Document Control

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Southern Inshore Fisheries and Conservation Authority (IFCA)
Marine Conservation Zone Fisheries Assessment (Part B)

Marine Conservation Zone: Bembridge MCZ

Feature: Subtidal mud, sea pens and burrowing megafauna

Broad Gear Type: Bottom Towed Fishing Gear

Gear type(s) Assessed: Light otter trawl; Beam trawl; Scallop Dredges.

Technical Summary

As part of the MCZ assessment process for the tranche 3 Bembridge MCZ, it was identified that trawling (specifically light otter trawl and beam trawl) and scallop dredging and their potential impacts required an in-depth assessment. Light otter trawling takes place at a medium to light level in the area north of the site. At any one time there are approximately 1-2 vessels actively participating in the activity, when weather allows, and other species/gear types are not favoured in that period. Scallop dredging takes place subtidally and is focused over areas of coarse and mixed sediments in the area off of the North East coast of the Isle of Wight. A maximum of 1-2 are seen near or within MCZ at any one time. The activity usually occurs in the Winter with the fishery usually lasting around one month.

The potential pressures likely to be exerted by the activity upon designated features were identified as abrasion, disturbance and penetration of the seabed below and on the surface of the seabed, changes in suspended solids (water clarity), the removal of target and non-target species, smothering and siltation rate changes. Scientific literature shows that whilst trawling and dredging have the potential to cause physical and biological disturbance, the extent and severity of impact largely depends on site-specific factors including sediment type and physical regime. As such, the level of impact can largely vary between studies conducted in 'similar' habitat types.

When considering the medium (1-2 times per week) to light (1-2 times per month) level of trawling and dredging within the Bembridge MCZ, in combination with other evidence (scientific literature, sightings data, feature mapping) and site-specific factors, it was concluded the activity is likely to pose a significant risk to sea pens and burrowing megafauna and subtidal mud features. As such, it is believed the activity could hinder the achievement of the designated features 'recover' general management approaches. Existing management measures are therefore considered not to be sufficient to ensure that trawling remains consistent with the conservative objectives of the site. Therefore, one or two additional closed areas, protecting the sea pens and burrowing megafauna and subtidal mud features in the site, will be developed. The areas will completely prohibit the use of bottom towed fishing gear (including trawling) over the features.

In conclusion, it is believed the activity, once such management measures are in place, will not hinder the achievement of the designated features to achieve their 'recover' general management approaches and that the activity will remain consistent with the site's conservation objectives. Fishing effort will continue to be monitored.

Contents

1 Introduction

1.1 Need for an MCZ assessment

This assessment has been undertaken by Southern IFCA in order to document and determine whether management measures are required to achieve the conservation objectives of Bembridge Marine Conservation Zone (MCZ). Southern IFCA has duties under section 154 of the Marine and Coastal Access Act 2009 which states;

154 Protection of marine conservation zones

(1) The authority for an IFC district must seek to ensure that the conservation objectives of any MCZ in the district are furthered.

(2) Nothing in section 153(2) is to affect the performance of the duty imposed by this section.

(3) In this section—

(a) “MCZ” means a marine conservation zone designated by an order under section 116;

(b)the reference to the conservation objectives of an MCZ is a reference to the conservation objectives stated for the MCZ under section 117(2)(b).

Section 125 of the 2009 Act also requires that public bodies (which includes the IFCA) exercise its functions in a manner to best further (or, if not possible, least hinder) the conservation objectives for MCZs.

This MCZ assessment will complement Southern IFCA’s assessment of commercial fishing activities in European Marine Sites (EMS) – designated to protect habitats and species in line with the EU Habitats Directive and Birds Directive. To bring fisheries in line with other activities, the Department for Environment, Food and Rural Affairs (DEFRA) announced on the 14th August 2012 a new approach to manage fishing activities within EMSs. This change in approach will promote sustainable fisheries while conserving the marine environment and resources, securing a sustainable future for both.

1.2 Documents reviewed to inform this assessment

- Reference list (Section 7)
- Defra’s matrix of fisheries gear types and European Marine Site protected features[1]
- Site map(s) – feature location and extent (Annex 1)
- Fishing activity data (map(s), etc) (Annex 8)
- Natural England’s Advice on Operations for West of Walney MCZ[2]
- Natural England’s Supplementary Advice on Conservation Objectives for West of Walney MCZ[3]
- Natural England’s Advice on Operations for the Needles MCZ[4]
- Natural England’s Supplementary Advice on Conservation Objectives for the Needles MCZ[5]
- Fisheries Impact Evidence Database (FIED)

[1] https://www.gov.uk/government/publications/fisheries-in-european-marine-sites-matrix

[2] https://designatedsites.naturalengland.org.uk/Marine/FAPMatrix.aspx?SiteCode=UKMCZ0045&SiteName=west&SiteNameDisplay=West+of+Walney+MCZ&countyCode=&responsiblePerson=&SeaArea=&IFCAArea=&NumMarineSeasonality=

[3] https://designatedsites.naturalengland.org.uk/Marine/SupAdvice.aspx?SiteCode=UKMCZ0045&SiteName=west&SiteNameDisplay=West+of+Walney+MCZ&countyCode=&responsiblePerson=&SeaArea=&IFCAArea=&NumMarineSeasonality=

[4] https://designatedsites.naturalengland.org.uk/Marine/FAPMatrix.aspx?SiteCode=UKMCZ0040&SiteName=the%20needles&SiteNameDisplay=The+Needles+MCZ&countyCode=&responsiblePerson=&SeaArea=&IFCAArea=&NumMarineSeasonality=

[5] https://designatedsites.naturalengland.org.uk/Marine/SupAdvice.aspx?SiteCode=UKMCZ0040&SiteName=the%20needles&SiteNameDisplay=The+Needles+MCZ&countyCode=&responsiblePerson=&SeaArea=&IFCAArea=&NumMarineSeasonality=,0

2 Information about the MCZ

2.1 Overview and designated features

The Bembridge MCZ was designated in May 2019 and covers an area surrounding the south east coast of the Isle of Wight stretching from Seaview on the north east of the Island, to Dunnose, Bonchurch on the south east. The site covers an area of approximately 75km^2 an protects a number of rare and fragile habitats including Maerl beds, seagrass beds, subtidal sediments and sheltered muddy gravels. Additionally, the site protects a number of rare species including two stalked jellyfish species, sea pens and burrowing megafauna, peacock's tail (*Padina pavonica*) and the short snouted seahorse (*Hippocampus hippocampus*).

A summary of the site's designated features is provided in Table 1, together with the recommended General Management Approach (GMA) for each feature. The GMA required for a feature in a MCZ will either be for it to be maintained in favourable condition (if it is currently in this state), or for it to be recovered to favourable condition (if it is currently in a damaged state) and then to be maintained in favourable condition.

Table 1. Designated features and their general management approach for the Bembridge MCZ.

Designated feature	General Management Approach
Short-snouted seahorse (*Hippocampus hippocampus*)	Maintain in favourable condition
Stalked jellyfish (*Calvadosia campanulata*)	Maintain in favourable condition
Stalked jellyfish (*Haliclystus* species)	Maintain in favourable condition
Subtidal coarse sediment	Maintain in favourable condition
Subtidal sand	Maintain in favourable condition
Sheltered muddy gravels	Maintain in favourable condition
Sea-pens and burrowing megafauna	Recover to favourable condition
Native oyster (Ostrea edulis)	Recover to favourable condition
Peacock's tail (*Padina pavonica*)	Recover to favourable condition
Maerl beds	Recover to favourable condition
Seagrass beds	Recover to favourable condition
Subtidal mixed sediments	Recover to favourable condition
Subtidal mud	Recover to favourable condition

Please refer to Annexes 1 for site feature maps of broad-scale habitats and features of conservation importance.

This feature data comes from the Natural England, 2019 data set given to Southern IFCA, containing a collation of marine habitat and species records that contribute to the designation of marine habitats and features. This corresponds with the feature data on Magic Map which represents Natural England's best available evidence (https://magic.defra.gov.uk/MagicMap.aspx).

2.2 Conservation objectives

The site's conservation objectives apply to the Marine Conservation Zone and the individual species and/or habitat for which the site has been designated (the "Designated features" listed below).

The conservation objective of each of the zones is that the protected habitats:

1. are maintained in favourable condition if they are already in favourable condition

2. be brought into favourable condition if they are not already in favourable condition

For each protected feature, favourable condition means that, within a zone:

1. its extent is stable or increasing
2. its structure and functions, its quality, and the composition of its characteristic biological communities (including diversity and abundance of species forming part or inhabiting the habitat) are sufficient to ensure that its condition remains healthy and does not deteriorate

Any temporary deterioration in condition is to be disregarded if the habitat is sufficiently healthy and resilient to enable its recovery.

For each species of marine fauna, favourable condition means that the population within a zone is supported in numbers which enable it to thrive, by maintaining:

1. the quality and quantity of its habitat
2. the number, age and sex ratio of its population. Any temporary reduction of numbers of a species is to be disregarded if the population is sufficiently thriving and resilient to enable its recovery.

Any alteration to a feature brought about entirely by natural processes is to be disregarded when determining whether a protected feature is in favourable condition.

3 MCZ assessment process

3.1 Overview of the assessment process

The assessment of commercial fishing activities within the Bembridge MCZ will be undertaken using a staged process, akin to that proposed by the Marine Management Organisation (MMO)[6], for marine license applications (Annex 2). The assessment process comprises of an initial screening stage to establish whether an activity occurs or is anticipated to occur/has the potential to occur within the site. Activities which are not screened out are subject to a simple 'part A' assessment, akin to the Test of Likely Significant Effect required by article 6(3) of the Habitats Directive. The aim of this assessment is to identify pressures capable of significantly affecting designated features or their related processes. Fishing activities and their associated pressures which are not screened out in the part A assessment and then subject to a more detailed 'part B' assessment, where assessment is undertaken on a gear type basis. A part B assessment is akin to the Appropriate Assessment required by article 6(3) of the Habitats Directive. The aim of this assessment is to determine whether there is a significant risk of the activity hindering the conservation objectives of the MCZ. Within this stage of assessment, 'hinder' is defined as any act that could, either alone or in combination:

- in the case of a conservation objective of 'maintain', increase the likelihood that the current status of a feature would go downwards (e.g. from favourable to degraded) either immediately or in the future (i.e. they would be placed on a downward trend); or

- in the case of a conservation objective of 'recover', decrease the likelihood that the current status of a feature could move upwards (e.g. from degraded to favourable) either immediately or in the future (i.e. they would be placed on a flat or downward trend) (MMO, 2013).

If the part B assessment is unable to conclude that there is no significant risk of an activity hindering the conservation objectives of the MCZ, then the activity may be subject to management and consideration will be given to whether or not the public benefit of the activity outweighs the risk of damage to the environment; and if so, whether the activity is able to deliver measures of equivalent environmental benefit to the damage that is likely to occur to the MCZ.

[6] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/410273/Marine_conservation_zones_and_marine_licensing.pdf

3.2 Screening and part A assessment

The aim of the screening stage and part A assessment is to determine whether, under section 125 and 154 of MCAA, fishing activities occurring or those which have the potential to occur within the site are compatible with the conservation objectives of the MCZ.

The screening of commercial fishing activities in Bembridge MCZ was undertaken using broad gear type categories. Sightings data collected by the Southern IFCA, together with officers' knowledge, was used to ascertain whether each activity occurs within the site, or has the potential to occur/is anticipated to occur in the foreseeable future. For these occurring/potentially occurring activities, an assessment of pressures upon MCZ designated features was undertaken using Natural England's Advice on Operations for West of Walney MCZ, which contains the feature sea pens and burrowing megafauna, and using Natural England's Advice on Operations for The Needles MCZ, which contains the feature subtidal mud.

Activities were screened out for further part B assessment if they satisfied one or more of the following criteria:

1. The activity does not occur within the site, does not have the potential to occur and/or is not anticipated to occur in the foreseeable future.

2. The activity does occur but the pressure(s) does not significantly affect/ interact with the designated feature(s).

3. The activity does occur but the designated feature(s) is not sensitive to the pressure(s) exerted by the activity.

3.2.1 Screening of commercial fishing activities based on occurrence

Initial screening was undertaken to identify the commercial fishing activities which currently occur within the site, together with those which have the potential to occur or/and are reasonably foreseen to occur in the future (Annex 3). To maintain consistency with Southern IFCA's assessment of commercial fishing activities in European Marine Sites, the individual gear types identified in Defra's matrix were assessed and these were grouped into broad gear types.

3.2.2 Screening of commercial fishing activities based on pressure-feature interaction

Fishing activities which were identified as occurring, have the potential to occur and/or are anticipated to occur in the foreseeable future within the site were screened with respect to the potential pressures which they may be exert upon designated features (Part A assessment). This screening exercise was undertaken using Natural England's Advice on Operations for The Needles MCZ and West of Walney MCZ (Annex 4,5,6 & 7). Supplementary Advice on Conservation Objectives was also used from these sites. The Advice on Operations provides a broad scale assessment of the sensitivity of designated features to different activity-derived pressures, using nationally available evidence on their resilience (an ability to recover) and resistance (the level of tolerance) to physical, chemical and biological pressures (Annex 4,5,6 & 7). The assessments of sensitivity to these pressures are measured against a benchmark. It should be noted that these benchmarks are representative of the likely intensity of a pressure caused by typical activities, and do not represent a threshold of an 'acceptable' intensity of a pressure. It is therefore necessary to consider how the level of fishing intensity observed within Bembridge MCZ compares with these benchmarks when screening individual activities.

Due to the broad-scale nature of the sensitivity assessments provided in Natural England's Advice on operations, each pressure is assigned a risk profile based upon the likelihood of the pressure occurring and the magnitude of the impact should that pressure occur. These risk profiles have been used, together with site-specific knowledge, to identify those pressures which could significantly affect designated features.

As Bembridge MCZ is a new site Natural England has not yet produced a site-specific Conservation Advice Package. However, Conservation advice packages, containing Advice on Operations and Supplementary Advice on Conservation Objectives for the relevant features is available in other MCZ Conservation Advice

Packages. This applies to sea pens and burrowing megafauna, which is a feature of the West of Walney MCZ, and Subtidal Mud which is a feature of The Needles MCZ. As the Advice on Operations in these packages is generic and not site specific these can be used to provide the sensitivity of the feature to the pressure. Similarly, in the Supplementary Advice on Operations the attributes and targets (not including the specification of maintain or recover) are also generic for these features, and can be used as the framework for assessing whether the activity will hinder the sites ability to meet its conservation objectives.

Table 2. Summary of fishing pressure-feature screening for Sea pens and burrowing megafauna and demersal trawls and dredges. Please not only pressures screened in for the Part B assessment are presented here.

Potential Pressures	Advice on Operations Gear Type (West of Walney MCZ)	Considered in Part B Assessment?	Justification	Relevant Attributes (effected by identified pressures)
Abrasion/disturbance of the substrate on the surface of the seabed	S	Y	This gear type is known to cause abrasion and disturbance to the seabed surface. Further investigation is needed on the magnitude of the pressure including spatial scale/intensity of the activity and location of the activity in relation to the feature.	Extent and distribution. Structure: sediment composition and distribution
Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion	S	Y	This gear type is known to cause penetration and disturbance to the seabed surface. Further investigation is needed on the magnitude of the pressure including spatial scale/intensity of the activity and location of the activity in relation to the feature.	Extent and distribution. Structure: sediment composition and distribution
Removal of non-target species	S	Y	Impacts on the feature and associated community may occur through the removal of the feature itself, larger epifaunal and potentially Infaunal species, whilst smaller organisms are likely to pass through the gear. Abrasion, resulting from contact with the gear, however is likely to disturb smaller species. There is no site-specific information on the communities associated with this feature as it is newly designated. General information on the designated features from the MCZ features catalogue. These communities include animals such as slender and tall sea pens, burrowing fireworks anemone as well as many large and small polychaetes. Further investigation is needed as to the magnitude of disturbance to associated communities/species and location of the activity in relation to the feature.	Distribution: presence and spatial distribution of biological communities. Structure and function: presence and abundance of key structural and influential species. Structure: species composition of component communities

Table 3. Summary of fishing pressure-feature screening for Subtidal Mud and demersal trawls and dredges. Please not only pressures screened in for the Part B assessment are presented here.

Potential pressures	Advice on operations	Considered in Part B Assessment	Justification	Relevant Attributes (effected by identified pressures)
Abrasion/disturbance of the substrate on the surface of the seabed	S	Y	This gear type is known to cause abrasion and disturbance to the seabed surface. Further investigation is needed on the magnitude of the pressure including spatial scale/intensity of the activity and location of the activity in relation to the feature.	Extent and distribution, Structure: Sediment composition and distribution, Structure and function: presence and abundance of key structural and influential species

Changes in suspended solids (water clarity)	S	Y	This gear type is known to cause the resuspension of finer sediments. Therefore, further assessment is required.	Supporting processes: water quality - turbidity
Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion	S	Y	This gear type is known to cause penetration and disturbance to the seabed surface. Further investigation is needed on the magnitude of the pressure including spatial scale/intensity of the activity and location of the activity in relation to the feature.	Extent and distribution, Structure: Sediment composition and distribution, Structure and function: presence and abundance of key structural and influential species
Removal of non-target species	S	Y	Dredging in the site targets scallops (Pecten maximus). Further, investigation is needed as to the magnitude of disturbance to associated communities/species and location of the activity in relation to the feature.	Distribution: presence and spatial distribution of biological communities, Structure: species composition of component communities
Removal of target species	S	Y	Dredging in the site targets scallops (Pecten maximus). Further, investigation is needed as to the magnitude of disturbance to associated communities/species and location of the activity in relation to the feature.	Distribution: presence and spatial distribution of biological communities
Smothering and siltation rate changes (Light)	S	Y	This gear type is known to cause the resuspension of finer sediments. Therefore, further assessment is required.	Supporting processes: water quality - turbidity

4 Part B Assessment

The aim of the part B assessment is for the IFCA to ensure that that there is no significant risk of a fishing activity hindering the conservation objectives of the MCZ; and to confirm that the authority is able to exercise its functions to further the site's conservation objectives.

In order to adequately assess the potential impacts of an activity upon a designated feature, it is necessary to consider the relevant attributes of that feature that may be affected. Attributes are provided in Natural England's Supplementary Advice on Conservation Objectives (SACOs) and represent the ecological characteristics or requirements of the designated species and habitats within a site. These attributes are considered to be those which best describe the site's ecological integrity and which if safeguarded will enable achievement of the Conservation Objectives. Each attribute has an associated target which identifies the desired state to be achieved; and is either quantified or qualified depending on the available evidence. No Supplementary Advice is currently available for Bembridge MCZ, therefore after relevant pressures were identified from the pressure-feature interaction screening (part A assessment), suitable attributes were identified from existing Natural England's Supplementary Advice packages for the West of Walney MCZ and The Needles MCZ. These are outlined in Table 2 & 3.

4.1 Assessment of trawling & dredging in the Bembridge MCZ

4.1.1 Summary of the Fishery

Trawling can take place all year round in the area surrounding the Bembridge MCZ. The level of activity is however very low with approximately 3 vessels taking part in the fishery, working predominantly in the east of the Solent, from Cowes to Bembridge. Inside the site however, the level of activity is very low, with no sightings in the site in the past three years. The activity does not target a specific species. The species caught is dependent on the time of year and catches can include common sole (*Solea solea*) and European plaice (*Pleuronectes platessa*), with a bycatch of bass.

Scallop dredging occurs in the area surrounding the Bembridge MCZ each autumn/winter. The activity targets the king scallop (*Pecten maximus*), a fishery which usually lasts one month.

4.1.2 Technical gear specifications

4.1.2.1 Light Otter Trawl

An otter trawl comprises of following design (see Figure 1). Two shaped panels of netting are laced together at each side to form an elongated funnel shaped bag (Seafish, 2015). The funnel tapers down to a cod-end where fish are collected (Seafish, 2015). The remaining cut edges of the net and net mouth are strengthened by lacing them to ropes to form 'wings' that are used to drive fish into the net (Seafish, 2015). The upper edge of the rope is referred to as the head line, the lower edge is referred to as the foot rope of fishing line and side ropes are known as wing lines (Seafish, 2015). Floats are attached to the headline to hold the net open and the foot rope is weighted to maintain contact with the seabed and prevent damage to the net (Seafish, 2015). The wings of the net are held open by a pair of trawl doors, also known as otter boards, and are attached to the wings by wires, ropes or chains known as bridles and sweeps (Seafish, 2015). The sweep connects the trawl door to top and bottom bridles which are attached to the headline and footrope of the net, respectively (Seafish, 2015). The choice of material used for the sweeps and bridles depends on the size of gear and nature of the seabed, with smaller inshore boats using thin wire and combination rope (Seafish, 2015). The trawl doors, which are made of wood or steel are towed through the water at an angle which causes them to spread apart and open the net in a horizontal direction (Seafish, 2015). The trawl doors are attached to the fishing vessel using wires referred to as trawl warps (Seafish, 2015). The trawl doors must be heavy enough to keep the net on the seabed as it is towed (Seafish, 2015). As the trawl doors are towed along the seabed they generate a sediment cloud which helps to herd fish towards the mouth of the trawl (Seafish, 2015). The bridles and sweeps continue the herding action of the trawl doors as the trail on the seabed and disturb the sediment, creating a sediment cloud (Seafish, 2015). The length of the sweeps and bridles and distance between the two trawl doors is tuned to the target species (Seafish, 2015). Species such as lemon sole and plaice can be herded into the trawl over long distances and so the length of the sweeps is longer (Seafish, 2015).

