp.* and *Palaemon sp*. Groups were also created for species which were not easily distinguished, at lower levels than genus, or were obscured and so identification was not possible using the current methods; such as unidentified algae, ascidians, bryozoans, bivalves, fish, gobies, hydroids, juvenile fish, juvenile squid, sponges, turf species (hydroids and bryozoans <1cm in height) and worms. Due the different levels of identification, species and groups will henceforth be referred to as taxa.

Video analysis methods followed those described in detail in Stevens et al. (2013), which allow for the quantification of densities of fauna through analysis of individual frames as well as analysis of the entire transect for infrequently occurring sessile fauna or mobile fauna. In the current study, 15 frames were analysed per transect rather than the 30 described in Stevens et al. (2013) due to a low number of frames meeting the criteria for analysis; this criteria includes the frame being in focus, not obstructed and the lasers being contained with the field of view of the frame.

To classify the habitats present in the survey, each transect was given a dominant habitat type; defined as the habitat type which covered more than 50% of the transect length. The habitat categories were formed of two parts, the epifauna type and the substrate type. The dominant epifauna type was assigned according to the presence of RAS (reef associated species), SAS (sand associated species) or a mix of the two. The dominant substrate type was classified into 1 of 4 categories: 'rock', 'veneer over rock', 'mixed large substrate' or 'sand'. Within 'sand', it was clarified whether the sand was stable or mobile. The combination of these terms resulted in the classification of 6 dominant habitat types, which, along with their definitions, can be seen in Table 1.

Table 12. Dominant habitat type definitions. RAS = Reef Associated Species, SAS = Sand Associated Species

Habitat Type	**Definition**
RAS on rocky reef	RAS on rock or boulder substrates.
RAS on sediment veneer	RAS on sand substrates of varying depths, indicating rock substrates beneath, e.g. bedrock, boulders or cobbles.
RAS and SAS on sediment veneer	RAS and SAS on sand substrates of varying depths, indicating rock substrates beneath, e.g. bedrock, boulders or cobbles.
RAS and SAS on cobbles and pebbles	RAS and SAS on large cobble and pebble substrates.
SAS on stable sand beds	SAS on stable, flat sand substrates.
SAS on mobile sand beds	SAS occurring mobile sand beds, occurring in swathes.

1.2.2 Infauna analysis

Samples were sieved through 2mm, 1mm and 0.5mm Endecott sieves. Infauna were picked from the remaining sediment in white trays and stored in 70% IDA.

Infauna samples were identified using light microscopy (Leica EZ4 microscope) with the aid of taxonomic keys (Hayward and Ryland, 1995; Hayward and Ryland, 2017). Any biological material deemed to have not been alive at the time the sample was collected was discarded. Organisms were identified to a minimum of family level; polychaetes were identified to family level as this has been found to be a high enough resolution to identify community changes and reduces the time required for analysis (Gray *et al*., 1990; Chapman, 1998; Sanchez-Jerez *et al*., 2018). Also due to time constraints, amphipods were similarly only identified to family level. The procedure was carried out in line with NMBAQC's Processing Requirements Protocol for marine invertebrate samples (Worsfold and Hall, 2010).

All infauna were quantified in individuals $m^{-2,}$ this was calculated by dividing the number of individuals recorded by 0.04. This unit was chosen due to the variability in the volumes of sediments collected, which ranged from 0.125L to 3L. This was assumed to be due to the different depths of sediments at each site; some of grabs were collected in areas of mobile sediment, while others were collected in varying depths of veneer.

References

Chapman, M.G. (1998). Relationships between spatial patterns of benthic assemblages in a mangrove forest using different levels of taxonomic resolution. Marine Ecology Progress Series, 162, pp.71-78.

Gray, J.S., Clarke, K.R., Warwick, R.M. and Hobbs, G. (1990). Detection of initial effects of pollution on marine benthos: an example from the Ekofisk and Eldfisk oilfields, North Sea. Marine Ecology Progress Series, 66, pp.285-299.

Hayward, P.J. and Ryland, J.S. (1995). Handbook of the Marine Fauna of North-West Europe. First Edition. Oxford University Press, Oxford.

Hayward, P.J. and Ryland, J.S. (2017). Handbook of the Marine Fauna of North-West Europe. Second Edition. Oxford University Press, Oxford.

Henriques, V., Mendes, B., Pinheiro, L. M., Goncalves, D. and Long, D. (2013) 'Recommended Operating Guidelines (ROG) for side-scan sonars'. MeshAtlantic Recommended Operating Guideline.

Sanchez-Jerez, P., Fernandez-Gonzalez, V., Mladineo, I., Matijević, S., Bogner, D., Grubišić, L. and Fernandez-Jover, D. (2018). Assessment of the impact of Atlantic bluefin tuna farming on Adriatic benthic habitats by analysing macroinvertebrate assemblage structure at family level. Mediterranean Marine Science, 19(2), pp.344-355.

Sheehan, E.V., Stevens, T. and Attrill, M.J. (2010). A Quantitative, Non-Destructive Methodology for Habitat Characterisation and Benthic Monitoring at Offshore Renewable Energy Developments. PLoS ONE, 5(12), e14461.

Sheehan, E.V., Vaz, S., Pettifer, E., Foster, N., Nancollas, S., Cousens, S., Holmes, L., Facq, J., Germain, G. and Attrill, M. (2016). An experimental comparison of three towed underwater video systems using species metrics, benthic impact and performance. Methods Ecol. Evol., 7, pp.843-852.

Worsfold, T. and Hall, D. (2010). Guidelines for processing marine macrobenthic invertebrate samples: a Processing Requirements Protocol. National Marine Biological AQC Coordinating Committee. Scottish Environment Protection Agency (SEPA). 26 pp.

12 Annex IV

Assigning EUNIS biotopes and sensitivity to towed video and benthic grab survey data

A precautionary assessment was applied to assign biotopes and corresponding activity-pressure sensitivity levels to habitats data from towed video and benthic grab surveys. Dominant tow habitat (>50% substratum type) was first assigned at Eunis L2 for reef substratum and reef/veneer (A4) and Eunis L3 for soft substratum (coarse A5.1, sand A5.2, mixed, A5.4). Epifauna species presence and abundance for each towed video transect (circalittoral rock A4) and infauna species presence and abundance for soft substratum habitats were reviewed, for similarities to species communities characterising habitat biotopes that have sensitivity assessments available via MARESA (Tyler-Walters et al., 2018, 2019). All relevant biotopes with associated MARESA sensitivity assessments (>Eunis level 4) were identified for the sublittoral substratum type and species presence and abundance for each towed video transect or benthic grab sample site. As towed video surveys in particular passed over multiple biotopes, all relevant biotopes were selected per transect. Biotope assignment was sense checked by reviewing towed video recordings with members of the ecology SCILL-E project team (AC, BR).

Assigning habitat sensitivity to pressures related to fishing activities

Assessment of sensitivity to fishing activities was based on the pressures:

1. 'Abrasion' (relating to otter trawl activity and potting activity above threshold levels on rock and soft substratum habitats)

2. 'Sub surface disturbance - penetration' (relating to scallop dredge activity on soft substratum habitats and for reef habitats where an assessment was completed by MARESA assessments (Harvey Tyler Walters et al., 2018)).

3. 'Habitat structure changes - removal of substratum (extraction) '(relating to scallop dredge activity on rock habitats (e.g. boulder and reef with sand veneer) in relation to evidence in MARESA assessments).

4. 'Physical change (to another seabed type)' (relating to intense fishing effort over circalittoral rock biotopes consisting of reef and boulders with scallop dredge is likely to remove or turn boulder substratum). The pressure 'physical change where boulders are physically moved or removed under a worst case scenario of bottom towed fishing activity would result in a fundamental change to the physical character of the biotope and species are considered unlikely to recover (Tyler-Walters et al., 2018).

Evidence relating to pressure 1 in relation to potting activity is provided by studies in Lyme Bay, UK by Rees (2018), whereby commercial potting reduced the number of two key sensitive sessile reef species (*Pentapora folicacea, Phallusia mammillata)* in Lyme Bay when potting density was high (>60 pots km^2).