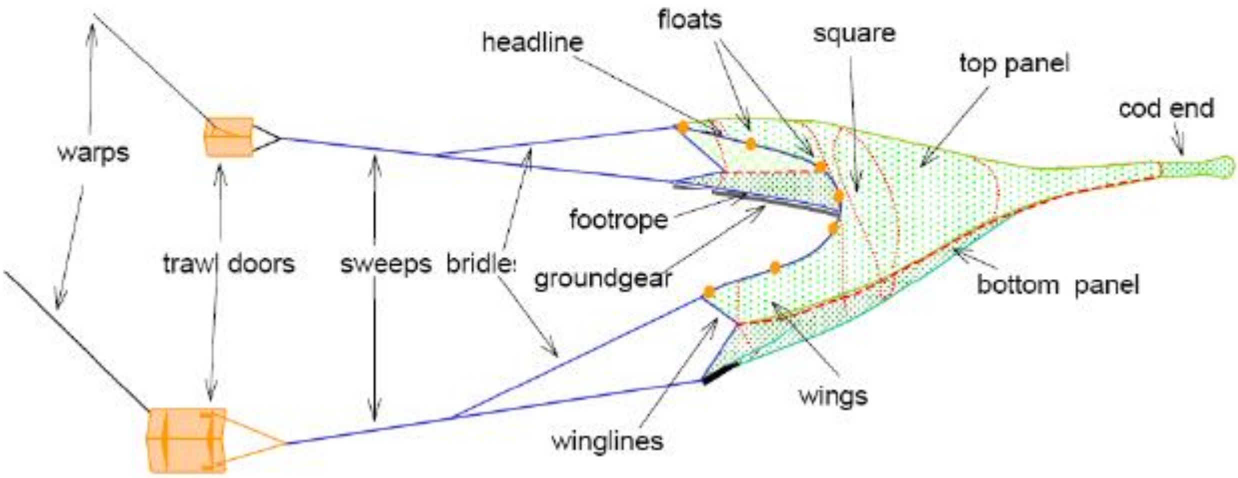


Figure 1. Key components of an otter trawl. Source: www.seafish.org/upload/b2b/file/r_d/BOTTOM%20TRAWL_5a.pdf

The mesh size of the net used varies depending on the type of trawl (Seafish, 2015). In the UK, there has been a move towards an increase in mesh size, particularly in the top panel and wings, in order to improve gear selectivity (Seafish, 2015).

The ground rope will have some form of ground gear attached to protect the netting from damage on the seabed (Seafish, 2015). The ground gear can largely vary. The most basic is where bare fishing line and the netting is laced directly to the rope of combination rope (Seafish, 2015). Chains may also be used and the style of attachment can vary (Seafish, 2015). Ground gear may also include bobbins and rock hoppers which commonly use small and large rubber discs (up to 600 mm) (Seafish, 2015).

The drag of the gear, combined with the floats on the headline, mean the weight of the trawl on the seabed is in the region of 10 to 20% of what it would be in air (Seafish, 2015).

A light otter trawl is one that uses anything less than the definition given for a heavy otter trawl, which include any of the following (MMO, 2014):

- Sheet netting of greater than 4 mm twine thickness
- Rockhoppers or discs of 200 mm or above in diameter
- A chain for the foot/ground line (instead of wire)

Generally, vessels will shoot and haul their gear over the stern of the boat (Seafish, 2015). Restrictions on vessels over 12 metres in length in the Southern IFCA district limits the size of gear that can be used within the district.

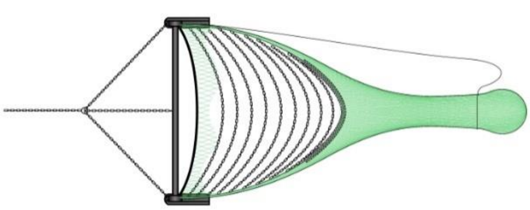
There is no typical gear set up used in the Solent and each individual has a different approach (Southern IFCA Committee Member Pers. Comm)[7]. The size and weight of trawl doors used in the Solent varies, however the largest doors likely to be used in the Solent are made of steel and measure approximately 52 x 38 inches, weighing 130 kg each (Southern IFCA Committee Member Pers. Comm). The ground rope used by the vessels ranges between 36 to 60 ft in length and commonly made of 16 mm wire with rubber discs of 4 to 6 inches, spaced 1 inch apart (Southern IFCA Committee Member Pers. Comm). The rubber discs are designed to maintain consistent contact with the seabed. Additional buoyancy may be attached to the ground rope to minimise contact with the seabed (Southern IFCA Committee Member Pers. Comm)**.** The length of the sweeps and bridles is approximately 90 ft (Southern IFCA Committee Member Pers. Comm). Trawls are towed at between 1 and 3.5 knots, depending on the state of the tide. In the Solent, the tow length is dependent on the level of weed and in some areas takes no longer than 10 minutes (Southern IFCA Committee Member Pers. Comm).

4.1.2.2 Beam trawl

A net is held open by a rigid framework to maintain trawl opening, regardless of towing speed, in addition to supporting the net (Seafish, 2015). The framework consists of a heavy tubular steel beam which is supported by steel beam heads at each end. Each beam head has wide shoes at the base which slide over the seabed (Seafish, 2015). A cone shaped net is towed from the framework, with the head rope attached to the beam and foot rope connected to the base of the shoes (Seafish, 2015). The footrope forms a ‘U’ shape curve behind the beam as it is towed over the seabed (Seafish, 2015). The beam is towed using a chain bridle which is attached to both shoes and at the centre of the beam; all coming together to form a single trawl warp which leads to the vessel (Seafish, 2015).

There are two types of beam trawl and these are referred to as ‘open gear’ and ‘chain mat gear’ (Seafish, 2015). Open gear uses a lighter rig, with a number of chains, known as ‘ticklers’, which are towed along the seabed across the mouth of the net (Figure 2) (Seafish, 2015). Tickler chains help to disturb fish from a muddy seabed. Open gear is used on clean and soft ground. Chain mat gear on the other hand is used for towing over harder and stonier seabed and if often used by larger vessels (Seafish, 2015). The chain mat gear uses a lattice work of chains which are towed from the back of the beam and attach to the footrope of the net (Figure 3) (Seafish, 2015). Lighter styles of beam, using fewer tickler chains and without a chain mat, are used to target shrimp (Seafish, 2015).

[7] Information was provided by a Southern IFCA Committee Member who has valuable knowledge and experience of the fishery.



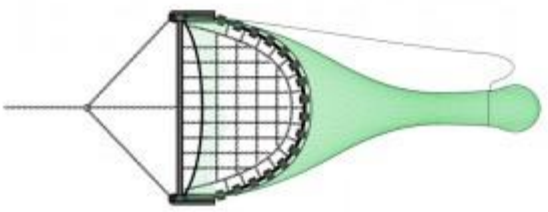


Figure 2. 'Open gear' beam trawl. **Figure 3. 'Chain mat gear' beam trawl.**

Generally, vessels below 12 metres, like those used in the Southern IFCA district, tow one trawl from the stern of the vessel (Seafish, 2015). The size of the beam towed, and the horsepower of many vessels, can be restricted by the local fishery regulations (Seafish, 2015). The sizes of trawls typically used in the Solent are approximately 3 m in width and weigh 650 kg with a chain matrix. These are not currently used within or on the fringes of the Bembridge MCZ.

4.1.2.3 Scallop dredges

Scallop dredges are rigid structures of the following design (see Figure 1). A triangular frame, with a width of up 85 cm in the Southern IFCA district, is attached to a collection bag and chain mesh which sits behind it. The triangular frame is fitted with a toothed bar at the front to dislodge scallops from the seabed and into the collection bag. In the Southern IFCA district, the dredge must be fitted with a spring-loaded tooth bar. The teeth on the bar are approximately 120 mm long; with 20 mm penetrating the seabed (depending on the substrate). The collection bag sits on top on the chain mesh. A number of dredges are attached to and towed behind a spreading bar with a bar usually deployed from each side of the vessel. The length of the bar and number of dredges depends on the size and power of the vessel. In Southern IFCA, the maximum number of dredges which may be towed at any time is twelve. However, the Solent Scallop fishers are typically under 10m, lower horse power vessels, and tow a maximum of 2 dredges of the stern of the vessel, usually one at a time.

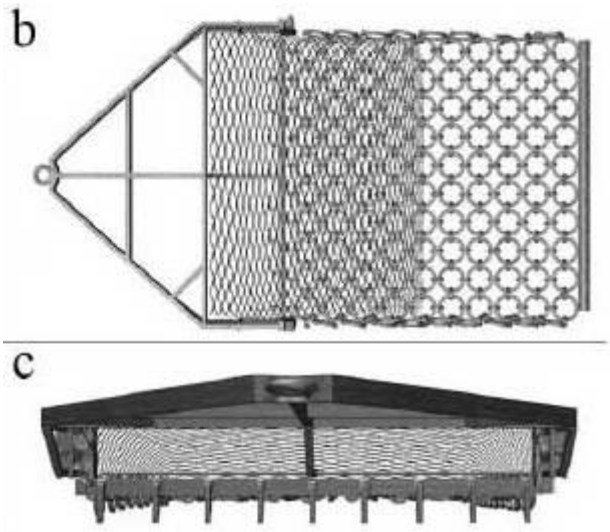


Figure 4.Typical scallop dredge set up used in the UK. (b) Chain mesh and collection bag (top side). (c) Spring-loaded toothed bar. Source: http://www.gov.scot/Publications/2012/10/7781/4

4.1.3 Location Effort and Scale of Fishing activities

Light otter trawling takes place subtidally and occurs frequently (weekly) in the area north of the site. The number of vessels engaged in the activity is approximately up to 6. These vessels operate out of

Southampton Water, Cowes and Portsmouth. However, at any one time there are approximately only 1-2 actively participating in the activity, when weather allows, and other species/gear types are not favoured in that period.

Based on the information described above; trawling occurs mainly outside of the site. Therefore, at worst trawling occurs in the site once per week in the MCZ. Hall *et al.* (2008) assessed the sensitivity of marine habitats and species to fishing activities. According to their fishing intensity categories[8] the fishing level in the Bembridge MCZ would be classed at worst as moderate (1 to 2 times a week in 2.5 nm x 2.5 nm) but would most likely be described as light (between 1-2 times a month during a season in 2.5nm x 2.5nm).

Sightings data displayed in Annex 8 illustrates trawling sightings since 2008. No trawling activity has been sighted in the site over the past 11 years. However, there have been multiple sightings of trawling activity surrounding the site in the past three years.

Scallop dredging takes place subtidally and is focused over areas of coarse and mixed sediments in the area off of the North East coast of the Isle of Wight. There is potential for up to 5 vessels to take part in the fishery, however a maximum of 1-2 are seen near or within MCZ at any one time. The activity usually occurs in the Autumn/Winter with the fishery usually lasting around one month.

Based on the information described above; scallop dredging occurs mainly outside of the site. Therefore, at worst scallop dredging could occur once per week in the site, although it is much more likely to occur around once per month over the scallop season. Hall *et al.* (2008) assessed the sensitivity of marine habitats and species to fishing activities. According to their fishing intensity categories the fishing level in the MCZ would be classed as Light (between 1-2 times a month during a season in 2.5nm x 2.5nm) and at worst moderate (1 to 2 times a week in 2.5 nm x 2.5 nm).

Sightings data (Annex 8) for dredging between 2008 and 2016 show that the activity has historically taken place within the north east area of the Bembridge MCZ, which is not protected by the Bottom Towed Gear Fishing Byelaw, in the small area of mixed sediments between Seaview and Bembridge Harbour. In the past three years no sightings of scallop dredging in the MCZ have been made. One sighting however lies along the most northern boundary of the site. The greatest number of sightings occur further into the East Solent, and further offshore outside of the Bembridge MCZ.

Please note that Southern IFCA's sightings data may reflect home ports of patrol vessels, high risk areas and typical patrol routes and therefore are only indicative of fishing activity. Over the ten-year period covered by sightings data (2005-2015), it is likely that the geographical extent of the fishery is well reflected, however intensity may be skewed by aforementioned factors.

4.2 Co-location of fishing activity and features under assessment

Maps of the broad scale habitat data for the site overlaid with fishing sightings data are available in Annex 8. This shows that trawling has not occurred within the site, over the past eleven years.

In the past 11 years scallop dredging has occurred within the site over the mixed sediments in the most north east corner, although no recent sightings of the activity have been made inside the site. Along the northern most boundary one recent sighting of this activity has been made, over what can be assumed to be mixed sediments.

Both trawling and scallop dredging activities are known to occur outside of but in close proximity to the northern section of the site directly opposite Bembridge Harbour.

4.3 Sea pens and burrowing megafauna

No information is available on the specific biotopes and communities found in the Bembridge MCZ. The sea pens and burrowing megafauna feature is recorded as a single record. However, information on sensitivity and recovery is available on two potential biotopes reported on in the Marine Life Information Network (MARLIN). These biotopes are known to support a rich infauna of polychaetes, bivalves, burrowing sea

[8] Heavy – Daily in 2.5 nm x 2.5 nm, Moderate – 1 to 2 times a week in 2.5 nm x 2.5 nm, Light – 1 to 2 times a month during a season in 2.5 nm x 2.5 nm, Single pass – Single pass of fishing activity in a year overall

urchins, brittle stars and sea cucumbers, as well as mobile epifauna such as crabs and starfish. However, the characterising species or groups of each varies slightly. ‘Sea pens and burrowing megafauna in circalittoral fine mud’ are characterised by the presence of the tall sea pen (*Funiculina quadrangularis),* whilst ‘Burrowing megafauna and *Maxmuelleria lankesteri* in circalittoral mud’ is characterised by the presence of burrowing mud shrimps (*Calocaris macandreae and Callianassa subterranean*), the Norway Lobster (*Nephrops norvegicus)*, and the volcano worm (*M. lankesteri).*

Very little research has been carried out on the sensitivity of these species to fishing activities. However, the research that does exist suggests that the due to the long lived nature (9-15 years, up to 44 years depending on species), slow growth and sporadic and patchy larval recruitment of the sea pen species, activities which lead to removal or mortality of sea pens within a population will lead to slow recovery and therefore low resilience.

For those species which can withdraw into their burrow within around 30 seconds (including the Slender sea pen) the dragging of creels over the feature did not uproot the species (Hoare & Wilson 1977; Eno et al., 2001; Ambroso et al. 2013). Whilst the phosphorescent sea pen and the tall sea pen, recovered within 144 hours from smothering with creels for 24 hours (Kinner et al. 1996; Eno et al 2001).

However, it was thought that these studies did not represent the true impact of trawling damage and underestimated the mechanical force of bottom towed gear. In the sea whip in Alaska, trawl damage was simulated, by abrading the whips with rubber disks, dislodging them from the sediment and breaking their axial rods. After 372 days 92% of the dislodged and 100% of the fractured specimens had substantial tissue loss and had died (Malecha & Stone, 2009).

For other species associated with these biotopes including the Norway lobster, mud shrimps and volcano worm again very little is known about their sensitivity to fishing activity impacts. *M. lankesteri and C. macandreae* are reported to be a long-lived species, with low recruitment rates (Hughes 1998; Buchanan, 1963). Similarly, the Norway Lobster whilst showing sexual maturity from 2.5 years, may live to be 15 years old, and adults do not move or migrate more that 100m from their burrows limiting potential recruitment from other populations (Chapman & Rice, 1971; Marine instituted, 2001). However, evidence from N. norvegicus fishing grounds suggests they can recover from targeted fishing activity (Vergnon & Blanchard, 2006; OSPAR, 2010; Ungfors et al. 2013).

4.4 Pressures

4.4.1 Abrasion/disturbance of the substrate on the surface of the seabed/ Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion

Abrasion and disturbance is generally related to the direct and physical effects of bottom towed fishing gear. Such effects include the scraping and ploughing of the substrate, scouring and flattening of the seabed, sediment resuspension and changes in the vertical redistribution of sediment layers (Roberts *et al*. 2010). The environmental impacts of bottom towed fishing gear are complex (Boulcott *et al*., 2014). The extent of disturbance depends on a number of factors including substrate type (Kaiser *et al*., 2002), design and weight of the gear (Boulcott & Howell, 2011) performance of the gear over a particular substrate (Caddy, 1973; Currie and Parry, 1999) and the sensitivity of the benthic community (Currie and Parry, 1996; Bergman *et al*., 1998; Collie *et al*., 2000a; Boulcott *et al*., 2014).

Scallop Dredging

Scallop dredging is considered to be one of the most destructive forms of bottom towed fishing (Kaiser *et al*., 2006; Hinz *et al*., 2011). A meta-analysis of 101 different fishing impact manipulation concluded that the most severe impact was caused by scallop dredging in biogenic habitats (those constructed or composed of primarily living biota) (Kaiser *et al*., 2006). The main effects of scallop dredging largely relate to the direct physical passage of gear over the seabed (Kaiser, Unpublished). Impacts include physical damage to soft rocky outcrops, soft or fragile and long-lived species are killed or damaged, removal of erect faunal species and large sessile species, reduction in biodiversity and a reduction in structural complexity and subsequent habitat homogenisation (Sewell & Hiscock, 2005).

The tooth bar on the gear is designed to penetrate into the seabed as the target species, *Pecten maximus*, will generally bury in the seabed so that their shell is level with the sediment surface (Kaiser, Unpublished). The teeth can penetrate up to 12 cm of the seabed (Kaiser, Unpublished). The dredge and penetration of the teeth lead to flattening of the seabed, visible teeth marks and mixing of the sediments (Boulcott et al., 2014). Rocky-reef habitats can also present a considerable risk to dredging gear, with the gear known to come fast (Boulcott and Howell, 2011).

Otter trawl

Otter trawl fishing gear has contact with the seabed through the ground rope, chains and bobbins, sweeps, doors and any chaffing mats or parts of the net bag (Jones, 1992). Otter boards, or doors, leave distinct tracks on the seafloor ploughing distinct groove or furrows, which can be 0.2-2 metres wide and up to 30 centimetres deep (Jones, 1992; Thrush & Dayton, 2002). The depth of furrows depends on the weight of the board, the angle of attack, towing speed, and the nature of the substrate, being greatest in soft mud (Jones, 1992; Løkkeborg, 2005). The passage of the doors also creates sediment mounds known as berms (Gilkinson *et al*. 1998; Johnson *et al*. 2002). Marks on the seabed caused by other parts of the gear are faint when compared with those caused by trawl doors (Løkkeborg *et al*. 2005). Ground ropes and weights can scour and flatten the seabed, skimming the surface sediment between the grooves left by the trawl doors (Jones, 1992; Roberts *et al*. 2010; Grieve *et al*., 2014). Spherical footrope bobbins can cause compressed tracks on surficial sediments (Brylinsky *et al*. 1994). In areas of surface roughness i.e. sand waves and ripples, features can be flattened and the habitat smoothed (Kaiser & Spencer, 1996; Tuck *et al*., 1998; Schwinghamer *et al*., 1996; 1998). It has been reported that the bridles do not appear to result in any marks on the seabed (Brylinsky *et al*. 1994).

Experimental flounder trawling, using an 18 m trawl with 200 kg doors and footrope with 29 cm rubber rollers, in the Bay of Fundy revealed that trawl doors made furrows that were 30 – 85 cm wide and up to 5 cm deep in an intertidal area characterised by silty sediments (Brylinsky *et al*. 1994). The same study reported an area of approximately 12% between the outer edges of the doors was visually disturbed (Brylinsky *et al*. 1994). A side-scan survey, used to assess the effects of otter trawl over sand and mud sediments in lower Narragansett Bay, revealed 5 to 10 cm deep tracks from otter trawl doors and 10 to 20 cm high berms in mud bottom channels (DeAlteris *et al*., 1999). No information on the type of gear used was provided in the study. Sediment profile images (SPIs) were used to estimate the physical impacts of experimental trawling using a shrimp otter trawl with a head rope length of 10 m, otter boards measuring 90 x 140 cm and weighing 125 kg each and ground rope of 14 m with 20 kg of lead weight distributed across its length in an area of muddy sediments in the Gullmarfjord (Nilsson & Rosenberg, 2003). Forty-three percentage of the images in trawl area had signs of physical disturbance (Nilsson & Rosenberg, 2003). A crude estimate of the scale of disturbance was made from the images, with an estimated depth of the trawl tracks at approximately 10 cm, and width between 30 and 60 cm (Nilsson & Rosenberg, 2003). It was calculated that one-tenth of the area affected by trawling would be directly affected by ploughing from the otter boards themselves (Nilsson & Rosenberg, 2003).

Beam trawl

The gear used by beam trawl is known to penetrate the seabed, leaving tracks and disturbing the surface sediments (Gubbay & Knapman, 1999). Beam trawls flatten seabed features and can also leave trenches in soft sediment (Tuck *et al*., 1998). It is important to point out however that generally speaking beam trawling does not occur in mud habitats as it cannot be used effectively in such habitat types (Kaiser *et al*. 2002). Studies have revealed that the penetration depth of tickler chains on a beam trawl range from a few centimetres to at least 8 cm (Løkkeborg, 2005).

Sediment character (general)

Towed demersal fishing gear has been shown to alter sedimentary characteristics and structure, particularly in subtidal muddy sand and mud habitats, as a result of penetration into the sediment (Jones, 1992; Gubbay & Knapman, 1999; Ball *et al*. 2000; Roberts *et al*. 2010). Surface organic material can be mixed into subsurface layers, changing the vertical distribution of sediment layers (Mayer *et al*., 1991; Jones, 1992).

Sediment structure may change through the resuspension of sediment, nutrients and contaminants and relocation of stones and boulders (ICES, 1992; Gubbay & Knapman, 1999). Trawling can increase the fraction of fine sediment on superficial layers of the seabed (Queirós *et al*. 2006). As fine material is suspended, it can be washed away from the surface layers (Gubbay & Knapman, 1999). Trimmer *et al*. (2005) reported significant correlations between fishing intensity and sediment silt content (Queirós *et al*. 2006). It is thought that continual sediment resuspension, as a result of trawling, can lead to the accumulation of fine sediments in the superficial layers of sediment in areas that are trawled if there is an absence of significant advective transport (Jennings & Kaiser, 1998; Trimmer *et al*. 2005). Changes in sediment structure from coarse-grained sand or gravel to fine sand and coarse silt has been reported to occur within beam trawl tracks (Leth & Kuijpers, 1996).

Johnson *et al*. (2002) found a number of studies on the effects of otter trawling in gravel and variable habitats and these revealed trawling physically removed fine sediments and biogenic structures through the removal of structure-forming epifauna, moved or overturned stones and boulders, smoothed the seafloor and exposed sediment/shell fragments (Bridger, 1972; Auster *et al*., 1996; Collie *et al*., 1997; Engel & Kvitek, 1998; Freese *et al*., 1999; Johnson *et al*., 2002; Sewell and Hiscock, 2005).

In Estero Bay of the Californian coast, grain size analyses were used to detect any changes in sediment grain size as a result of experimental trawling using a small footrope otter trawl (61 ft head rope, 60 ft ground rope, 8 inch and 4 inch discs, 3.5 ft x 4.5 700 lbs ft trawl doors) (Lindholm *et al*., 2013). The study plots were located at a depth of 160-170 m and sediment analyses revealed the nature of the sediment to be coarse silt/fine sand (Lindholm *et al*. 2013). Post-trawl samples displayed the same grain size distribution as pre-trawl samples, albeit with a slight increase in silt content and 2% decrease in the fine sand fraction (Lindholm *et al*. 2013). Despite these differences, average mean grain size per plot indicated no visible differences between pre- and post- trawl samples and no quantifiable significant sedimentary differences were observed between trawled and control pots or between sample periods (Lindholm *et al*. 2013). These results are supported by a number of other studies including Tuck *et al*. (1998) and Schwinghamer *et al*. (1998), both of which reported no significant differences in sediment grain size in relation to trawling disturbance. Tuck *et al*. (1998) investigated the physical effects of trawling disturbance on a sheltered sealoch in Scotland at 35-40 m depth in an area characterised by 95% silt and clay using modified rockhopper ground gear without a net. Unfortunately, further details on the gear are not available. Schwinghamer *et al*. (1998) examined physical impacts of experimental otter trawling in the Grand Banks in an area of sandy habitat at 120-146 m depth using an Engel 145 otter trawl with 1250 kg oval otter boards and 46 cm rock hopper gear. Despite reporting no change in sediment grain size, acoustic data did reveal that trawling changed small-scale biogenic sediment structures (such as tubes and burrows) down to 4.5 cm (Schwinghamer *et al*. 1998), indicating a reduction in habitat complexity (Løkkeborg, 2005).

4.4.2 Smothering and siltation rate changes; Changes in suspended solids

The resuspension of sediment can impact upon benthic communities through smothering, burial and increased turbidity. These effects may extend to organisms living a distance away from the fished area (Kyte & Chew, 1975). If high levels of sediment are resuspended and exposure to such events is regular, impacts may be severe (Mercaldo-Allen & Goldberg, 2011). Increased turbidity can inhibit respiratory and feeding functions of benthic organisms, in addition to causing hypoxia or anoxia (Morgan & Chuenpagdee, 2003). Sediment resuspension can jeopardise the survival of bivalves and fish as a result of clogged gills and inhibition of burrowing activity (Dorsey & Pederson, 1998). Small organisms and immobile species are particularly vulnerable to smothering (Manning, 1957). A redistribution of finer sediment can also hinder the settlement of organisms if shell or cultch material is buried (Tarnowski, 2006). The severity of such impacts are largely determined by sediment type, the level of sediment burden and the tolerance of organisms which is largely related to their biology (i.e. size, relationship to substrate, life history, mobility) (Coen, 1995).

4.4.3 Removal of non-target species

Bottom towed fishing gear can result in the mortality of non-target species through direct physical damage inflicted by the passage of the trawl or indirectly through damage, exposure and subsequent predation (Roberts *et al*. 2010). This can lead to long-term changes in the benthic community structure (Jones, 1992), including decreases in biomass, species richness, production, diversity, evenness (as a result of increased dominance) and alterations to species composition and community structure (Tuck *et al*., 1998; Roberts *et al*. 2010). Disturbance from repeated trawling selects for more tolerant species, with communities becoming dominated by smaller-bodied infaunal species with fast life histories, juvenile stages, mobile species and rapid colonists (Engel & Kvitek, 1998; Gubbay & Knapman, 1999; Kaiser *et al*. 2000; Jennings *et al*. 2001; Kaiser *et al*. 2002). In addition, larger individuals may become depleted more than smaller individuals (Jennings *et al*. 2002).

The impacts of fishing activities on benthic communities varies with gear type, habitat and between taxa (Collie *et al*. 2000; Thrush & Dayton, 2002; Kaiser *et al*. 2006). Reported effects are habitat-specific (Roberts *et al*. 2010). A meta-analysis conducted by Kaiser *et al*. (2006) revealed that soft-sediment, especially muddy sands were vulnerable to fishing impacts, with otter trawling and beam trawling all producing a significant immediate impact on this habitat. In mud communities, otter trawling was reported to have a significant negative short-term impact, but positive long-term effect with respect to the mean abundance of benthic taxa (Kaiser *et al*. 2006). A number of studies found no detectable impacts, specifically in relation to different forms of trawling in sand habitats (Van Dolah *et al*., 1991; Kaiser & Spencer, 1996; Kenchington *et al*., 2001; Roberts *et al*., 2010), although this is not true in all cases. Such habitats are likely to be pre-adapted to higher levels of natural disturbance and are characterised by relatively resistant fauna (Kaiser *et al*. 2006).

Scallop Dredging

In a meta-analysis, scallop dredging was reported to cause an immediate reduction in mean abundance of animals from -22% to 98%, with the greatest declines observed for sea-fans and sponges in biogenic habitats (Kaiser *et al*., 2006).

Typically scallop dredging occurs over gravel or mixed substrata, although can occur in areas of mud or harder seabed type which support populations of the target species (Shumway and Parsons, 2006; Hinz *et al*., 2011). On mixed-substrate, sites which are not scallop dredged have been found to have significantly higher faunal turf coverage (Boulcott et al., 2014).

The level of the effect is varied depending on the gear type used (Hinz et al., 2009). When the effects of an otter trawl (with rock hopper ground rope), traditional scallop dredges (0.76m wide with 17 x 6cm teeth), and new scallop dredges (1.95m wide with rubber lip instead of teeth) were compared bycatch was found to be significantly higher in the two dredges. Epifauna biomass was only significantly reduced after dredging using the new scallop dredges. However, changes in abundance and biomass of scavengers and vulnerable species between treatments showed no significant differences. Similarly, infauna biomass showed only significant differences after impact for the new dredge type.

Hinz *et al*. (2011) investigated the impacts scallop dredging in Lyme Bay SCI, a marine protected area, adjacent to the Chesil Beach and Stennis Ledges MCZ, where Pink sea-fans occur. The study compared areas subject to different fishing activity levels. These were arranged around 4 voluntary reserved closed to fishing and included 2 fixed treatments with 2 levels (1. Protection i.e. stations inside the reserves (Closed) and outside (Open); 2. Past Fishing Activity i.e. stations that had been fished prior to the implementation of the reserves (Fished) and stations that had experienced no prior dredging or at very low intensities (Not Fished). Fished sites were estimated to have been dredged on average 1.2 times per year. The study found sessile emergent epifauna occurred at significantly lower levels and abundances at fished sites compared to unfished sites, with a significant negative effect on 3 out of 9 species analysed. The abundance of ross coral *Pentapora fascialis* and dead men's fingers *Alcyonium digitatum, and presence of Axinella dissimilis* (erect sponge) were 73%, 67% and 54% lower in fished sites compared to non-fished sites, respectively.

Otter trawls

The impact of otter trawls on benthic communities varies between studies, notably between sediment types. In a meta-analysis of experimental fishing impact studies, conducted by Kaiser *et al*. (2006), otter trawling was found to have one of the least negative impacts, compared to other gear and substrata combinations. The initial impact on benthic communities from otter trawl disturbance on mud was estimated to be -29%, -15% on sand and +3% on gravel (Kaiser *et al*., 2006; Hinz *et al*., 2009).

Direct mortality of different megafaunal taxa groups varied after a single sweep with a commercial otter trawl (dimensions unknown) over shallow (30-40 m) sandy areas and deeper (40-50 m) silty sand areas in the southern North Sea (Bergman & van Santbrink, 2000). In areas of silty sand, direct mortality ranged from 0-52% for bivalves, 7% for gastropods, 0-26% for echinoderms, and 3-23% for crustaceans. In areas of sand, direct mortality ranged from 0-21% for bivalves, 12-16% for echinoderms and 19-30% for crustaceans. Experimental otter trawling (dimensions unknown) on the continental shelf of northwest Australia, in an area presumed to be sand, led to an exponential decline in the mean density of macrobenthos with increasing tow numbers (Moran & Stephenson, 2000; Johnson *et al*. 2002). Density was reduced by approximately 50% after four tows and 15% after a single tow (Moran & Stephenson, 2000; Johnson *et al*. 2002). A trawl with 20 cm disks, separated by 30 to 60 cm spacers was used (Johnson *et al*. 2002). No further information on the trawl used is known. The impacts of otter trawling on benthic communities on a sandy bottom in Grand Banks, Newfoundland were studied over a three-year period (Kenchington *et al*., 2001). Three experimental corridors with adjacent reference corridors were established and experimental corridors were trawled 12 times within 5 days for three years using an Engel 145 otter trawl with 1250 kg otter doors, 60 m door spread and 46 cm rockhopper foot gear. Changes in the benthic community were sampled using an epibenthic sledge. The sled is largely used to sample epifauna and some infauna as the sled penetrates to a depth of 2 to 3 cm. Samples collected using the benthic sled revealed a 24% reduction in average biomass in trawled corridors compared to reference corridors. This decrease was caused by reductions in biomass of sand dollars, brittle stars, soft corals, sea urchins and snow crabs. No significant effects were observed for mollusc species. The mean total abundance per grab sample was 25% lower immediately post trawling in one of the three years and declines were demonstrated for 13 taxa primarily made up of polychaetes, which also declined in biomass (Løkkeborg *et al*., 2005).

Valentine and Lough (1991) investigated the impact of scallop dredging and trawling on sand and gravel habitats using side scan sonar and a submersible on eastern Georges Bank. The study documented the most obvious signs of disturbance on gravel pavement habitats. Unfished gravel areas (as a result of the presence of large boulders) had more biologically diverse communities with an abundance of epifaunal organisms. In fished areas, the attached epifaunal community was limited. Similarly, Collie *et al*. (1997) investigated the effects of multiple methods of bottom towing fishing gear (otter trawl and scallop dredging) on benthic megafaunal communities in gravel habitat on Georges Bank at depths between 47 to 90 metres. No information on the types of otter trawls used were given. Numerical abundance of organisms, biomass and species diversity were all significantly greater at undisturbed sites, whilst evenness was greater at disturbed sites (Collie *et al*., 1997). Disturbed sites are likely to have greater evenness because disturbance of towed gear prevents one species becoming numerically dominant (Collie *et al*., 1997). Small fragile polychaetes, shrimps and brittle stars were absent or less common at disturbed sites. At undisturbed sites epifauna such as tube-dwelling polychaetes, bushy bryozoans and hydroids provide a complex habitat.

Engel and Kvitek (1998) documented differences between lightly (average of 220 trawl hours per year) and heavily (average of 816 trawl hours per year) otter trawled areas with similar bottom types (gravel, coarse sand, medium-fine sand and silt-clay) off central California. The densities and abundance of all invertebrate epifaunal species were higher in the lightly fished area when compared to the heavily fished area, including significant differences in species of sea pens, sea stars, sea anemones and sea slugs. Opportunistic species including oligochaetes, nematodes, ophiuroids were found in greater densities in the heavily fished area in each year of the study (1994-1996), whilst significantly more polychaete species were reported in lightly fished areas and no significant difference in the number of crustaceans between the two areas. The study concluded that high levels of trawling can lead to a decrease in habitat complexity and biodiversity and lead to subsequent increases in opportunistic species.

Thrush *et al*. (1998) assessed the importance of fishing pressure (by collecting samples along a fishing pressure gradient) in accounting for variation in community composition in an area characterised by varied sediment characteristics (from 1 to 48% mud) in Hauraki Gulf in New Zealand at depths between 17 to 35 metres. In this area, a major fin fishery for snapper (*Chrysophrys auratus*) exists. The typical trawl gear used consists of 480 kg doors, ground rope of 140-150 mm diameter rubber bobbins, steel balls, with a total ground rope mass of 240 kg (not including sweeps and bridles). After accounting for differences in environmental conditions, the study reported 15-20% of the variability in the macrofauna community composition was attributed to fishing. Observations following reduction in fishing pressures included increases in the density of echinoderms, long-lived surface-dwelling organisms, total number of species, individuals and species diversity. Decreased fishing pressure led to significant increases large epifaunal densities.

Experimental fishing manipulations investigating the impacts of otter trawling on muddy sediments report relatively modest changes in benthic communities in the short-term (Hinz *et al*., 2009). Tuck *et al*. (1998) investigated the biological effects of trawling disturbance on a sheltered sealoch in Scotland at 35-40 m depth in an area characterised by 95% silt and clay using modified rockhopper ground gear without a net. Unfortunately, further details on the gear are not available. Trawling was conducted one day per month for 16 months and biological surveys were completed after 5, 10 and 16 months of disturbance and then for a further 6, 12 and 18 months after trawling disturbance in trawled and untrawled control areas (Tuck *et al*., 1998; Johnson *et al*. 2002). The response of different community parameters (i.e. species diversity, abundance) to trawling disturbance varied. Infaunal community structure became significantly altered after 5 months of fishing and remained so throughout the duration of the experiment. No significant differences in infaunal species richness however were detected during the first 10 months of trawling. After 16 months of trawling disturbance, and throughout the recovery period, species richness was significantly higher in the trawled site. Infaunal abundance was greater in the trawled site prior to fishing and after 12 months of recovery, although not after 18 months of recovery. The abundance of certain species (predominantly polychaetes), increased within the trawled site and others (i.e. bivalves) declined. Species diversity was lower in the fished site throughout the whole period, including prior to fishing commencing and no effects on total biomass were reported. Experimental trawling, with a commercial otter trawl (dimensions unknown), over a muddy substrate at a depth of 30 to 40 m off the Catalan coast in Spain reported a similar percentage abundance of most major taxa between fished (polychaetes, 51.5%; crustaceans, 10.9%; molluscs, 34.7%; other taxa, 2.9%) and unfished (polychaetes, 48.9%; crustaceans, 11.3%; molluscs, 36.1%; other taxa, 3.7%) sites (Sanchez *et al*., 2000). Analysis of species richness and diversity indicated that the infaunal community did not alter during the first 102 hours following a single sweep. The number of individuals and taxa were significantly greater after 150 hours in an area subject to a single sweep, although no effect was detected after 72 hours in an area subject to a double sweep. For some taxa, significant differences in abundance were between fished and unfished areas including Chaetopteridae, a family of polychaete worms, and *Amphiura chiajes* whose abundances were greater in fished areas after a single sweep and Cirratulidae, another family of polychaete worms, whose abundance were greater in unfished areas after a double sweep. The authors speculated a decrease in the abundance of certain species in the unfished area may indicate the effects of natural variability at the site exceeds that of fishing disturbance.

The initial impacts of otter-trawl gear on muddy habitats are relatively modest, however cumulative long-term disturbance can lead to significant changes in benthic communities (Hinz *et al*., 2009). Hinz *et al*. (2009) investigated the biological consequences of long-term chronic disturbance caused by the otter trawl *Nephrops norvegicus* (Norway lobster) fishery along a gradient of fishing intensity over a muddy fishing ground in the northeastern Irish Sea. Trawling intensity and its spatial distribution was estimated using overflight data and log book records of hours spent fishing. The study reported reductions in infaunal abundance of 72% from the lowest trawling effort recorded (1.3 times trawled/year) to the highest (18.2 times trawled/year). Over the same range of trawl intensities, infaunal biomass was reduced by 77% and species richness decreased by 40%, whilst epifaunal abundance was reduced by 81% and epifaunal species richness decreased by 18%. It is worth noting that community descriptors were log transformed and therefore the reported reductions in abundance, biomass and species richness are greatest at low trawling intensities and less severe at higher trawling intensities. Hiddink *et al*. (2006a) conducted an assessment of large-scale impacts of a bottom trawl fishery on benthic production, biomass and species richness in the North Sea, using a size-based approach for assessing trawling impacts on benthic communities. Model development allowed for the effects of habitat parameters on the dynamics of benthic communities and to predict the effects of trawling on species richness. Data used to validate the model was collected from 33 sampling stations in four areas of soft sediment in the North Sea subject to different levels of trawling intensity. The model predicted that benthic community biomass was reduced by 56% and production by 21%. Queirós *et al*. (2006), analysed the biomass, production and size structure of two communities from a muddy sand and a sandy habitat with respect to quantified gradients of trawling disturbance on real fishing grounds in the

Dogger Bank (sandy) and Irish Sea (muddy sand). The Dogger Bank is mostly fished by beam trawlers targeting plaice and the Irish Sea is fished by otter trawls targeting Norway lobster. In the muddy sand habitat, chronic trawling was found to have a negative impact on biomass and production of benthic communities, whilst no impact was identified on benthic communities within the sandy habitat. The differences in result for each habitat type are caused by differences in size structure between the two communities that occur in response to an increase in trawling disturbance. Lindholm *et al*. (2013) reported similar results in an area of coarse silt/fine sand at 160-170 m depth with experimental trawling using a small footrope otter trawl (61 ft head rope, 60 ft ground rope, 8 inch and 4 inch discs, 3.5 ft x 4.5 700 lbs ft trawl doors) (Lindholm *et al*., 2013). The study reported no measurable effects of trawling on densities of invertebrates, including sessile and mobile epifauna and infauna. The study area was characterised by a high level of patchiness in both space and time with regards to invertebrate assemblage, particularly with respect to opportunistic species (polychaete worms and brittestars). Densities of sessile and mobile invertebrates were low in the study and varied considerably between plots and study periods, suggesting that the effects on trawling should be considered with background environmental variation in mind.