In relation to pressure 1, high intensity otter trawling was identified to have had a significant, negative effect on benthic infauna abundance, biomass, and species richness. At highest trawling intensity (18.2 times trawled/year), Heinz et al., (2009) recorded that infauna abundance was reduced by 72%, biomass by 77%, and species richness by 40%. Even at low trawling intensity 1.3 times trawled per year abundance, biomass and species richness were reduced (Heinz et al., 2009). Kaiser et al., (2006) Identified that reduction of benthic taxa following otter trawl disturbance was greatest on mud habitats (estimated to be −29%) and on sand habitats (−15%). Otter trawling on sparsely colonised gravel habitats did not have a negative effect on benthic taxa (+3%) Kaiser et al. 2006).

In relation to pressure 1 and 2, high (and even lower) intensity of scallop dredging was identified to have a significant negative effect on number of individuals and biomass of macrofauna, associated with mixed substrata (such as fauna within/on soft substratum and cobbles and boulders) (Parnovi et al., 2000). Jenkins et al., (2001) identified that most of the mortality to epifauna species appears to be left on the seabed dredge tracks rather than occurring as bycatch, concluding, therefore, the destruction of seabed organisms may be underestimated.

Evidence relating to implications of pressure 3 and 4 is provided by sensitivity assessment reviews in Tyler Walters et al., (2018) for relevant circalittoral rock biotopes. For instance, Picton & Goodwin (2007) noted that an area of boulders with a rich fauna of sponges and hydroids on the east coast of Rathlin Island, Northern Ireland was significantly altered since the 1980s. Scallop dredging had begun in 1989 and boulders were observed to have been turned and the gravel harrowed. In addition, many of the boulders had disappeared and rare hydroid communities were greatly reduced (Picton & Goodwin, 2007). Freese et al. (1999) also noted that trawling could remove important substratum such as boulders. Therefore, where relevant sponge and hydroid biotopes occur on boulders that could be subject to removal or extraction, resistance is likely to be 'Low'. Hence, as resilience is probably 'very low', sensitivity is assessed as 'High' (Tyler-Walters et al., 2018).

For each of the MARESA biotopes assigned to the towed video data the sensitivity for the most sensitive biotope identified in relation to each tow transect was selected as a precautionary measure, to apply across the towed video transect.

Relationship comparable methods for assigning sensitivity of habitat to activities.

Comparable methods to assign sensitivity included 1. Assigning the most sensitive biotope occurring under each Eunis Level 2-3 level within the given pressures for an activity, using a sub-set of biotopes identified to occur in the wider UK region (Natural England Pers. Comm. 2020). 2. Assigning the median sensitivity under each Eunis L2-3 stage, using a set of biotopes identified to occur in the wider UK region (JNCC Pers. Comm. 2020). For the SCILL-E project option 1 was identified to be overly precautionary, as there was original survey data available. It was discussed that option 1 resulted in biotopes (such as biogenic reefs) being assigned although they were not identified in the survey data. Option 2 was likely to under estimate sensitivity, as high sensitivity habitats would be provided a lower sensitivity and thereby risk underassessment of implications of management decisions.

As primary survey data were available to identify marine habitats present in Isles of Scilly IFCA District, the sensitivity level (not sensitive, low, medium, high) for the most sensitive habitat/biotope from those identified to occur within each L2/3 category, in the Isles of Scilly IFCA District, were assigned when existing habitat data did not provide > Eunis L2 (e.g. modelled data only was available).

Results

Table 13 provides detail of biotopes identified that were relevant to each towed video, or benthic grab sample, and associated sensitivity to pressures associated with fishing activities.

Table 13 Eunis habitats (biotopes) >L4 identified from towed video and benthic grab sample data and sensitivity of most sensitive habitat to the pressures, 'Abrasion' (intense potting and otter trawl) and Sub surface – disturbance or habitat structure changes - removal of substratum (extraction)/ physical change (to another seabed type) (high spatial intensity interaction with scallop dredge). Not sensitive = 0, low sensitivity = 1, medium = 2, high =3.