Beam trawls

Repeated experimental trawling (3 times) with a 7000 kg, 12 m beam trawl with tickler chains led to a significant 40-65 % decrease in the density of starfishes, small heart urchins, tube-dwelling polychaete worms and small crustaceans, although other species, namely worm and mollusc species, did not change and a number increased (Bergman *et al*. 1990; Bergman & Hup, 1992). The study was conducted in the North Sea in an area of medium hard sandy sediments at a depth of 30 m. Bergman and van Santbrink (2000) reported similar mortality levels of 5-40% in gastropods, starfish, crustaceans and annelid worms and a 20-65% mortality of bivalves using a 12 m and 4 m beam trawl with ticklers and a 4 m beam with chain matrix over shallow sandy areas and deep silty sand areas in the North Sea. Direct mortality in a number of infaunal species was higher in silty areas than in sandy areas (Bergman & van Santbrink, 2000). The 12 m beam trawl caused the highest annual fishing mortality (Bergman & van Santbrink, 2000). In an area of stable coarse sand and gravel, experimental trawling (10 to 12 passes) with a 3.5 tonne 4 m beam trawl with chain matrix led to a 54% reduction in the number of infaunal species and 40% reduction in individuals, a decrease in slow moving epifauna and an increase in mobile species (Kaiser & Spencer, 1996, Kaiser *et al*., 1996, 1998, 1999). At the scale and intensity of the study, no changes in densities were detected (Kaiser & Spencer, 1996, Kaiser *et al*., 1996, 1998, 1999). The same experimental treatment was applied to an area characterised by mobile sand ribbons and megaribbons, however no differences in the benthic community were detected (Kaiser & Spencer, 1996b, Kaiser *et al*., 1996b, 1998, 1999). A study on the impacts of chronic beam trawling in central regions of the North Sea reported significant decreases in infaunal biomass and production in a region of muddy sand sediment and depth of 55 to 75 m (Silver Pit) in response to trawling intensity (Jennings *et al*. 2001). The effects of trawling disturbance were not significant on epifauna and in another region, characterised by sand with a depth of 40-65 m (The Hills) and smaller range of trawling intensity, a relationship between infaunal biomass and production could not be established (Jennings *et al*., 2001). Another study, also based in the central North Sea, investigated the impacts of experimental beam trawling (using a 4 m beam trawl with a chain matrix) on meiofauna and reported that meiofauna are more resistant to trawling disturbance than macrofauna and have the potential to withstand chronic trawling impacts (Schratzberger *et al*. 2002).

Size of fauna

Many studies have observed a shift in benthic community structure from one dominated by relatively high biomass species to one dominated by a high abundance of small-sized organisms (Collie *et al*., 2000). The predicted change in shallow water communities, as a result of trawling disturbance, is an increase in r-strategists (i.e. polychaetes) and decrease K-strategist (i.e. molluscs and crustaceans) (Jones, 1992). A shift towards small-sized species has the potential to alter benthic productivity as body mass is negatively correlated with individual production to biomass ratio (Jennings *et al*., 2001; Queirós *et al*., 2006). Overall reductions in benthic productivity have been reported in areas where intense bottom trawling takes place (Jennings *et al*., 2001). Increases in the biomass or production of smaller infauna have been found to be small in relation to losses in overall community biomass and production that occurred as a result of the depletion of larger individuals (Jennings *et al*., 2001). Smaller bodied fauna are incapable of utilising resources that become available as larger fauna are removed from the community (Queirós *et al*., 2006). Under such conditions, resources may be redirected to other parts of the system (Queirós *et al*., 2006). In areas of natural disturbance, the dominance of smaller bodied fauna may be a general adaptation to such a dynamic environment and therefore the community may seem relatively unaffected by trawling (Queirós *et al*., 2006).

Populations of larger, longer-lived species are less resilient to fishing impacts than smaller, short-lived species as they are able to compensate for any increases in mortality (Roberts *et al*., 2010). In addition, lighter animals are often pushed aside by the pressure wave in front of the net (Gilkinson *et al*., 1998; Jennings *et al*., 2001). Larger fauna are mainly affected through direct physical contact with the gear and may be removed from the community (Bergman & van Santbrink, 2000; Queirós *et al*., 2006). Bergman and van Santbrink (2000) revealed a size-dependent trend for some species with respect to direct mortality from a 12 and 4 m beam trawl. In areas of silty sediments, individuals of the bivalve species *Chamelea gallina* above 2 cm were more vulnerable with mortalities ranging between 22-26%, compared to smaller specimens (4-7% mortality). The impact caused by contact with the fishing gear is not comparable to natural disturbance, and mortalities in more mobile and dynamic sediments will not necessarily be lower than in stable sediments (Bergman & van Santbrink, 2000). The impacts on densities of small individuals may however be greater if the larger animals in question live deeper in the sediment, in addition to their potentially more efficient escape possibilities (Bergman & Hup, 1992; Gubbay & Knapman, 1999).

Studies have shown that trawling impacts on meiofuna (animals that pass through a 500 µm mesh sieve but are retained in a 63 µm mesh sieve) are relatively limited (Brylinsky *et al*., 1994; Scratzberger *et al*., 2002). Brylinsky *et al*. (1994) reported reductions in the abundance of nematodes after experimental flounder trawling on the intertidal in the Bay of Fundy, although the rate of recovery was rapid following trawling disturbance. Scratzberger *et al*. (2002) reported no short- to medium- term (1-392 days after experimental trawling) impacts on diversity or biomass of meiofauna from experimental fishing with a 4 m beam trawl in muddy sand in the southern North Sea. Mild effects on community structure were reported at one location however these impacts were minor in relation to seasonal change. The authors suggested that meiofauna are more resistant to beam trawling than macrofauna and they have the potential to withstand the effects of chronic trawling. Their resistance to trawling is thought to be related to their small body size as they are resuspended rather than killed, combined with their short generation cycles which allow populations to withstand elevated mortality.

Faunal groups and species responses

The relative impact of bottom towed fishing gear on benthic organisms is species-specific and largely related to their biological characteristics and physical habitat. The vulnerability of an organism is ultimately related to whether or not it is infaunal or epifaunal, mobile or sessile and soft-bodied or hard-shelled (Mercaldo-Allen & Goldberg, 2011). Fragile fauna (i.e. bivalves and sea cucumbers) have been shown to be particularly vulnerable to trawling damage and disturbance and sedentary and slowing moving species can be significantly lower (Kaiser & Spencer, 1996; Gubbay & Knapman, 1999). Motile groups and infaunal bivalves have shown mixed responses to trawling disturbance, with life history considerations such as habitats requirements and feeding modes likely to play a key role in determining a species response (McConnaughey *et al*., 2000; Johnson *et al*., 2002). In a meta-analysis of experimental fishing impact studies, conducted by Kaiser *et al*. (2006), otter trawling was found to have the greatest impact on suspension feeders in mud habitats, perhaps reflecting the depth of penetration from the otter doors, whilst the response of suspension feeders and deposit feeders to beam trawling was highly variable. The most negative effect on deposit feeders was found in gravel habitats and the most negative effect on suspension feeders was found in sand habitats (Kaiser *et al*., 2006). Suspension feeding bivalves, such as *Corbula gibba*, are largely unable to escape burial of more than 5 cm (Maurer *et al*., 1982) and are also sensitive to high sedimentation rates that may occur following intensive trawling (Howell & Shelton, 1970; Tuck *et al*., 1998). Having said this, larger-sized individuals have been shown to be more resistant to trawling disturbance as they are relatively robust (Bergman & van Santbrink, 2000).

Studies have revealed mixed effects on epifauna (organisms that inhabit the seabed surface). Jennings *et al*., (2001) found that chronic trawling disturbance had no significant effect on epifauna in the North Sea. Similarly, no long term effects on the number of epifaunal species or individuals were detected by Tuck *et al*. (1998), although a number of species-specific changes in density did occur (increase in *Ophiura* sp. and decreases in *Hippoglossoides platessoides*, *Metridium senile* and *Buccinum undatum*). The lack of long term effects detected by Tuck *et al*. (1998) is likely to be compounded by the fact that beam trawl gear used was not equipped with a net, as greater effects on epifauna may be expected. The removal of 7 tonnes of epifaunal was reported by Pitcher *et al*. (2000) during experimental trawling, however no significant changes in the density of epifauna were reported (Thrush & Dayton, 2002). Kenchington *et al*. (2001) investigated the impacts of otter trawling on benthic communities on a sandy bottom in Grand Banks, Newfoundland over a three year period. Changes in the benthic community were sampled using an epibenthic sledge. The sled is largely used to sample epifauna and some infauna as the sled penetrates to a depth of 2 to 3 cm. Samples collected using the benthic sled revealed a 24% reduction in average biomass in trawled corridors compared to reference corridors. Hinz *et al*. (2009) investigated the biological consequences of long-term chronic disturbance caused by the otter trawl *Nephrops norvegicus* (Norway lobster) fishery along a gradient of fishing intensity over a muddy fishing ground in the northeastern Irish Sea. The study reported reductions in epifaunal abundance of 81% from the lowest trawling effort recorded (1.3 times trawled/year) to the highest (18.2 times trawled/year). Over the same range of trawl intensities, epifunal species richness decreased by 18%, while no effect was evident for epibenthic biomass.

Epifaunal biomass at high trawling intensity sites was reported to be dominated by *Asterias rubens*, a possible response to elevated food availability in the form of biota killed or damaged by trawling (Hinz *et al*., 2009). Starfish species can respond rapidly to prey availability (Freeman *et al*., 2001) and are known to be resilient from the damaging impacts of trawls (Hinz *et al*., 2009). Similarly, despite lower diversity, a greater dominance of the sea star, *Asterias amurensis*, was reported in heavily fished areas of the eastern Bering Sea (McConnaughey *et al*., 2000). The overall mean abundance of *A. amurensis* was 58.5 kg/ha in the heavily fished, compared with 53.1 kg/ha in the unfished area. In contrast, Bergman and Hup (1992) reported a 43% reduction in the mean density of *A. rubens* after a single beam trawling. Generally speaking, a number of studies have shown to have adverse impacts on echinoderms, including a 0-26% mortality in silty sand and 12-16% mortality in sand as a result of otter trawling in the North Sea (Bergman & van Santbrink, 2000) and a 24% reduction in total biomass of mega-epibenthic species as a result of otter trawling on a sandy bottom in Grand Banks, owing primarily to reductions in sand dollars, brittle stars, soft corals, sea urchins and snow crabs (Kenchington *et al*., 2001). Trawling caused significant damage only to echinoderms, with the highest probability of damage occurring on the sea urchin (10 percent damage) (Kenchington *et al*., 2001). Large and fragile echinoderms particularly suspectible to trawling, include the sea urchins *Brissopsis lyrifera* and *Echinocardium cordatum* (Ball *et al*., 2000), the latter of which has been reported to have a mortality of 10-40% after the single passage of a 4 m and 12 m beam trawl (higher in silty areas than in sandy areas) (Bergman & van Santbrink, 2000). Jennings *et al*. (2001) reported highly significant reductions in the biomass of burrowing sea urchins in response to a chronic beam trawling in the North Sea.

A meta-analysis by Kaiser *et al*. (2006) showed beam trawling in sand to have a greater individual impact on crustaceans, echinoderms and molluscs when compared with annelids, whilst otter trawling in muddy sand appeared to have a greater impact on crustaceans than annelids and molluscs. The single passage of a 4m and 12 m beam trawl in sand and silty sand led to direct mortalities of up to 22% in small-sized bivalves and crustaceans and in megafaunal species up to 68% for bivalves and 49% for crustaceans (Bergman & van Santbrink, 2000). Bivalves such as *Mya truncata*, *Lutraria lutraria* and *Nucula nitidosa* showed greater densities in samples taken after trawling compared to those taken prior to trawling. By contrast, Tuck *et al*. (1998) reported a decline in *Nucula nitidosa* and *Corbula gibba* in abundance in the trawled area relative to reference area, with the former species being identified as sensitive. Other mollusc species reported to be sensitive to trawling disturbance includes the tellin shells, *Tellina fabula* (Bergman & Hup, 1992). Jennings *et al*. (2001) reported highly significant reductions in the biomass of bivalves in response to a chronic beam trawling in the North Sea. The physical interaction with trawl doors with the sea bed was simulated in a test tank in order to examine physical disturbance and biological damage (Gilkinson *et al*., 1998). During the simulation, bivalves which were buried in the scour path were displaced to the berm and 58-70% of displaced individuals were completely or partially exposed on the surface. Despite this, of the 42 specimens in the scour path, only two showed major damage, despite being displaced. A number of studies have reported limited impacts of molluscs in general as a result of trawling disturbance (Bergman & Hup, 1992; Prena *et al*., 1999).

Experimental fishing manipulations have shown that the impacts of trawling disturbance on annelids are limited, and in some instance may be positive, particularly with respect to polychaetes Experimental flounder trawling on an intertidal silty habitat in the Bay of Fundy revealed no impact on either the composition or abundance of polychaetes, the majority of which are tube dwelling (Brylinsky *et al*., 1994). Whilst the single passage of a 4 m and 12 m beam trawl on sandy and silty sediment led to direct mortalities of 31% for annelids, principally the tubedwelling polychaete *Pectinaria koreni*, the mortality of many other small annelids observed was negligible (Bergman & van Santbrink, 2000). Ball *et al*. (2000) reported a decrease in abundance in most species following experimental trawling with a Nephrops otter trawl, except for most polychaete species which increased in abundance following trawling. These species included small opportunistic species such as such as *Chaetozone setosa* (52%), *Prionospio fallax* (149%) and *Scolelepis tridentate* (457%) or large scavenges such as *Nephtys incisa* (16%). Tuck *et al*. (1998) reported a consistently higher proportion of polychaetes in the treatment areas, with an increase in the abundance of opportunistic polychaete species belonging to the cirratulid famly, *Chaetozone setosa and Caullenella zeflandica*, in response to trawling disturbance. The polychaete, *Pseudopolydora paucibranchiata*, also increased in density, immediately following trawling disturbance (Tuck *et al*., 1998). Other polychaete species however did decline in response to fishing disturbance, including *Scolopolos armiger*, *Nephtys cirrosa* and *Terebellides stroemi* (Tuck *et al*., 1998). *Scolopolos armiger* is thought to be sensitive to burial, whilst *N. cirrosa* and T*. stroemi* are larger bodied and therefore more likely to be adversely affected by trawling disturbance (Tuck *et al*., 1998). Bergman and Hup (1992) found that three-fold trawling had minimal effect on the densities of worm species, except for *Magelona*, *Lanice* and *Spiophanes*, although densities of the former species significantly increased after experimental trawling for larger individuals. Jennings *et al*. (2001; 2002) reported no significant changes in polychaetes in in response to a chronic beam trawling in the North Sea. In contrast to the aforementioned studies, Kaiser *et al*., (1998) studied the effect of beam trawling of megafauna in an area of stable sediments in the north eastern and found a reduction the abundance in the polychaetes *Aphtodita aculeata* and *Nephtys* spp., although these differences were no longer apparent 6 months after trawling.

A number of studies have identified common trends for certain species in response to trawling disturbance. The gastropod *Buccinum undatum* is shown to decline in areas of trawling disturbance (Tuck *et al*., 1998; Kaiser *et al*., 2000), with one study stating the effects of trawling persisted for 6 months into the recovery period (Tuck *et al*., 1998). Similarly, *Echinocarodium cordatum* has been identified as a fragile and highly vulnerable to trawling disturbance (Bergman & Hup, 1992; Bergman & van Santbrink, 2000), showing declines of 40 to 60% in density in one study (Bergman & Hup, 1992). Similar reductions were shown by the polychaete *Lanice conchilega* (Bergman & Hup, 1992), a species of polychaete which is highly incapable of movement in response to disturbance and therefore take a significant period of time to recolonise disturbed habitats (Goss-Custard, 1977). Other species that have been reported to exhibit adverse effects of trawling include the polychaete species *Nephtys* (Kaiser *et al*., 1998; Tuck *et al*., 1998) and *Magelona* (Bergman & Hup, 1992; Kaiser *et al*., 2000) and the emergent soft coral *Alcyonium digitatum* (Kaiser *et al*., 1998; 2000; Depestele *et al*., 2012). By contrast, the brittle star, *Ophiura* sp., has been reported to increase or remain constant in response to trawling disturbance (Tuck *et al*., 1998; Gubbay & Knapman, 1999; Kaiser *et al*., 2000; Callaway *et al*., 2007).

4.4.4 Sampling constraints

Experimental trawling studies provide a valuable tool for investigating the mechanisms by which bottom-trawl disturbance physically and biologically impacts on benthic habitats (Hinz *et al*., 2009). These experimental fishing manipulations are however often small-scale at spatial scales of km^2 to ha (Hinz *et al*., 2009). Some contain the caveat that the study area chosen may have been markedly affected by previous fishing activities (Tuck *et al*., 1998). If there are substantial changes in the benthic community in the initial period of trawling development, it may be difficult to detect subsequent trends or impacts from fishing because the community is resistant to such effects or because effects are relatively insignificant compared to those caused previously

(Tuck *et al*., 1998). The benefits of using pristine, unfished sites which are then subject to experimental trawling gives a good idea of a benthic community's response and allows recovery to be quantified following fishing disturbance (Hinz *et al*., 2009). These findings provide helpful indications of instantaneous effects and relative severity of impacts for different gear types (Collie *et al*., 2000; Kaiser *et al*., 2006). Comparisons of high, low or no fishing intensity involves the classification of such areas in these fishing intensity levels (Hinz *et al*., 2009). These are often relative measures that are specific to each study, limiting generality and comparability (Hinz *et al*., 2009). Study sites chosen as unfished sites are often inaccessible to fisheries due to an obstruction and these can generate confounding effects (Hinz *et al*., 2009). Likewise, areas used as control sites may be subject to different environmental conditions, leading to further confounding effects (Hinz *et al*., 2009).

Experimental studies do however have a number of significant limitations (Hinz *et al*., 2009). Quantifying the effects of fishing impacts under realistic fishing conditions is difficult and the spatial and temporal scale of disturbance generated by a trawling fleet is unfeasible in an experimental context (Hinz *et al*., 2009). The occurrence of chronic fishing disturbance over large spatial scales can be expected to lead to greater effects and slower recovery rates than those reported in experimental studies (Hinz *et al*., 2009).

Measures used to detect changes in the benthic community (i.e. abundance, biomass) can be subject to considerable temporal variability and make it difficult to detect any changes caused by trawling disturbance (Løkkeborg, 2005). A number of studies have shown that control areas experience considerable change throughout the duration of a study and such temporal changes occur irrespective of trawling disturbance (Kenchington *et al*., 2001; Løkkeborg, 2005). It can be difficult to attribute long-term changes to benthos to trawling alone, since other forces are likely to be acting on the community, including natural fluctuations, chemical dumping and eutrophication (Pearson & Barnett 1987; Rees & Eleftheriou 1989; Jones 1992). Sanchez *et al*. (2000) concluded the decrease in certain species in unfished areas was likely to indicate natural variability at the site exceeds the effects of fishing disturbance. Similarly, Kaiser *et al*. (1998) concluded that only subtle changes in community structure were caused by trawling and effects caused by seasonal fluctuations and natural disturbance were more pronounced (Løkkeborg, 2005).

4.4.5 Removal of Target Species

The king scallop (*Pecten maximus*) can be found throughout most of the inshore waters of the English Channel (Le Goff *et al.,* 2017). Throughout the Southern IFCA district both in the east around the Isle of Wight and the West in Lyme Bay the king scallop is harvested and landed as an important commercial species (Le Goff *et al.,* 2017). *Pecten maximus* contribute 6-20% of the total catch weight in scallop dredges in the English Channel, with shell and rock making up the majority of the catch (Szostek *et al.,* 2017; Jenkins *et al.,* 2001). Of the live biomass caught within the dredge the king scallop accounts for, on average, 81%, indicating the fishing method is relatively selective (range 55-83%) (Szostek *et al.,* 2017). In a Newhaven style scallop dredge, of those scallops which are brought to the surface within the dredge between 5 and 6% have died (Shephard *et al.,* 2009). Of those scallops which are undersized and returned to sea, it is generally considered that unless badly damaged these scallops survive (Howell and Frazer 1984).

On the seabed only 15% of scallops disturbed by a dredge remain recessed within the sediment (Jenkins *et al.,* 2001). Of all the scallops both brought up within the dredge and those which remain in the dredge track more than 90% show very little damage (Jenkins *et al.,* 2001).

However, in the lab, experimental simulations of dredging have caused a significant increase in scallop (*P. maximus*) time taken to respond to a predator stimulus and the adduction number of the response (Jenkins and Brand, 2001). Larger scallops take longer to respond than smaller individuals. After 1 hour's recovery time, scallops showed a similar response indicating recovery from dredging takes more than 1 hour (Jenkins and Brand 2001).

Bremec *et al.* (2004) studied the survival of the Patagonian scallop (*Zygochlamys patagonica*) after exposure to 30 minutes of air onboard a fishing vessel, the equivalent time to that which it takes to sort the catch for commercial sizes (>55mm). Survival of this scallop species was high with a mean value of 95.5%, with more than 90% of scallops surviving exposure times of up to 4 hours (Bremec *et al.,* 2004). Jenkins and Brand

(2001) found that exposure to air (20 mins) had a negative effect on 3 out of 4 predator response variables of *P. maximus*.

Specific experiments have looked at the effect of simulated dredging and tow speed on the stress of small scallops (<75mm) (Maguire *et al.,* 2002). Higher tow speeds led to greater stress, however, the low tow speed also caused to stress. The ability of scallop to self-right and recess into the sediment declined only in individuals exposed to the high tow speed (Maguire *et al.,* 2002). Tow length does not have a significant effect on scallop stress level. Repeated dredging at a lower speed after 24 hours leads to a cumulative effect of scallop stress but no additional increases was found after repeated dredging at 48 h. Tows at the higher speed additional dredge disturbance did not lead to a cumulative effect (Maguire *et al.,* 2002). Importantly for all stimulation's scallops recovered relatively quickly, between 2 and 6 hours after dredging (Maguire *et al.,* 2002).

The average efficiency of dredges 1.2m wide, with 12 teeth and bag belly rings of 83mm diameter was studied by Chapman *et al.* (1977). The dredge efficiency of standard dredges in Scotland showed large variations from 0 to 35.7% capture efficiency (Chapman *et al.,* 1977). The average efficiency for all scallop sizes was around 20%, but slightly higher for larger scallops. Only 3.3 % of scallops smaller than 80mm were caught. The overall efficiency of a spring-loaded dredge varied from 2.5 to 37.5 %, at an average of around 13 % (Chapman *et al.,* 1977). 4.3% of scallops left behind in a dredge track showed mortality, compared to 2.6 % in an unfished control group. Mortality occurred mostly in those individuals which were severely damaged. Only 5% or less of those scallops within the dredge track and dredge catch showed sever damage (Chapman *et al.,* 1977).

When areas of the seabed are protected from scallop dredging and other forms of towed gears, the density of scallops on the seabed can increase (Leigh *et al.,* 2014). Scallops can live for considerably longer and grow to much larger sizes if not harvested, with exploitable and reproductive biomass also increasing, compared to open fishing grounds (Leigh *et al.,* 2014). Juvenile scallops can be as much as 350% more abundant in no take zones than in fished areas. Overall, it has been found that bottom towed gear closures or no take zones, not only increase the productivity of scallop populations inside the zones, but this also positively effects scallop populations on active fishing grounds (Leigh *et al.,* 2014).

A study of the effects of scallop dredging in Lyme bay found that within three years an area was closed to all bottom towed gears, scallop numbers had significantly increased in a newly closed area when compared to open controls (Sheehan *et al.,* 2013). On the other hand, a study in the same area found fishing history treatment and time had no significant effect upon the abundance of king scallops in a before and after study (9 years) (Kaiser *et al.,* 2018).

Changes in scallop density have been found to be primarily driven by seasonal fluctuations in Cardigan Bay, Wales (Sciberras *et al.,* 2013).

4.4.6 Natural disturbance

Communities that exist in areas of high natural disturbance rates are likely to have characteristics that provide resilience to additional disturbance (Hiddink *et al*., 2006a). Any vulnerable species would be unable to exist within conditions of frequent disturbance (Hiddink *et al*., 2006a). The impact of trawling is therefore expected to be higher in areas that experience low levels of natural disturbance and lower at locations of high levels of natural disturbance (Hiddink *et al*., 2006a). Despite the significance between benthic community responses to trawling disturbance and levels of natural disturbance, the relationship remains unquantified (Hiddink *et al*., 2006a). There can often be a failure to detect the effect of experimental fishing disturbance in areas exposed to high levels of natural disturbance (Thrush & Dayton, 2002). Whilst it may be appropriate to equate effects of natural disturbance to some effects of trawling disturbance, it is not always the case. Fishing can involve a higher intensity of disturbance, although this is dependent on frequency and extent (Thrush & Dayton, 2002). A trawl effects small-sized organism through sediment perturbations, which is comparable to that of natural disturbance, whereas its impacts on larger-bodied organisms will be through physical contact with fishing gear (Bergman & van Santbrink, 2000). The relatively low impact on benthic communities inhabiting mobile sediments might therefore only apply to small-bodied animals (Bergman & van Santbrink, 2000).

The Solent, including the Bembridge MCZ, is a dynamic area with strong tidal flows around Nab Tower reaching up to 2.1 knots on a spring tide[9]. Bolam *et al*. (2014) modelled natural seabed disturbance as part of a study looking at the sensitivity of microbenthic second production to trawling in the English sector of the greater North Sea. Natural seabed disturbance was represented by tidal bed stress and kinetic energy at the seabed. Maps showing the probability of natural forces disturbing the seabed to 1 and 4 cm for a range of frequencies (once, 10 times, and 17 times were also created). These maps cover the Solent (Figures 4 and 5), although the resolution is low as the area covered includes the North Sea and western English Channel. These maps however do demonstrate that the Solent, particularly the area between the Isle of Wight and the main land, including the north section of the Bembridge MCZ, is subject to relatively high levels of natural disturbance. Annual tidal bed stress ranges from 1.0-2.5 NM^2 in the northern part of the Bembridge MCZ. Kinetic energy at the seabed ranges from moderate to high within the site. The probability of natural forces disturbing the seabed to 1 cm reach the highest probability (0.81-1.00) at all frequencies.

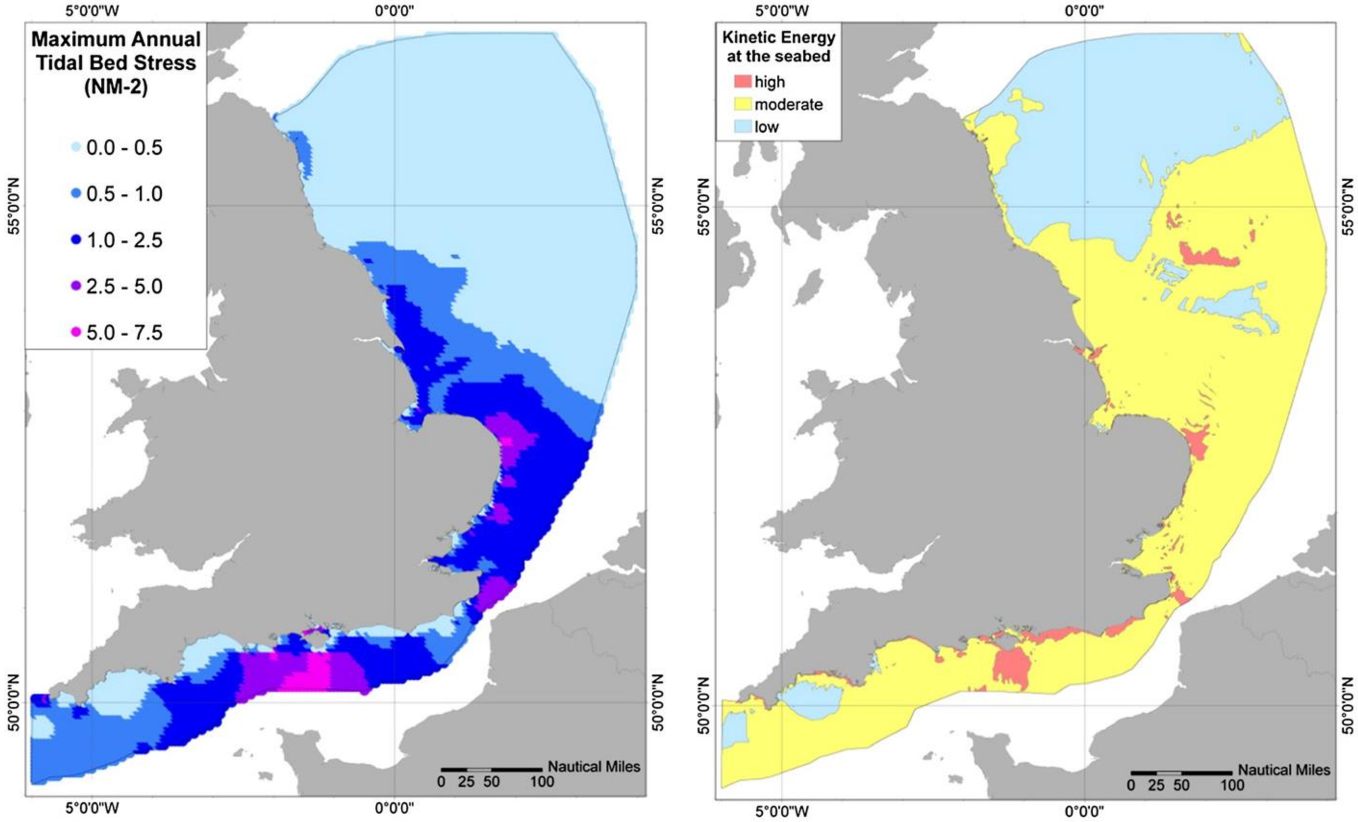


Figure 5. Maps of modelled natural disturbance of the seabed, represented by tidal bed stress (left) and kinetic energy (right). Source: Bolam *et al*., 2014

9 Information and diagrams on the tidal streams experienced in the western Solent can be found at https://www.visitmyharbour.com/articles/3187/hourly-tidal-streams-east-solent-area-np337

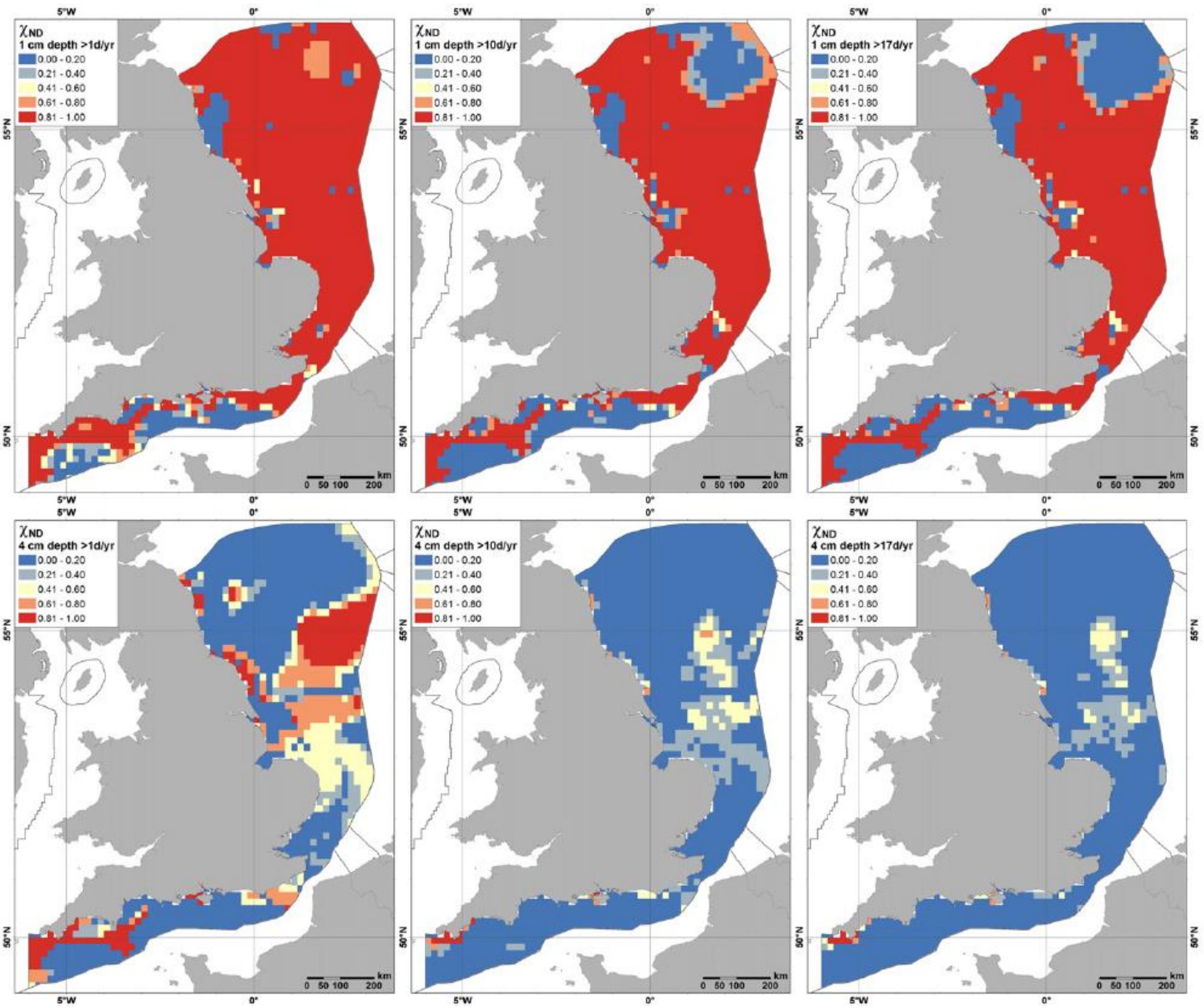


Figure 6. Maps of the modelled probability that natural forces disturb the seabed to different depths of 1 and 4 cm for a range of frequencies per year (once, 10 and 17 times). Source: Bolam *et al.*, 2014

In the context of MPA management, it is important to qualify which changes occur to naturally dynamic communities as a result of natural variability within the environment, as opposed to that resulting from anthropogenic pressures (Goodchild *et al*., 2015). The reason being that the conservation objectives of a site are 'subject to natural change (Goodchild *et al*., 2015). It can therefore prove difficult in ascertaining if the conservation objective of a site is being compromised by anthropogenic pressures if the MPA feature is also subject to natural variability (Goodchild *et al*., 2015). Potential changes caused by towed fishing gear could be masked by the impacts of natural sediment movements which maintain the benthic community in a state of successional flux (Løkkeborg, 2005; Goodchild *et al*., 2015). A recent study attempted to analyse existing data to study effects of towed fishing gears on mobile sediments against a background of natural variability, however, it concluded the results of the study were of little direct value in terms of MPA management (Goodchild *et al*., 2015)

4.4.7 Sensitivity

Habitat type

In a meta-analysis of 39 studies, which were conducted on varying sediment types, the most negative impacts occurred in muddy sand and gravel habitats (Collie *et al*., 2000). Surprisingly, the meta-analysis revealed the least impact was observed on mud habitats and not sand, which was not consistent for the results obtained for abundance and species richness (Collie *et al*., 2000). It was however noted that this may have been explained by the fact most studies conducted on mud habitats were looking at the impacts of otter trawls and that if data were available for the effect of dredgers a more negative response for this habitat may have been observed (Collie *et al*., 2000). In a separate meta-analysis of 101 different fishing impact manipulations, the initial and long-term impacts of different fishing types were shown to be strongly habitat-specific (Kaiser *et al*., 2006). Kaiser *et al*. (2006) reported that soft sediments, particularly muddy sands, were vulnerable to fishing impacts. Beam trawling had significant negative short-term impacts in sand and muddy sand habitats, although the relative effect was less and recovery times shorter than for intertidal dredging (Kaiser *et al*., 2006). Otter trawling had a significant initial effect on muddy sand and mud habitats, although long-term impacts, post trawling, on mud habitats were positive (Kaiser *et al*., 2006). The initial impact on benthic communities from otter trawl disturbance on mud was estimated to be -29%, -15% on sand and +3% on gravel (Kaiser *et al*., 2006; Hinz *et al*., 2009).

A number of studies have found limited detectable impacts of trawling in sand habitats (Van Dolah *et al*., 1991; Kaiser & Spencer, 1996; Kenchington *et al*., 2001; Roberts *et al*., 2010). Queirós *et al*. (2006) investigated the impact of chronic trawling on two communities from a muddy sand and a sandy habitat in the Irish Sea and Dogger Bank respectively. Chronic trawling was found to have an adverse effect on the biomass and production of benthic communities in muddy sand, whilst no impact was identified on benthic communities within the sandy habitat. It is important to note the two areas are fished with different gear types; the Dogger Bank is mostly fished by beam trawlers targeting plaice and the Irish Sea is fished by otter trawls targeting Norway lobster. Another study by Lindholm *et al*. (2013) reported no measurable effects of otter trawling using a small footrope otter trawl on the density of benthic invertebrates in areas of coarse silt/fine sand.

Bolam *et al*. (2014) investigated the relative sensitivity of benthic macrofauna to trawling, both short- and long-term and used this information to describe the spatial variation in sensitivity of secondary production. In general, it was found that the more sensitive and productive regions (northern North Sea and western English Channel) are associated with poorly-sorted, gravelly or muddy sediments, whilst less sensitive and less productive regions (southern North Sea) are associated with well-sorted sandy sediments (Bolam *et al*., 2014). Faunal assemblages, whose total production has a low overall sensitivity to trawling, occur in sandy sediment sediments containing low silt/clay and/or gravel fractions and such sensitivity inversely correlates with levels of natural disturbance. Thus, total production is more sensitive to trawling in deep regions with little or no natural sediment disturbance (Bolam *et al*., 2014). This is largely driven by long-term sensitivity of taxa and less so by instantaneous sensitivity (Bolam *et al*., 2014).

The reason for the sensitivity of different sediment types to the impacts of bottom towed fishing gear is related to the physical stability of the seabed (Collie *et al*., 2000). Fauna living within unconsolidated sediments such as those in shallow and sandy environments, are more adapted to dynamic environments, periodic resuspension and smothering and therefore able to recover more quickly (Tuck *et al*., 1998; Collie *et al*., 2000). Experimental studies investigating disturbance in shallow sandy environments indicate changes in community response are generally short-term (Kaiser *et al*., 1998) or non-existent (Queirós *et al*., 2006; Lindholm *et al*., 2013). Impacts of bottom towed gear are therefore greatest in areas with low levels of natural disturbance (Hiddink *et al*., 2003).

Sensitivity analyses

A number of recent studies have endeavoured to map the sensitivity of habitats to different pressures (Tillin *et al*., 2010) and fishing activities (Hall *et al*., 2008).

Tilin *et al*. (2010) developed a pressure-feature sensitivity matrix, which in effect is a risk assessment of the compatibility of specific pressure levels and different features of marine protected areas. The approach used considered the resistance (tolerance) and resilience (recovery) of a feature in order to assess its sensitivity to relevant pressures (Tilin *et al*., 2010). Where features have been identified as moderately or highly sensitive to benchmark pressure levels, management measures may be needed to support achievement of conservation objectives in situations where activities are likely to exert comparable levels of pressure (Tilin *et al*., 2010). In the context of this assessment, the relevant pressures likely to be exerted are penetration and abrasion of the seabed and removal of non-target species. Sensitivity of subtidal sediment types to these pressures vary from not sensitive to high, generally with low confidence in these assessments (Table 7).

Subtidal mixed sediments appear to be sensitive overall, followed by subtidal mud, whilst subtidal coarse sediment and sand appears to has relatively low sensitivity overall.

Hall *et al*. 2008 aimed to assess the sensitivity of benthic habitats to fishing activities. A matrix approach was used, composed of fishing activities and marine habitat types and for each fishing activity sensitivity was scored for four levels of activity (Hall *et al*., 2008). The matrix was completed using a mixture of scientific literature and expert judgement (Hall *et al*., 2008). The type of fishing activities chosen were 'beam trawl & scallop dredges' and 'demersal trawls' as these encompassed the fishing activities under consideration. Generally, stable habitat types exhibit high sensitivity to heavy gear intensities for beam trawls and scallop dredges and demersal trawls (Table 8). A large number of habitat types exhibit medium sensitivity to moderate gear intensities, except for beam trawls and scallop dredges in subtidal muddy sand and stable rich mixed sediments. All habitat types, except stable rich mixed sediments, exhibit low sensitivity to light fishing intensity and all habitat types exhibit low sensitivity to a single pass (Table 8). Generally, sensitivity across all habitat types is lower for light demersal trawls and seines, as would be expected (Table 8).

Table 4. Sensitivity of SAC features to pressures identified by Tillin *et al.* (2010). Confidence of sensitivity assessment is included in brackets.

	Pressure			
Feature	Penetration and/or disturbance of the substrate below the surface of the seabed – structural damage to seabed >25mm	Shallow abrasion/penetration – damage to seabed surface and penetration <25mm	Surface abrasion: damage to seabed surface features	Removal of non-target species
Subtidal mud	Medium (Low)	Medium (Low)	Low – Medium (Low)	Medium (Low to High)

Table 5. Sensitivity of SAC features to different intensities (high, medium, low, single pass) of oyster/mussel dredging as identified by Hall *et al.* (2008).