Sample #	**Site**	**Dominant Tow Classification**	**Eunis L2/L3**	**Eunis habitats represented by species presence and abundance**	**Sensitivity to Abrasion**	**Sensitivity to subsurface disturbance / physical change**
040619_1	A4	Reef/sand fauna colonised veneer over rock	A4	A4.135, A4.1312, A4.134, A4.131, A5.444	2	3
040619_2	A5	Reef/sand fauna colonised veneer over rock	A4	A4.135, A4.1312, A4.134, A4.131, A5.444	2	3
040619_3	A7	Reef/sand fauna colonised veneer over rock	A4	A4.131, A4.135, A5.444	2	3
040619_4	B7	Reef/sand fauna colonised veneer over rock	A4	A4.213, A5.444	2	3
040619_5	B6	Reef fauna colonised veneer over rock	A4	A4.12, A4.1312, A4.134, A4.135, A4.131	3	3
040619_6	B5	Reef fauna colonised veneer over rock	A4	A4.135, A4.134, A4.135, A4.131	2	3
040619_7	B3	Sand fauna colonised sand	A5.1	A5.151, A5.134	1	2
050619_2	C4	Sand fauna colonised sand	A5.2	A5.262, A5.151, A5.134,	2	2
050619_4	C5	Reef fauna colonised veneer over rock	A4	A4.135, A4.211, A4.133, A5.444	2	3
050619_5	C6	Reef fauna colonised veneer over rock	A4	A4.135, A4.132, A4.1312, A5.444	2	3
050619_6	C7	Reef fauna colonised veneer over rock	A4	A4.132, A4.135, A4.212, A4.139, A5.444	2	3
050619_7	C8	Reef fauna colonised veneer over rock	A4	A4.132, A4.214, A5.444	1	3
050619_8	B8	Reef fauna colonised veneer over rock	A4	A4.135, A4.313, A4.132, A5.444	2	2
090619_1	G1	Reef fauna colonised veneer over rock	A4	A4.135, A4.213, A4.132,	2	2
090619_2	E1	Mixed large substrate	A5.4	A5.444	2	3
090619_3	D1	Sand	A5.1	A5.145	1	2
090619_5	B1	Sand fauna colonised sand	A5.1	A5.251, A5.142	1	1
090619_6	A1	Reef/sand fauna colonised veneer over rock	A4	A4.212, A4.214, A4.313	2	3
090619_7	A2	Reef fauna colonised rock	A4	A4.1312, A4.135	2	3
100619_1	A3	Reef fauna colonised veneer over rock	A4	A4.214 , A4.2142, A4.135, A4.132, A5.444	2	3
100619_2	D3	Sand fauna colonised sand	A5.1	A5.145, A5.137	**1**	**2**
100619_3	E3	Sand fauna colonised sand	A5.1	A5.251, A5.137	1	1
100619_5	G2	Reef fauna colonised veneer over rock	A4	A4.212, A4.135	2	3
100619_6	F2	Reef fauna colonised veneer over rock	A4	A4.1312, A4.132, A4.312	2	3

Continued on next page..