Gear Type	**Habitat Type**	**Gear Intensity***			
		Heavy	Moderate	Light	Single pass
Beam trawls & scallop dredges	**Subtidal stable muddy sands, sandy muds and muds**	High	High	Low	Low
Demersal trawls	**Subtidal stable muddy sands, sandy muds and muds**	High	Medium	Low	Low
Light demersal trawls and seines	**Subtidal stable muddy sands, sandy muds and muds**	Medium	Low	Low	Low

*Gear activity levels are defined as follows; Heavy – Daily in 2.5 nm x 2.5 nm, Moderate – 1 to 2 times a week in 2.5 nm x 2.5 nm Light – 1 to 2 times a month during a season in 2.5 nm x 2.5 nm, Single pass – Single pass of fishing activity in a year overall

4.4.8 Recovery

Recovery ultimately depends on the level of impact which is related to the weight of gear on the seabed, towing speed, the nature of bottom sediments and strength of tides and currents (Jones, 1992).

Habitat type and biological recovery

The timescale for recovery largely depends on sediment type, associated fauna and rate of natural disturbance (Roberts *et al*., 2010). Experimental studies have reported a variety of responses to trawling disturbance (Dernie *et al*., 2003). Such variation arises from characteristics specific to the site, i.e. location, gear fishing, season and habitat (Dernie *et al*., 2003). This hinders the formation of general conclusions and recovery rates of communities that would of use for ecosystem management (Dernie *et al*., 2003).

Generally speaking, in locations where natural disturbance levels are high, the associated fauna are characterised by species adapted to withstand and recover from disturbance (Collie *et al*., 2000; Dernie *et al*., 2003; Roberts *et al*., 2010). More stable habitats, which are often distinguished by high diversity and epifauna, are likely to take a greater time to recover (Roberts *et al*., 2010). In a relatively recent meta-analysis on the biological impacts of different fishing activities, recovery of muddy sands was predicted to take months to years and sand was predicted to take days to months (Kaiser *et al*., 2006). Similarly, Dernie *et al*. (2003) reported clean sand communities to have the most rapid rate of recovery following disturbance, with muds having an 'intermediate' recovery rate and muddy sand habitats having the longest recovery rates. More specifically, Kaiser *et al*. (2006) reported recovery times in the abundance of biota of less than 50 days from beam trawling in highly energetic, shallow, soft-sediment habitats of sand and muddy sand. In more stable gravel sediments, biota were still reduced by 40% after 50 days (Kaiser *et al*., 2006). Collie *et al*. (2000) reported recovery times of 100 days in sandy sediment communities from trawling disturbance. Kaiser *et al*. (1998) investigated the impacts of beam trawling on megafaunal communities in two areas characterised by mobile megaripple structures and stable uniform sediments. Effects of trawling in mobile sediments were not detectable and in uniform sediments were no longer evident after 6 months (Kaiser *et al*., 1998). The impacts of otter trawling on benthic communities on a sandy bottom in Grand Banks, Newfoundland a 120-146 m depth was studied over a three-year period (Kenchington *et al*., 2001). The sampling programme was not designed to determine the long-term effects and recovery, although available data indicated a recovery of the habitat and biological community within a year or less (Løkkeborg, 2005). Tuck *et al*. (1998) studied the biological effects of otter trawling in a sheltered sealoch in Scotland at 35-40 m depth in an area characterised by 95% silt and clay. A similar condition to the reference site was reached after 18 months, with the abundance of individuals shown to return to similar levels recorded prior to trawling (Tuck *et al*., 1998). Partial recovery of infaunal species occurred after 12 months and effects on epifauna were largely indistinguishable from the reference site 6 months after fishing ceased (Tuck *et al*., 1998; Johnson *et al*., 2002). Brylinsky *et al*. (1994) reported a rapid recovery of nematode abundance within 4 to 6 weeks following experimental flounder trawling on intertidal silty sediments in the Bay of Fundy.

Foden *et al*. (2010) investigated recovery of different sediment types based on the spatial and temporal distribution of benthic fishing. Vessel monitoring system data (2006 to 2007) was used to estimate the distribution and intensity of scallop dredging, beam trawling and otter trawling in UK marine waters. This data was then linked to habitat in a geographic information system. Recovery periods for different habitats were estimated based on existing scientific literature for gear types and fishing intensity (Table 10), with recovery rates generally increasing with sediment hardness. It was estimated that based on mean annual trawl frequencies that 80% of bottom-fished areas were able to recover completely before repeat trawling. In 19% percentage bottom-fished areas however, the frequency of scallop dredging in sand and gravel and otter trawling in muddy sand and reef habitats occurred at frequencies that prevented full habitat recovery. At average fishing intensities (for each gear type), sand and mud habitats were able to recover fully, whilst gravel, muddy sand and reef habitats were fished at frequencies in excess of the estimated recovery period (shown in Figure 6 where the mean index of recovery exceeds 1).

For scallop dredged areas recovery will depend on life history characteristics of the species affected, including the ability of damaged adults to repair lost or damaged parts and the ability of larvae to reach and recolonise a habitat (Roberts *et al*., 2010).

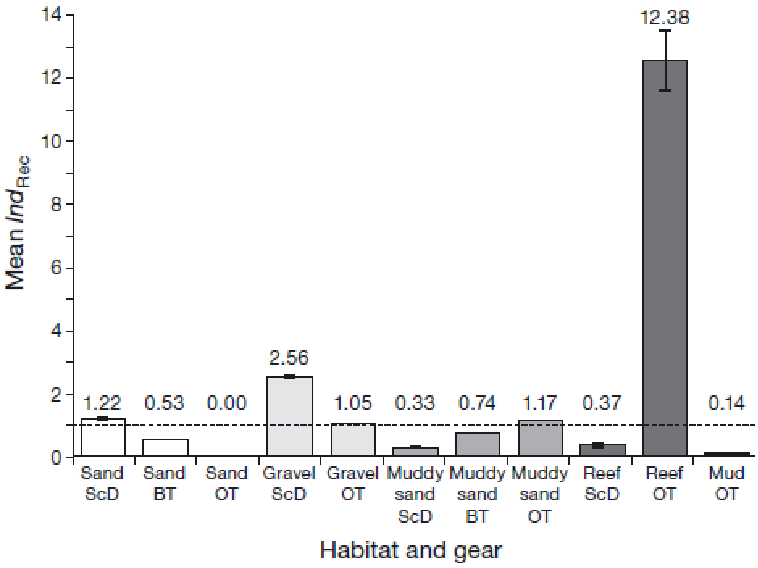
Table 6. Recovery rates (days) of different habitats for different fishing gear types. ND: No Data. Source: Foden *et al*., 2010.

Gear Type	Habitat Type	
	Muddy sand	Mud
Beam trawl	236[a]	ND

Otter trawl	213[b]	8[a]
Scallop dredge	589[b]	ND

[a] Kaiser *et al*. (2006); [b] Ragnarsson & Lindegarth (2009)

Figure 7. Mean index of recovery (Ind_{Rec}) for gear-habitat combinations using fishing intensity data derived from Vessel Monitoring Systems in 2007. At Ind_{Rec} Rec = 1, the recovery period is equal to fishing frequency (horizontal dashed line), at Ind_{Rec} <1 fishing frequency is less than the predicted recovery period and at Ind_{Rec} fishing frequency exceeds the recoveyr period. BT: Beam Trawl, OT: Otter Trawl and ScD: Scallop Dredge. Source: Foden *et al*., 2010.



Physical disturbance from chronic trawling occurs over large spatial scales and it may be expected that recovery rates will be slower than those assumed from experimental studies (Hinz *et al*., 2009). Recovery at small experimental scales is likely to simply be immigration, which is a form of recovery that is unlikely in large and repeatedly trawled areas (Jennings *et al*., 2001). The recovery of chronically disturbed benthic communities on fishing grounds will be largely dependent on recruitment and population growth, rather than on immigration from adjacent untrawled areas (Hiddink *et al*., 2006b). The importance of larval recruitment for the recolonization of a disturbed area increases with the size of the disturbed area (Smith & Brumsickle, 1989; Foden *et al*., 2010). The time of year when disturbance takes place may also influence the mode of recovery and recovery rate of the affected community (Foden *et al*., 2010). The recruitment supply of larvae and adult infauna will vary at different times of year and in relation to the physical characteristics at a specific location (Foden *et al*., 2010). The hydrodynamic regime will influence the rate of recolonization by influencing the deposition of infaunal adults and larval stages (Foden *et al*., 2010).

Population recovery rates are known to be species specific (Roberts *et al*., 2010). Long-lived bivalves will undoubtedly take longer to recovery from disturbance than other species (Roberts *et al*., 2010). Megafaunal species such as molluscs and shrimp over 10 mm in size, especially sessile species, are more vulnerable to impacts of fishing gear than macrofaunal species as a result of their slower growth and therefore are likely to have long recovery periods (Roberts *et al*., 2010). Short-lived and small benthic organisms on the other hand have rapid generation times, high fecundities and therefore excellent recolonization capacities (Coen, 1995). For example, slow-growing large biomass biota such as sponges and soft corals are estimated to take up to 8 years, whilst biota with short life-spans such as polychaetes are estimated to take less than a year (Kaiser *et al*., 2006).

Habitat type and physical recovery

The persistence of marks produced as a result of trawling depend on a number of factors including their depth, sediment type, current, wave action and biological activity (Tuck *et al*., 1998; Fonteyne, 2000; Smith *et al*., 2000; Humborstad *et al*., 2004 in Løkkeborg *et al*., 2005). In high energy environments physical recovery can take days, whereas recovery in low energy areas can take months (Northeast Region EFHSC, 2002; Wallace & Hoff, 2005). Trawl marks persist for longer periods of time when there is less energy to erode these marks (Mercaldo-Allen & Goldberg, 2011). Marks are likely to persist longer in deep water and in sheltered areas with fine sediments (Tuck *et al*., 1998; Løkkeborg *et al*., 2005). Trawl marks in areas of faster water movement are likely to be filled in within a shorter period (Jones, 1992).

Marks from towed gear have been showed to be relatively short lived in coarse sediments, lasting from a few days to no more than a year (De Groot and Lindeboom, 1994; Lindeboom & de Groot 1998). In a sandy habitat on the Grand Banks at 120-146 m depth, marks left by trawl doors (1250 kg oval otter boards) were visible for at least 10 weeks, although were not visible or faintly visible after a year (Schwinghamer *et al*. 1998). Tracks from a 4 metre beam trawl with tickler chain matrix remained visible for 52 hours in coarse sand and 37 in fine sand at a depth of 20 to 30 metres on the Goote Bank off Belgium and the Netherlands (Fonteyne, 2000). Trawl door scars (10 cm deep and 20 cm wide) from 2300 kg trawl doors on a sandy/gravel bottom were shown to disappear within less than five months in an area of strong currents in the Barents Sea (Humborstad *et al*. 2004). Hand-dug trenches (15 cm deep and 1.2 m long) at a 7 m deep sandy site lasted for 1 to 4 days in Narragansett Bay, Rhode Island (DeAlteris *et al*., 1999). In the same study, but in the areas of mud at a depth of 14 m, trawl scars (5-10 cm deep with berms 10-20 cm high) persisted for more than 60 days (DeAlteris *et al*. 1999).

In areas characterised by silt or mud, tracks and scars appear to remain visible for longer periods of time compared to sandy and coarser sediments as expected. In a sheltered sealoch in Scotland characterised by sediment with 95% silt and clay, side-scan results revealed that disturbance tracks could still be seen after 18 months after experimental trawling had ceased (Tuck *et al*., 1998). An alternative measure of seabed properties were altered by fishing was also obtained from RoxAnn measurements (Tuck *et al*. 1998), an acoustic bottom classification system based on the seabeds hardness and roughness (Løkkeborg, 2005). RoxAnn data however indicated recovery after 6-month for physical effects (Tuck *et al*. 1998). Smith *et al*. (2007) also used side scan sonar, as well as underwater video technology, to record the impact of trawling on silty clay sediment at depths of 200 m in Herkalion Bay (Roberts *et al*., 2010). Trawl marks were evident throughout the year in the study area, including throughout a closed season of four months, by the end of which trawl marks were less visible indicating biogenical weathering (Smith *et al*. 2007; Roberts *et al*., 2010). No information on the gear type was given. Furrows (5 cm deep, 30-85 cm wide) made by experimental flounder trawl doors (200 kg) in the Bay of Fundy were visible for at least 2 to 7 months in an area of coarse sediment overlain by up to 10 cm of silty sediment (Brylinsky *et al*. 1994).

The persistence of trawl scars does not necessarily indicate a lack of biological recovery. Trawl scars are likely to persist in areas characterised by low energy, during which time biological recovery may have taken place. It is therefore important to consider the type of environment in which the scars are present as biological recovery may take place over shorter timescales.

Depth

There is an inverse relationship between wave action and depth and so the natural mobility of bottom sediments tends to decrease with depth (Wheeler *et al*., 2014). The impact of trawling might therefore be more substantial in deeper subtidal habitats due a lack of water movement (Jones, 1992).

In a literature review by Johnson *et al*. (2002), studies which took place at greater depths (>120 m) revealed trawling tracks were evident up to a year after trawling, whilst those at shallow sites (<7m) were no longer visible after a few days.

Benthic communities in dynamic shallow water are likely to be more capable of overcoming disturbance than those in inhabiting deeper and less dynamic environments and as such are likely to have longer recovery times (Jones, 1992).

4.5 Existing management measures

All Bottom Towed Gears:

- **Bottom Towed Fishing Gear** byelaw – prohibits bottom towed fishing gear over sensitive features including most of the site from Bembridge harbour to Steel bay closing most of the site to these activities.
- **Vessel Used in Fishing** byelaw – prohibits commercial fishing vessels over 12 metres from the Southern IFCA district. The reduction in vessel size also restricts the type of gear that can be used, with vessels often using lighter towed gear and restricted to carry less static gear.

Shellfish dredging:

- European minimum size, listed under Technical Conservation Regulation 1241/2019, specify the minimum conservation reference size for King Scallop (*Pecten maximus*) is 110mm in area 7d and 100mm in 7e.
- The **Scallop Fishing (England) Order 2012** states that no more than 8 dredges per side to be towed at any one time and provides details for dredge configuration (i.e. the frame cannot exceed 85 cm in width).
- **The Scallop Fishing** byelaw – prohibits any person from taking or fishing for scallops before 0700 local time and after 1900 local time. The byelaw dictates the fishing set up that can be used including a limit on the maximum which number of dredges that can be towed at any one time (up to 12), all dredges must be fitted with a spring loaded tooth bar, the mouth of a dredge must not exceed 85 cm in overall width and no more than two tow bars can be used any time with a maximum length of 5.18 metres (including attachments).

Trawling:

- Southern IFCAs **Minimum Fish Sizes** Byelaw prohibits the taking of fish under the specified size (Black Seabream, Brill, Dab, Conger Eel, Flounder, Red Mullet, Shad, Turbot, Witch Flounder).
- A separate Minimum Size Southern IFCA byelaw exists for Skates and Rays and this states that no person shall take any ray that measures less than 40 cm between the extreme tips of the wings or any wing which measures less than 20 cm in its maximum dimension and which is detached from the body of a skate or ray.
- Other regulations include minimum sizes, mesh sizes and catch composition as dictated by European legislation. European minimum sizes, listed under Technical Conservation Regulation 1241/2019 and Bass Emergency Measures 2020/123 specify the minimum size for bass is 42 cm

4.6 Table 7. Assessment of trawling activity on sea pens and burrowing megafauna, and subtidal mud.

Feature	Attribute	Target	Potential pressure(s) and Associated Impacts	Likelihood of Impacts Occurring/Level of Exposure to Pressure	Current mitigation measures
Sea Pens and Burrowing Megafauna And subtidal mud	Distribution: presence and spatial distribution of biological communities; Structure and function: presence and abundance of key structural and influential species; Structure species composition of component communities	Not available.	Abrasion/disturbance of the substrate on the surface of the seabed, penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion and removal of non-target species were identified as potential pressures. Bottom towed gear can lead to the removal, damage or mortality of non-target species, reduction in structural complexity and reduction in biodiversity and composition of benthic assemblages. Studies on the impacts of trawling in mud habitats report relatively modest changes in associated benthic communities in the short-term, with more significant changes in communities after cumulative long-term disturbance. Benthic macrofauna in poorly sorted, gravelly or muddy sediments are reported to be more sensitive to trawling disturbance than well-sorted sandy sediments. The timescale for recovery after trawling disturbance largely depends on sediment	There is potential for up to 6 vessels to take part in the trawl fishery. At any one time there are approximately only 3 vessels actively trawling in the Solent. No trawling activity has been sighted in the site over the past 11 years. However, the activity is known to occur to the North East of the site. There is potential for up to 5 vessels to take part in the scallop fishery, however a maximum of 1-2 are seen at any one time in proximity to the Bembridge MCZ. The activity usually occurs over winter and lasts one month. Scallop dredging has historically taken place within the north east area of the Bembridge MCZ, in the small area of mixed sediments between Seaview and Bembridge Harbour. One recent sighting however lies along the most northern boundary of the site. The greatest number of sightings occur further into the East Solent, and further offshore outside of the Bembridge MCZ. There is a lack of information surrounding the biotope and species present within the Bembridge MCZ. A species list is provided within the post-survey site report, however no information on the substrate type and certain species are found is provided, making it hard to ascertain site-specific impacts of bottom towed fishing gear (BTFG) on associated communities. The generic descriptions of sea pens and burrowing megafauna identifies that they occur over stable plains of fine mud at depth below 15m. The habitat supports communities of Norway lobster, mud shrimps, the Fries' goby, slender and tall sea pens, and fireworks anemone, many of which are rear in UK waters. Only 1 record of Sea pens has been reported in the MCZ and is located just north of the known subtidal mud area in what appears to be mixed sediments. However, it is known that these species associate themselves with areas of mud sediment and therefore it is likely that this sea pen is in an area of mud which has been classified as mixed sediment due to the broadscale of the data collected. Trawl damage was simulated on the sea whip in Alaska, by abrading the whips with rubber disks, dislodging them from the sediment and breaking their axial	**Vessel Used in Fishing** byelaw – prohibits vessels over 12m fishing in the district. **Scallop Fishing** byelaw – prohibits any person from taking or fishing for scallops before 0700 local time and after 1900 The byelaw dictates the fishing set up that can be used (up to 12 dredges), all dredges must be fitted with a spring loaded tooth bar, the mouth of a dredge must not exceed 85 cm in overall width and no more than two tow bars can be used any

			type, associated fauna and rate of natural disturbance, and variation in recovery arises from characteristics specific to the site. Generally speaking, locations subject to high levels of natural disturbance, the associated fauna are likely to be adapted to withstand and recover from disturbance. Mud communities are reported to have an 'intermediate' recovery rate. Trawl damage was simulated on the sea whip in Alaska, and after 372 days 92% to 100% of the specimens had died (Malecha & Stone, 2009). Very little is known about the Norway lobster, mud shrimps and volcano worm sensitivity to fishing impacts.	rods. After 372 days 92% of the dislodged and 100% of the fractured specimens had substantial tissue loss and had died (Malecha & Stone, 2009). Little is known about the sea pens, Norway lobster, mud shrimps and volcano worm's sensitivity to fishing impacts. However, they are long lived species with low recruitment rates and therefore it is predicted they will be sensitive to this type of activity. Hall *et al*. (2008) assessed the most relevant habitat type (subtidal stable muddy sands, sandy muds and muds) to have high sensitivity to moderate activity (1-2 times per week) with respect to beam trawls and shellfish dredges (table 8). For light trawls and demersal trawls sensitivity for this activity level was assessed as low to medium. For light fishing activity (1-2 times per month) sensitivity is low for all fishing types. Ragnarsson & Lindegarth (2009) estimated mud habitat recovery rates could be from 8 to 589 days for bottom towed fishing gear activity. The lack of site-specific information on biotope and associated communities makes assessing the impacts of trawling & dredging disturbance difficult. However, research and species biology indicate that the species associated with this community could be highly sensitive to pressures caused by bottom towed fishing gear. The communities are associated with subtidal muds which are considered to be highly sensitive to moderately sensitive. Therefore, based on the above it is believed that trawling & dredging will pose a significant risk to the sea pens and burrowing megafauna and subtidal mud in the MCZ, and could therefore hinder the ability of the features to achieve their recover general management approach (GMA). It is worth noting that in the absence of a condition assessment for the site, Natural England undertook a vulnerability assessment for each feature as a proxy for condition. This assessment considers the activities which take place in the site and determines the GMA for each feature. However, such an assessment is relatively generic and does not take into a number of site-specific factors.	time with a maximum length of 5.18 metres (including attachments).
Subtidal mud	Distribution: presence and spatial distribution of biological communities;	Not available.	Removal of target species (Scallop dredging) was identified as a potential pressure.	There is potential for up to 5 vessels to take part in the scallop fishery, however a maximum of 1-2 are seen at any one time in proximity to the Bembridge MCZ. Typically, however, dredging takes place outside of the MCZ further north and west in the Solent in Osbourne Bay. Historically, Scallop dredging has overlapped with the north east area of the Bembridge MCZ, in the small area of mixed sediments between Seaview and Bembridge Harbour. One	**European minimum size**, listed under Technical