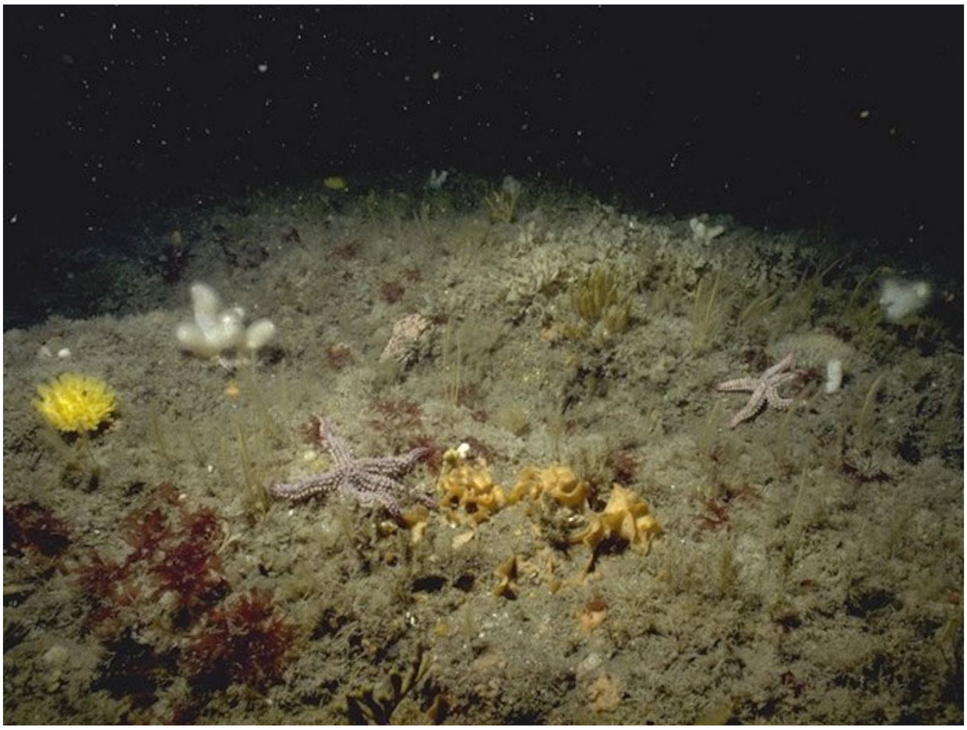
Sample #	Site	Dominant Tow Classification	Eunis L3	Eunis habitats represented by species presence and abundance	Sensitivity to Abrasion	Sensitivity to subsurface dis-turbance / physical change
100619_7	D2	Sand	A5.1	A5.251, A5.145, A5.143	1	2
100619_8	B2	Sand fauna colonised sand	A5.1	A5.137, A5.134, A5.152	1	2
130619_6	G8	Sand fauna colonised sand	A5.2	A5.233	1	1
130619_7	F8	Sand	A5.1	A5.151, A5.262	2	2
130619_8	E8	Sand fauna colonised sand	A5.1	A5.151, A5.262, A5.444	2	2
130619_9	E7	Sand fauna colonised sand	A5.1	A5.145, A5.137	1	2
140619_1	F7	Sand	A4	A4.2141	1	2
140619_2	G7	Sand fauna colonised sand	A4	A4.132, A4.135	2	2
140619_3	G6	Sand fauna colonised sand	A5.2	A5.233	1	1
140619_4	G3	Sand fauna colonised sand	A5.1	A5.145, A5.251	1	2
140619_5	G4	Sand fauna colonised sand	A5.1	A5.151, A5.262, A5.262	2	2
150619_1	E6	Sand	A5.2	A5.233, A5.251	1	1
150619_2	F6	Sand fauna colonised sand	A5.4	A5.272, A5.444, A5.441, A5.441	2	2
150619_3	F5	Sand fauna colonised sand	A5.4	A5.272, A5.441	2	2
150619_4	D5	Sand fauna colonised sand	A5.2	A5.145, A5.232	1	2
150619_5	D4	Sand fauna colonised sand	A5.2	A5.251, A5.233	1	1
150619_6	E4	Sand fauna colonised sand	A5.2	A5.251, A5.233	1	1
300918_3	N/A	Sand fauna colonised sand	A5.4	A5.441, A5.444, A5.137	2	2
300918_6	N/A	Mixed large substrate	A4	A4.132, A4.134, A4.215	1	3
300918_7	N/A	Reef fauna colonised rock	A4	A4.2111	3	3
011018_1	N/A	Reef fauna colonised rock	A4	A4.135	2	2
011018_4	N/A	Reef fauna colonised rock	A4	A4.2122	1	3
011018_5	N/A	Reef fauna colonised rock	A4	A4.2111, A4.1311	3	3
031018_1	N/A	Reef fauna colonised rock	A4	A4.2111, A4.1311	3	3
031018_3	N/A	Reef fauna colonised rock	A4	A4.2111, A4.1311	3	3
031018_4	N/A	Reef fauna colonised rock	A4	A4.2111, A4.1311	3	3
031018_5	N/A	Reef fauna colonised rock	A4	A4.2111, A4.1311	3	3
041018_2	N/A	Reef fauna colonised rock	A4	A4.2111, A4.1311	3	3
041018_4	N/A	Reef fauna colonised rock	A4	A4.2122, A4.2111	2	3