			Commercial fishing directly removes and harvests a specific species or group of fauna. The sustainability, including the size and age composition, of the stock can be compromised if unmanaged, leading to indirect effects such as impacts to energy flows through food webs.	recent sighting lies along the most northern boundary of the site. The greatest number of sightings occur further into the East Solent (Osbourne Bay), and further offshore outside of the Bembridge MCZ. Scallop dredges are considered to be relatively selective with 81% of biomass caught comprising of scallops (Szostek *et al.,* 2017). Their capture efficiency however is relatively low (20%), being considerably less for small scallops (3.3%) (Chapman *et al.,* 1977). Levels of mortality in the dredge track are only 1.8% greater than natural mortality (Chapman *et al.,* 1977). Only scallops which are severely damaged may die. Of all scallops (left in dredge track and brought to surface) sever damage occurs in only 5%. Scallops which are both exposed to air or disturbed by a dredge do experience a level of stress which can inhibit their predator response and recessing behaviours (Jenkins and Brand 2201 and Maguire *et al.,* 2002). However, scallops have been found to r3ecover from this stress within 6 hours (Maguire *et al.,* 2002). Area's of the seabed protected from scallop dredging have been found to have greater numbers of scallops (Leigh *et al.,* 2014) however this has not been found in all cases (Kaiser *et al.,* 2018 and Sciberras *et al.,* 2013) where it has been found that scallop populations are driven greatly by seasonal fluctuations and habitat suitability. Scallop dredging is a closely managed fishery in England with minimum conservation reference sizes, gear configuration regulations and within the southern in IFCA district the activity is not permitted between the hours of 19:00 and 07:00. Based upon the very low level of scallop dredging occurring actually within the MCZ, the low efficiency of scallop dredges along with high survival rates of both scallops returned to sea or left within the dredge track, with the current mitigation of current management measures it is believed that dredging will not pose a significant risk to the subtidal mud biological communities in the MCZ through removal of target species, and will not therefore hinder the ability of the feature to achieve it's 'recover' general management approach (GMA).	Conservation Regulation 1241/2019, specify the minimum conservation reference size for King Scallop (*Pecten maximus*) is 110mm in area 7d and 100mm in 7e. **The Scallop Fishing** byelaw – prohibits any person from taking or fishing for scallops before 0700 and after 1900 local time. The byelaw dictates the fishing set up that can be used including a maximum total number of dredges to be towed at any time (12)

					and all dredges must be fitted with a spring-loaded tooth bar, the mouth of a dredge must not exceed 85 cm in overall width and no more than two tow bars can be used at any time with a maximum length of 5.18 metres (including attachments). The **Scallop Fishing (England) Order 2012** states that no more than 8 dredges per side to be towed at any one time and provides details for dredge configuration

Sea Pens and Burrowing Megafauna; Subtidal Mud	Extent and distribution. Structure: sediment composition and distribution.	Not available.	Abrasion/ disturbance of the substrate on the surface of the seabed and penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion and removal of non-target species were identified as potential pressures. Physical impacts on the seabed from trawling include scraping and ploughing, creation of depressions, trenches, scouring and flattening of the seabed, sediment resuspension and changes in the vertical distribution of sediment layers. Studies on the effects of otter trawling in gravel and variable habitats have revealed trawling can lead to the removal of fine sediments and biogenic structures, moved or overturn stones and boulders, smooth the seafloor and exposed sediment/shell fragments. Otter boards and tickler chains can leave distinct grooves or furrows. The depth of such marks on the seafloor depend on the nature of the substrate, and are more in areas of finer sediments.	Addressed above and in addition: In muddy sediments trawl doors can create furrows 20-200cm wide and up to 10cm deep. Surface organic material can be mixed into sub surface layers, resuspension of sediment, nutrients and contaminants may occur. Fine sediment can be washed away, or can resettle on the sediment surface. Trawling also changes small-scale biogenic sediment structures (tubes and burrows). Scallop dredging leads to flattening of the seabed, visible teeth marks and mixing of the sediments. The lack of site-specific information on biotope and associated communities makes assessing the impacts of trawling disturbance difficult. However, considering the sensitivity of the habitat to trawl and dredge disturbance, the potential recovery times, and potential for activity to occur over the feature it is believed that trawling & dredging will pose a significant risk to the extent and distribution of the sea pens and burrowing megafauna and subtidal muds in the MCZ, and could therefore hinder the ability of the feature to achieve its recover general management approach (GMA). It is worth noting that in the absence of a condition assessment for the site, Natural England undertook a vulnerability assessment for each feature as a proxy for condition. This assessment considers the activities which take place in the site and determines the GMA for each feature. However, such an assessment is relatively generic and does not take into a number of site-specific factors.	Addressed above
Subtidal mud	Supporting processes: water quality - turbidity	Not available	Changes in suspended solids (water clarity) was identified as a pressure.	Addressed above and in addition: Research has found that high levels of sediment and regular exposure can cause sever impacts. Increased turbidity can inhibit respiratory and feeding	As above

			The resuspension of sediment can impact upon benthic communities through smothering, burial and increased turbidity. These effects may extend to organisms living a distance away from the fished area. The timescale for recovery after trawling disturbance largely depends on sediment type, associated fauna and rate of natural disturbance, and variation in recovery arises from characteristics specific to the site. Generally speaking, locations subject to high levels of natural disturbance, the associated fauna are likely to be adapted to withstand and recover from disturbance. Mud communities are reported to have an 'intermediate' recovery rate.	functions of benthic organisms, and cause hypoxia or anoxia. Small organisms and immobile species are particularly vulnerable to smothering. The severity of the impact is determined by sediment type, the level of sediment burden and the sensitivity of organisms which is largely related to their biology (i.e. size, relationship to substrate, life history, mobility). The Solent is known to be highly variable in terms of suspended sediment concentrations. At Southampton Water's mouth concentrations can vary from around 25 to 40 mg/l, and in peak spring tides reach 60 mg/l (ABP Mer, 2014). Tidal streams in the Solent take this water out from the mouth of the Solent and east past Bembridge MCZ. Therefore, natural turbidity in Bembridge MCZ is expected to be high. Research has found that increased turbidity can lead to sever impacts to benthic organisms. However, the Solent is known to have natural high variability in turbidity levels. In addition to low numbers of vessels fish at any one time for both trawling and dredging additionally the duration of the scallop season is short. Therefore, it is believed that trawling & dredging will not significantly increase the turbidity around or near to subtidal mud in the MCZ when compared to natural variation and therefore will not hinder the ability of the feature to achieve its 'recover' general management approach (GMA). It is worth noting that in the absence of a condition assessment for the site, Natural England undertook a vulnerability assessment for each feature as a proxy for condition. This assessment considers the activities which take place in the site and determines the GMA for each feature. However, such an assessment is relatively generic and does not take into a number of site-specific factors.	

4.7 Site condition

As this site is newly designated a condition assessment has not yet been completed by Natural England. Additionally, this site is not underpinned by a Site of Special Scientific Interest and therefore, no condition assessment of areas within the site are available.

Part of the site overlaps with the Solent Maritime SAC, for which an assessment of the condition of the site has been made. However, this site covers a very large area encompassing much of the Solent and the intertidal area, and therefore the conditions assessment is not relevant to the Bembridge MCZ.

5 Proposed mitigation measures

In recognition of the potential pressures of bottom towed fishing gear (particularly trawling and scallop dredging) upon designated features and their supporting habitats, Southern IFCA will follow the process of introducing permanent bottom towed fishing gear closure areas in order to protect sea pens and burrowing megafauna and subtidal muds in the Bembridge MCZ.

The bottom towed gear fishing closure areas are designed to fully protect subtidal mud and sea pens and burrowing megafauna against BTFG, by completely prohibiting all types of bottom towed fishing, including trawling and scallop dredging, over the features within the site. Each area has been designed to incorporate a buffer around the feature data. The buffer distance is determined by the following formula: Deepest feature depth * 4 + 10m. The buffer ensures that if fishing were to occur along the line of the closed area, the actual trawl location would not occur over the feature itself.

The measures presented are draft and used to illustrate protection based purely on location. When developing management other evidence such as fishing activity and consultation with the local community may feed into the development of spatial closed areas.

Management will be introduced in the upcoming update to the Southern IFCA Bottom towed Fishing Gear Byelaw 2016. The primary reason for management options is to protect subtidal mud and sea pens and burrowing megafauna, which are known to be highly sensitive to BTFG against the impacts caused by bottom towed fishing gear.

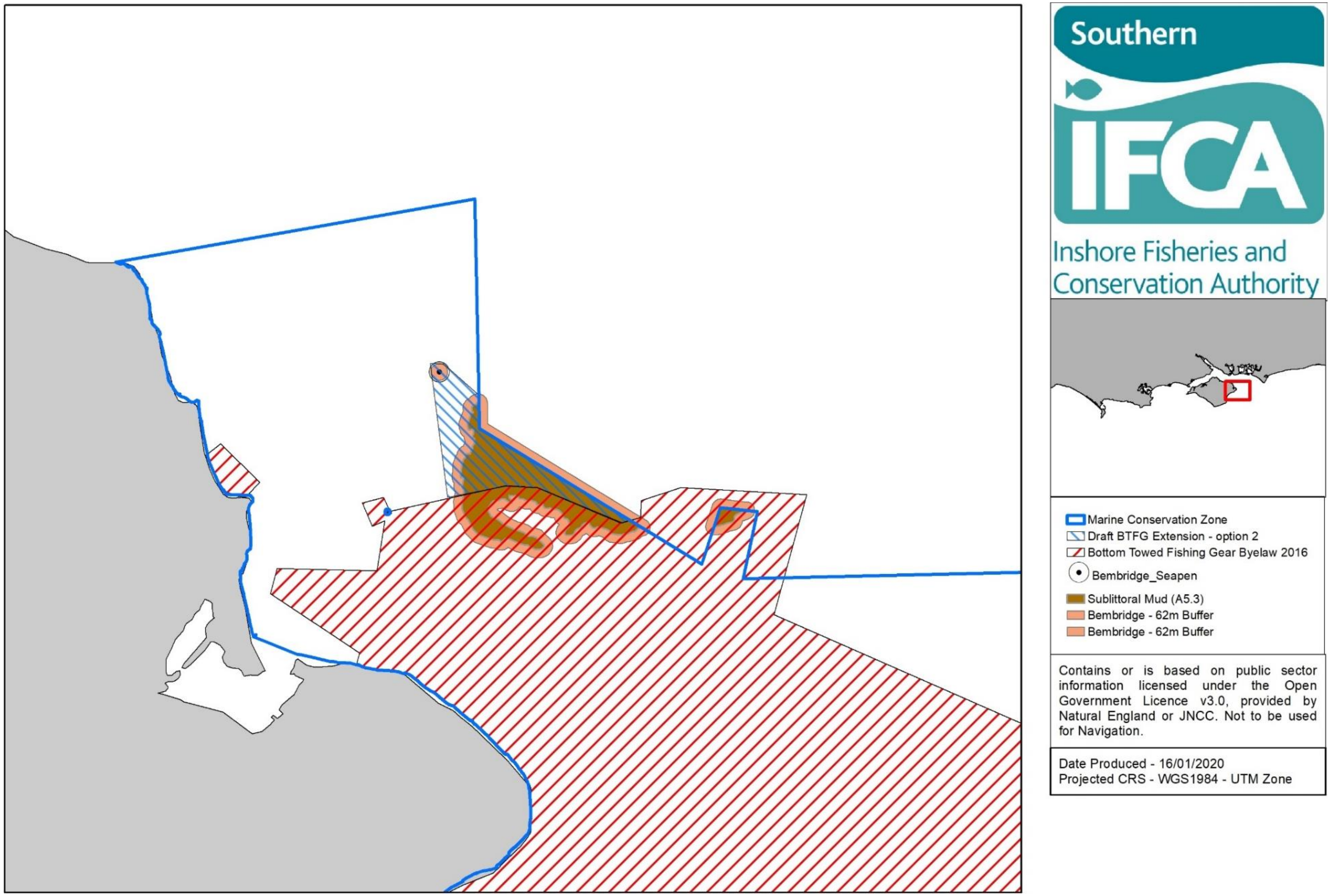


Figure 8. Draft Bottom Towed Fishing Gear Extension in the Bembridge MCZ to protect subtidal mud and sea pens and burrowing megafauna.

6 Conclusion

In order to conclude whether types of bottom towed fishing gear (trawls and scallop dredges) pose a significant risk, it is necessary to assess whether the impacts of the activities will hinder the achievement of the general management approach of the designated feature (Sea pens and burrowing megafauna and subtidal mud) of 'recover to favourable condition' and the sites conservation objectives, namely:

"The conservation objective of each of the zones is that the protected habitats:

1. are maintained in favourable condition if they are already in favourable condition
2. be brought into favourable condition if they are not already in favourable condition

For each protected feature, favourable condition means that, within a zone:

1. its extent is stable or increasing
2. its structure and functions, its quality, and the composition of its characteristic biological communities (including diversity and abundance of species forming part or inhabiting the habitat) are sufficient to ensure that its condition remains healthy and does not deteriorate

Any temporary deterioration in condition is to be disregarded if the habitat is sufficiently healthy and resilient to enable its recovery.

The review of the research into the impacts of bottom towed fishing gear on sediment habitats reported type (subtidal stable muddy sands, sandy muds and muds) to have high sensitivity to moderate fishing activity (1-2 times per week) and low to medium for light fishing activity (1-2 times per month). For light trawls and demersal trawls sensitivity for this activity levels were assessed as low to medium. Recovery times were estimated to be up to 589 days for scallop dredging over mud. Therefore, it was concluded that the level of fishing activity in and outside of the site could prevent the ability of these features to attain their 'recover' general management approach.

Having reviewed a wide range of evidence, including scientific literature, IFCO knowledge, habitat feature mapping (including bathymetric data), it has been concluded that bottom towed fishing gear is likely to pose a significant risk to sea pens and burrowing megafauna and their supporting habitat within the Bembridge MCZ. The rationale for this conclusion is summarised below:

- IFCO knowledge indicates that trawling and scalloping activity occur mostly outside of the site but also over mixed and coarse sediments within the site. However, at any one time 1-2 vessels might interact with the fringes of the site. Multiple historic sightings of dredging have been made in the site, with trawling sightings also made just outside of the site.
- Scallop dredging is the main threat to sea pens and burrowing megafauna due to the focus of this activity over soft and mixed sediment habitats.
- A review of scientific literature demonstrated that bottom towed fishing gear at any intensity can lead to the damage, removal, and mortality of non-target species. Additionally, bottom towed fishing gear can lead to physical disturbance of the seabed including creation of furrows and mixing of sediment layers. Sea pens in particular are thought to be highly sensitive to the impacts of bottom towed fishing gear, however it is important to note that few studies have been completed.
- Sensitivity of mud habitats to pressures associated with beam trawls and dredges at moderate intensity is high. For light trawls and demersal trawls sensitivity for this activity levels were assessed as low - medium.
- Recovery of subtidal muds are predicted to be more than a year.

Additionally, the location, timing, duration and intensity of bottom towed fishing gear within the site will be influenced by existing management measures which currently protect some areas of subtidal mud (section 4.5). These measures mitigate somewhat against the significant risk posed by the activities.

It is therefore recognised that the activities will pose a significant risk upon the following Sea pen and burrowing megafauna and subtidal mud attributes:

- Distribution: presence and spatial distribution of biological communities;
- Structure and function: presence and abundance of key structural and influential species;
- Structure: species composition of component communities
- Extent and distribution
- Structure: sediment composition and distribution.

It is therefore recognised that the activities will pose a significant risk upon the following sea pen and burrowing megafauna and subtidal mud attributes:

- Distribution: presence and spatial distribution of biological communities;
- Structure and function: presence and abundance of key structural and influential species;
- Structure: species composition of component communities
- Extent and distribution
- Structure: sediment composition and distribution.

Upon the provision of additional evidence, including conservation advice for the site, and up to date habitat maps, Southern IFCA feel it is now appropriate for refinement to the spatial extent of the current closure and inclusion of additional bottom towed fishing gear closed areas. This is to support the general management approach to ‘recover’ the sea pens and burrowing megafauna and subtidal muds to a favourable condition. The primary reason for management is to protect the sea pens and burrowing megafauna feature.

In summary, when the above evidence, fishing activity levels, current and proposed management measures are considered it has been concluded that bottom towed fishing gear will not pose a significant risk to the achievement of sites conservation objectives to ‘recover’ sea pens and burrowing megafauna and subtidal muds to favourable condition. Southern IFCA must seek to ensure that the conservation objectives of any MCZ in the district are furthered.

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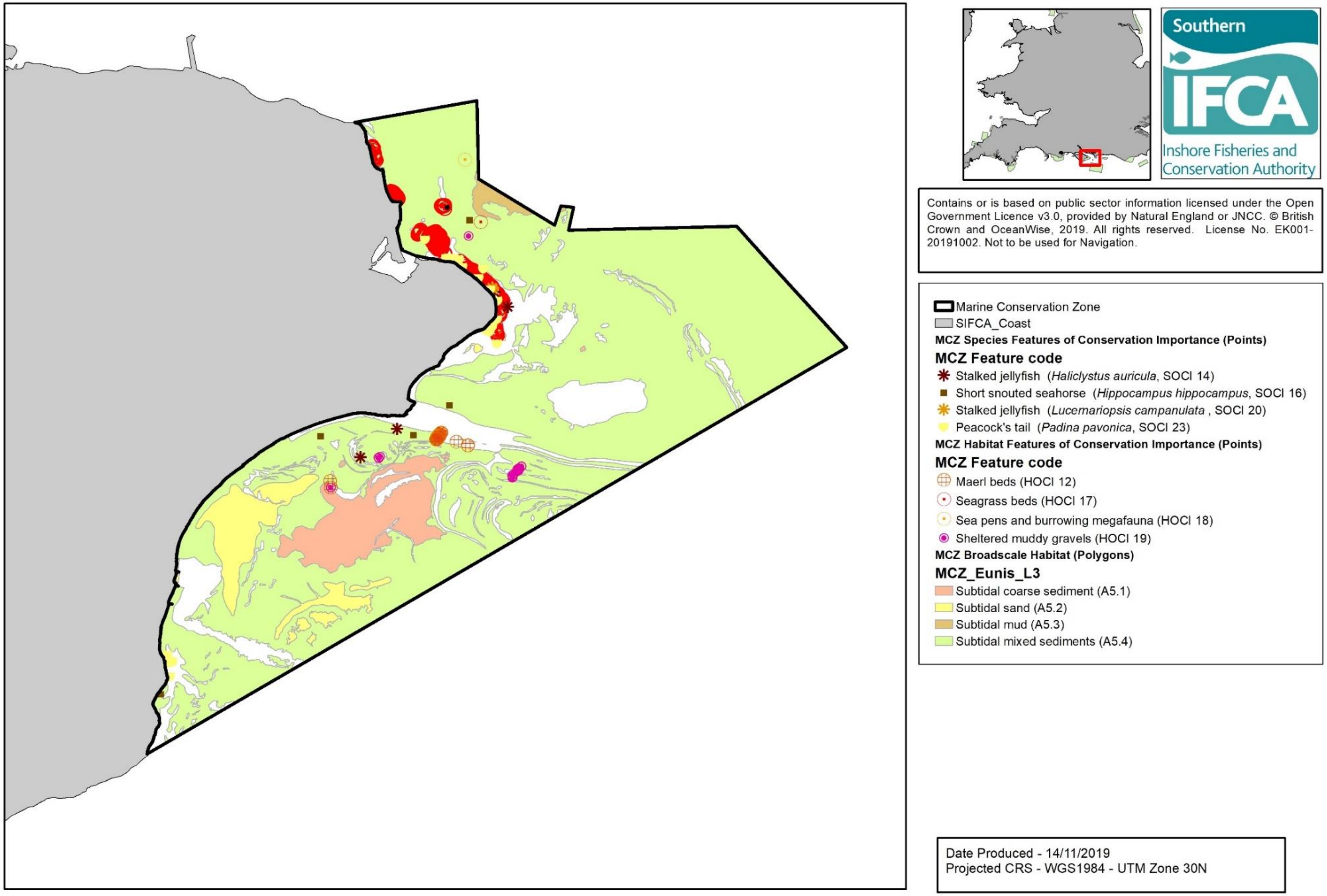
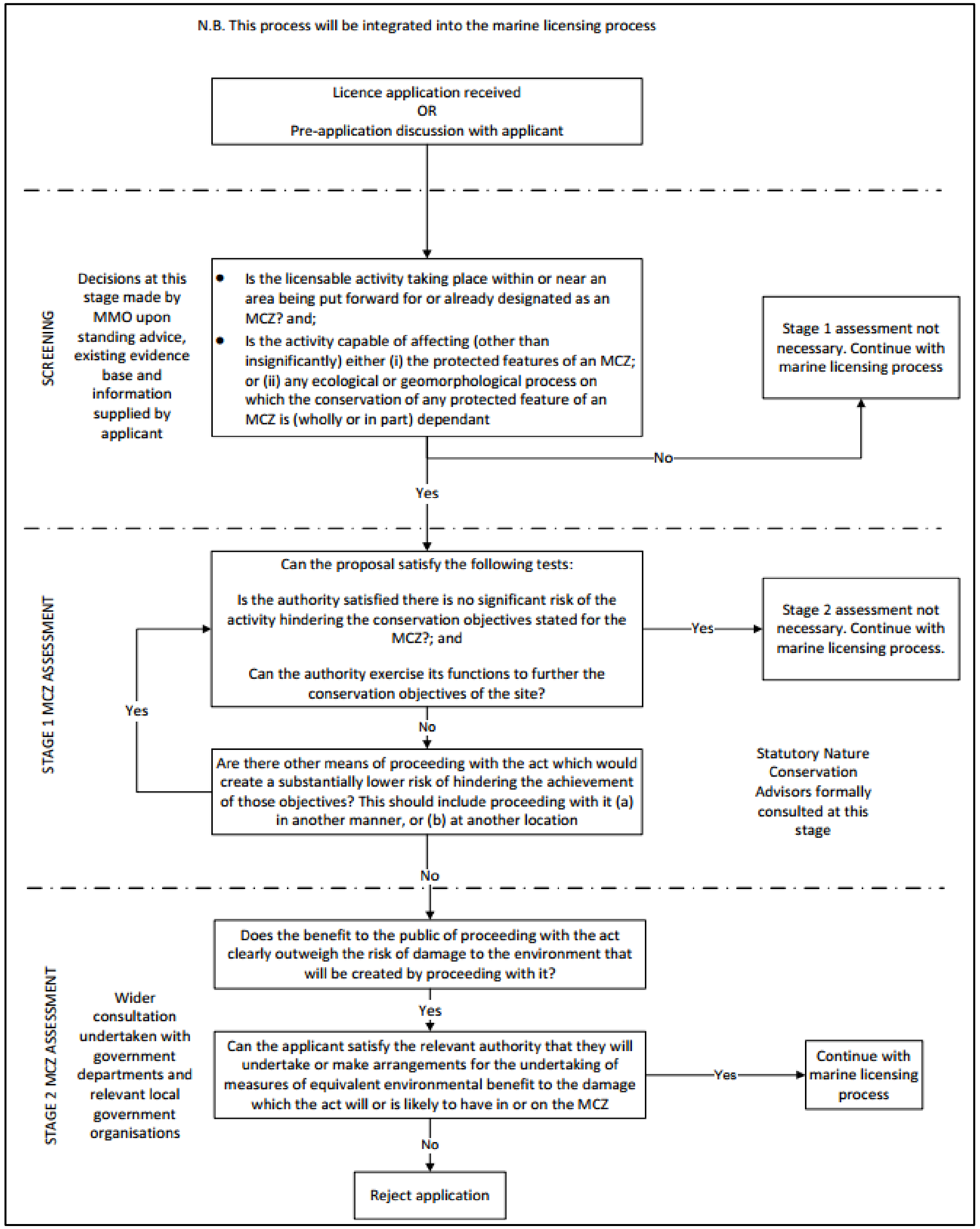
Annex 1 Broad-scale habitat and Features of Conservation Importance (FOCI) map for the Bembridge MCZ. Source: Natural England Marine Protected Area feature data set 2019.