Limitations

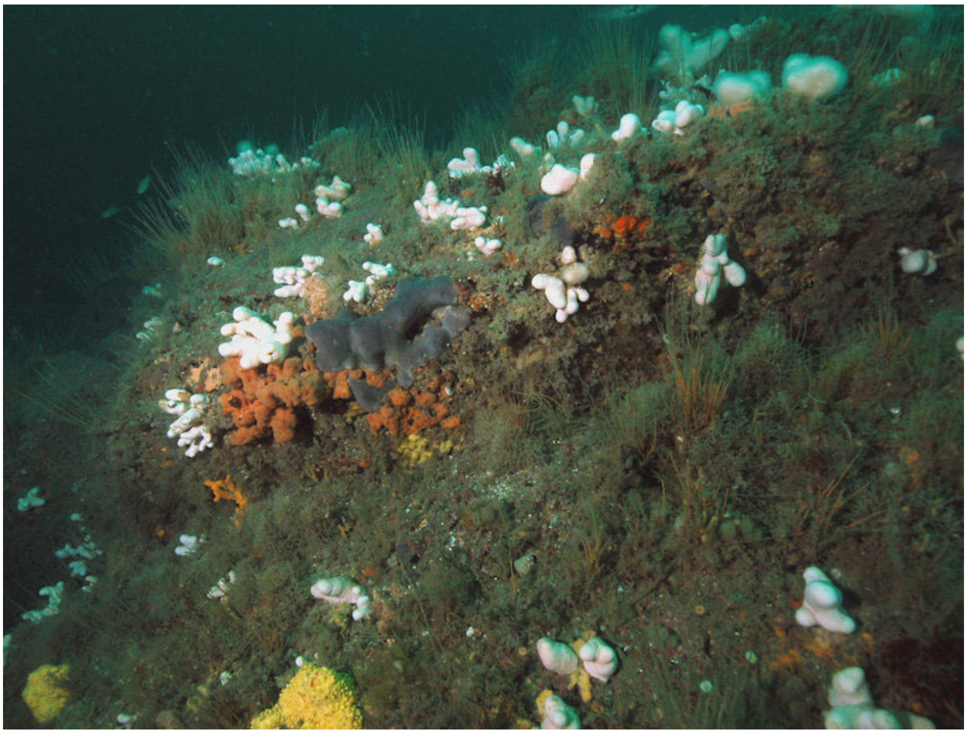
- Sensitivity assessments may over or under estimate sensitivity as primary survey data were not available for the entire IFCA district.
- Where surveys had taken place, only substratum type and species presence and abundance were identified in the region of the towed video view (1m). Biotope identification was based on physical and biological features in the survey track only.
- To create a habitat and sensitivity map across the regions with primary survey data, a buffer of 500m was created around the towed video transect. More or less sensitive habitats may

occur within this buffer, outside of the towed video track. These limitations need to be taken into account when using the evidence to undertake spatial management decisions.

Typical habitats for reef substratum and sand substratum are displayed in Figure 21 below.



A4.1312 Mixed turf of bryozoans and erect sponges with Dysidia fragilis and Actinothoe sphyrodeta on tide-swept wave-exposed circalittoral rock (Photo: Keith Hiscock, Tyler Walters et al., 2019).



A4.139 Sponges and anemones on vertical circalittoral bedrock (Photo: Keith Hiscock, Tyler Walters et al., 2019).

A5.444 *Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment (Photo: aquatera.co.uk)

A5.137 - Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand (Photo: Keith Hiscock, Tyler Walters et al., 2019)

Figure 21 Images of habitats commonly identified in relation to towed video and benthic grab survey data in Isles of Scilly IFCA district SCILL-E ecological surveys.