Annex 2 Summary of MMO assessment process for MCZs



Annex 3 Initial screening of commercial fishing activities in the Bembridge MCZ.

Broad Gear Type (for assessment)	Aggregated Gear Type (EMS Matrix)	Fishing gear type	Does it Occur?	Details	Sources of Information	Potential for Activity Occur/ Is the activity anticipated to occur?	Justification	Suitable for Part A Assessment?	Priority
Bottom towed fishing gear	Towed (demersal)	Beam trawl (whitefish)	Unknown		Local IFCO	Y	Vessels in the area actively light otter trawl. Some of these have beam trawl equipment and so this activity has the potential to occur (i.e. suitable trawl ground due to coarse substrate). If the activity were to occur, it would most likely be on an irregular basis on the fringes of the site and has not been seen in the site. The likelihood of the activity occurring is therefore considered to be low.	Y	High
		Beam trawl (shrimp)	N		Local IFCO	N	Target species does not occur.		
		Beam trawl (pulse/wing)	N		Local IFCO	N	Prohibited via Electric fishing byelaw.		
		Heavy otter trawl	N		Local IFCO	N	The activity has the potential to occur but is not anticipated to occur. The boats which operate within the district (and the Solent) are small in nature (restricted to 12 m or less in length) and so are restricted in the size of gear used. This means light otter trawls are used instead of heavy otter trawls.		
		Multi-rig trawls	N		Local IFCO	Y	This activity has not historically occurred and is not currently known to occur. One small vessel operating within district has multi rig trawl gear but has not been seen active in the area. Therefore, the activity is not anticipated to occur.		
		Light otter trawl	Y	Approx. 3 vessels, fishing when weather permits, on the fringes of the site, mainly between March and	Local IFCO	Y	Activity is known to occur.	Y	High

				October when it is not clamming season.					
		Pair trawl	N		Local IFCO	N	It is not anticipated to occur as it has not historically occurred. Furthermore there is limited potential due to the space required to accommodate two vessels and the size/power of vessels needed.		
		Anchor seine	N		Local IFCO	N	Gear type has not been historically used within the area and is not anticipated to occur. Activity needs a large area and in the site considered would be limited. In addition, large vessels are also required for this gear type and vessels over 12 m in length are prohibited from fishing within the Southern IFCA district.		
		Scottish/fly seine	N		Local IFCO	N	Gear type has not been historically used within the area and is not anticipated to occur. Activity needs a large area and in the site considered would be limited. In addition, large vessels are also required for this gear type and vessels over 12 m in length are prohibited from fishing within the Southern IFCA district.		
Pelagic towed fishing gear	Towed (pelagic)	Mid-water trawl (single)	N		Local IFCO	N	Gear type has not been historically used within the area. Activity has the potential to occur however this gear type does not come into contact with the seabed and therefore there is no chance for interaction with designated features.		
		Mid-water trawl (pair)	N		Local IFCO	N	Gear type has not been historically used within the area. Activity has the potential to occur however this gear type does not come into contact with the seabed and therefore there is no chance for interaction with designated features. Also limited potential due to the restricted area of the site to accommodate for two vessels.		

		Industrial trawls	N		Local IFCO	N	Activity is not able to occur due to the size of vessel required. Vessels over 12 m are prohibited from fishing within the Southern IFCA district.		
Bottom towed fishing gear	Dredges (towed)	Scallops	Y	The activity occurs with up to 5 vessels taking part in the fishery. However, a maximum of 3 at a time are seen on the fringes of the site. The fishery occurs over the winter and usually lasts around one month.	Local IFCO	Y	The activity is known to occur.	Y	High
		Mussels, clams, oysters	N		Local IFCO	N	Clam and mussel target species are not known to occur within the site. Oyster dredging has historically taken place within the Solent which the site sits on the outskirts off. The Solent oyster population has since been in decline and there are currently no indications of recovery, however restoration efforts commenced in 2015 and continue to do so. Based on the current status of the Solent oyster population and the direction of decline (from west to east) in the Solent, the activity is not anticipated to occur within the site within the foreseeable future. Furthermore, most of the Solent oyster fishery has been closed to fishing through Southern byelaws over the past several years, and is now entirely closed to oyster fishing.		
		Pump scoop (cockles, clams)	N		Local IFCO	N	A Statutory instrument prohibits pump scoop fishing in the Solent.		

Suction	Dredges (other)	Suction (cockles...)	N		Local IFCO	N	Suction dredging for cockles, clams, mussels and oysters is prohibited (by default) in the Southern IFCA district (by Southern IFCA byelaws).		
Tractor		Tractor	N		Local IFCO	N	The activity has not historically occurred within the site. The potential for activity to occur is limited due to limited access and substrate suitability.		
Intertidal work	Intertidal handwork	Hand working (access from vessel)	N		Local IFCO	N	Hand working with access from a vessel infers a muddy habitat where there difficulty accessing areas. At this site, the dominance of mixed sediments means there is limited need for a vessel as the substrate means the area is accessible on foot.		
		Hand work (access from land)	Y		Local IFCO	Y	Activity is known to occur.	Y	Low to Medium
Static - pots/traps	Static - pots/traps	Pots/creels (crustacea/gastropods)	Y		Local IFCO	Y	Activity is known to occur.	Y	Low to Medium
		Cuttle pots	Y		Local IFCO	Y	Activity is known to occur.		Low to Medium
		Fish traps	N		Local IFCO	N	Activity has not historically occurred within the site and is not anticipated to occur.		
Demersal nets/lines	Static - fixed nets	Gill nets	Y	Less than ten vessels use nets in the site. Some are active all year round whilst others only operate the activity in the summer. The target species are bream, sole, plaice, smooth hound and others.	Local IFCO	Y	Activity is known to occur.	Y	Low to Medium

		Trammels	Y		Local IFCO		See 'gill nets'		Low to Medium
		Entangling	Y		Local IFCO		See 'gill nets'		Low to Medium
Pelagic nets/lines	Passive - nets	Drift nets (pelagic)	N		Local IFCO	N	Activity is not anticipated to occur and potential for the activity is limited by the rushing tide that effects the site, particularly the outer areas.		
Demersal nets/lines		Drift nets (demersal)	N		Local IFCO	N	Activity is not anticipated to occur and potential for the activity is limited by the rushing tide that effects the site, particularly the outer areas.		
	Lines	Longlines (demersal)	Unknown		Local IFCO	Y	It is anticipated that demersal longlines have the potential to be used within the site as they are used in the Solent.	Y	Low to Medium
Pelagic nets/lines		Longlines (pelagic)	Unknown		Local IFCO	N	It is anticipated that demersal longlines have the potential to be used within the site as they are used in the Solent. However this gear type does not come into contact with the seabed and therefore there is no chance for interaction with designated features.		
		Handlines (rod/gurdy etc)	Y		Local IFCO	Y	The activity is known to occur however this gear type does not come into contact with the seabed and therefore there is no chance for interaction with designated features. Shore-based angling is limited and due to the nature of the shoreline is highly unlikely to interact with any of the designated features (which are predominantly subtidal).		
		Jigging/trolling	Y	See 'handlines (rod/gurdy etc)'	Local IFCO	Y	See 'handlines (rod/gurdy etc)'		
Purse seine	Seine nets and other	Purse seine	N		Local IFCO	N	Activity has not historically occurred within the site and is not anticipated to occur.		
Demersal nets/lines		Beach seines/ring nets	N		Local IFCO	N	Activity has not historically occurred within the site and is not anticipated to occur.		

Miscellaneous		Shrimp push-nets	Unknown		Local IFCO	Y	The occurrence of the activity is unknown as it could occur by recreational fishers. It is not anticipated to occur as it is not thought to have occurred historically within the site. The activity has the potential to occur but is unlikely to because of a lack of areas with suitable substrate to support the target species. In addition, activity is conducted intertidally and designated features are not intertidal and therefore whilst there is limited potential for the activity to occur it will not take place over designated features.		
EA Only		Fyke and stake nets	**EA Only**						
Miscellaneous	Miscellaneous	Commercial diving	N			N	Activity has not historically occurred and is not anticipated to occur.		
Bottom towed fishing gear		Bait dragging	N			N	Activity has not historically occurred within the site and is not anticipated to occur. The majority substrate present is not suitable for the activity to take place. As such, the target species are also not present.		
Miscellaneous		Crab tiling	N			Y	There is the potential that the activity could occur within the site.	Y	
Intertidal work	Bait collection	Digging with forks	Y	Hand gathering activity is believed to occur.		Y	There is potential that hand gathering activity using forks could occur in the site.	Y	

Annex 4 Advice on operations for commercial fishing activities in The Needles MCZ (Demersal trawl only)

Pressure Name	Habitat										Species		
	High energy infralittoral rock	Moderate energy infralittoral rock	Seagrass beds	Sheltered muddy gravels	Subtidal chalk	Subtidal coarse sediment	Subtidal mixed sediments	Subtidal mud	Subtidal sand	Moderate energy circalittoral rock	Native oyster	Peacock's tail	Stalked jellyfish (Calvadosia campanulata)
Abrasion/disturbance of the substrate on the surface of the seabed	S	S	S	S	S	S	S	S	S	S	S	S	S
Changes in suspended solids (water clarity)	S	S	S	S	S	S	S	S	S	S	S	NS	S
Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion		S	S	S	S	S	S	S	S	S	S		S
Removal of non-target species	S	S	S	S	S	S	S	S	S	S	S	S	S
Smothering and siltation rate changes (Light)	NS	S	S	S	S	IE	S	S	S	S	S	S	S
Deoxygenation	IE	S	NS	S	IE	S	S	S	S	S	NS	NS	IE
Hydrocarbon & PAH contamination	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Introduction of light	S	S	S	IE	S	IE	IE	NS	S	IE	NS	NS	IE

Introduction or spread of invasive non-indigenous species (INIS)	S	S	S	S	S	IE	S	S	S	S	S	IE	IE
Litter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nutrient enrichment	S	NS	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	S
Organic enrichment	S	S	S	S	NS	S	S	S	S	S	IE	NS	S
Physical change (to another seabed type)	S	S		S						S	S	S	S
Physical change (to another sediment type)			S		S	S	S	S	S		NS		S
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Transition elements & organo-metal (e.g. TBT) contamination	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Underwater noise changes							NS	NS	NS	NS			
Visual disturbance		NS			NS		NS	NS	NS	NS			

Annex 5 Advice on operations for commercial fishing activities in The Needles MCZ (Dredges only)

Pressure Name	Habitat										Species		
	High energy infralittoral rock	Moderate energy infralittoral rock	Seagrass beds	Sheltered muddy gravels	Subtidal chalk	Subtidal coarse sediment	Subtidal mixed sediments	Subtidal mud	Subtidal sand	Moderate energy circalittoral rock	Native oyster	Peacock's tail	Stalked jellyfish (Calvadosia
Abrasion/disturbance of the substrate on the surface of the seabed	S	S	S	S	S	S	S	S	S	S	S	S	S
Changes in suspended solids (water clarity)	S	S	S	S	S	S	S	S	S	S	S	NS	S
Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion		S	S	S	S	S	S	S	S	S	S		S
Removal of non-target species	S	S	S	S	S	S	S	S	S	S	S	S	S
Removal of target species	NA	NA	S		NA	NA	NA	NA	NA	NA	S		
Smothering and siltation rate changes (Light)	NS	S	S	S	S	IE	S	S	S	S	S	S	S
Visual disturbance		NS			NS		NS	NS	NS	NS			
Deoxygenation	IE	S	NS	S	IE	S	S	S	S	S	NS	NS	IE
Hydrocarbon & PAH contamination	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Introduction of light	S	S	S	IE	S	IE	IE	NS	S	IE	NS	NS	IE
Introduction of microbial pathogens	S	S	S	S	NS	IE	S	S	S	S	S	IE	IE
Introduction or spread of invasive non-indigenous species (INIS)	S	S	S	S	S	IE	S	S	S	S	S	IE	IE
Litter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nutrient enrichment	S	NS	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	S
Organic enrichment	S	S	S	S	NS	S	S	S	S	S	IE	NS	S
Physical change (to another seabed type)	S	S		S						S	S	S	S
Physical change (to another sediment type)			S		S	S	S	S	S		NS		S
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Transition elements & organo-metal (e.g. TBT) contamination	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Underwater noise changes							NS	NS	NS	NS			

Annex 6 Advice on operations for commercial fishing activities in The West of Walney MCZ (Demersal trawl only)

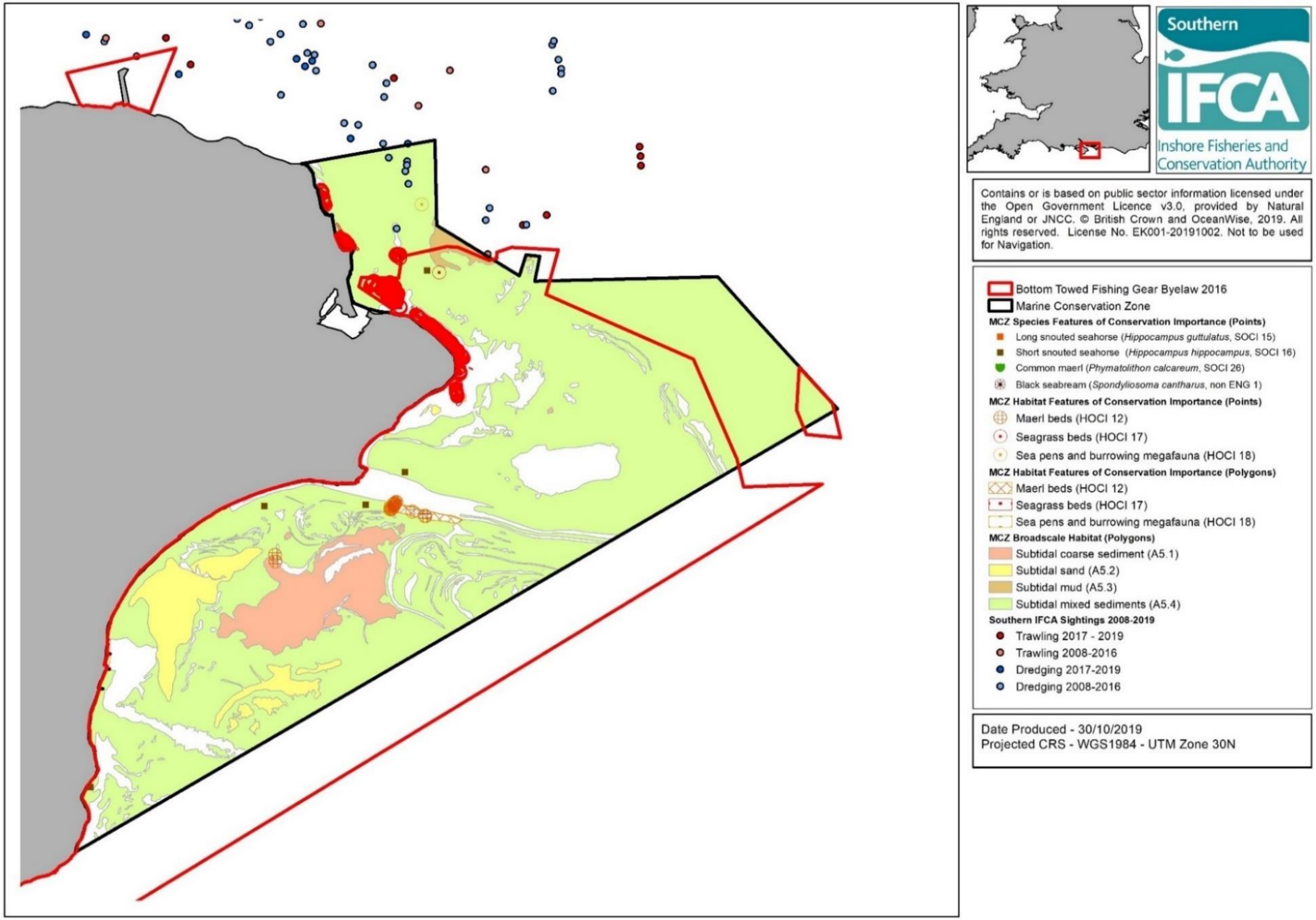
	Habitat		
Pressure Name	Subtidal mud	Subtidal sand	Sea pens and burrowing megafauna
Abrasion/disturbance of the substrate on the surface of the seabed	S	S	S
Changes in suspended solids (water clarity)	S	S	NS
Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion	S	S	S
Removal of non-target species	S	S	S
Removal of target species			NS
Smothering and siltation rate changes (Light)	S	S	NS
Deoxygenation	S	S	S
Hydrocarbon & PAH contamination	NA	NA	NA
Introduction of light	NS	S	NS
Introduction or spread of invasive non-indigenous species (INIS)	S	S	IE
Litter	NA	NA	NA
Nutrient enrichment	NS	NS	NS
Organic enrichment	S	S	S
Physical change (to another sediment type)	S	S	S
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	NA	NA	NA
Transition elements & organo-metal (e.g. TBT) contamination	NA	NA	NA
Underwater noise changes		NS	

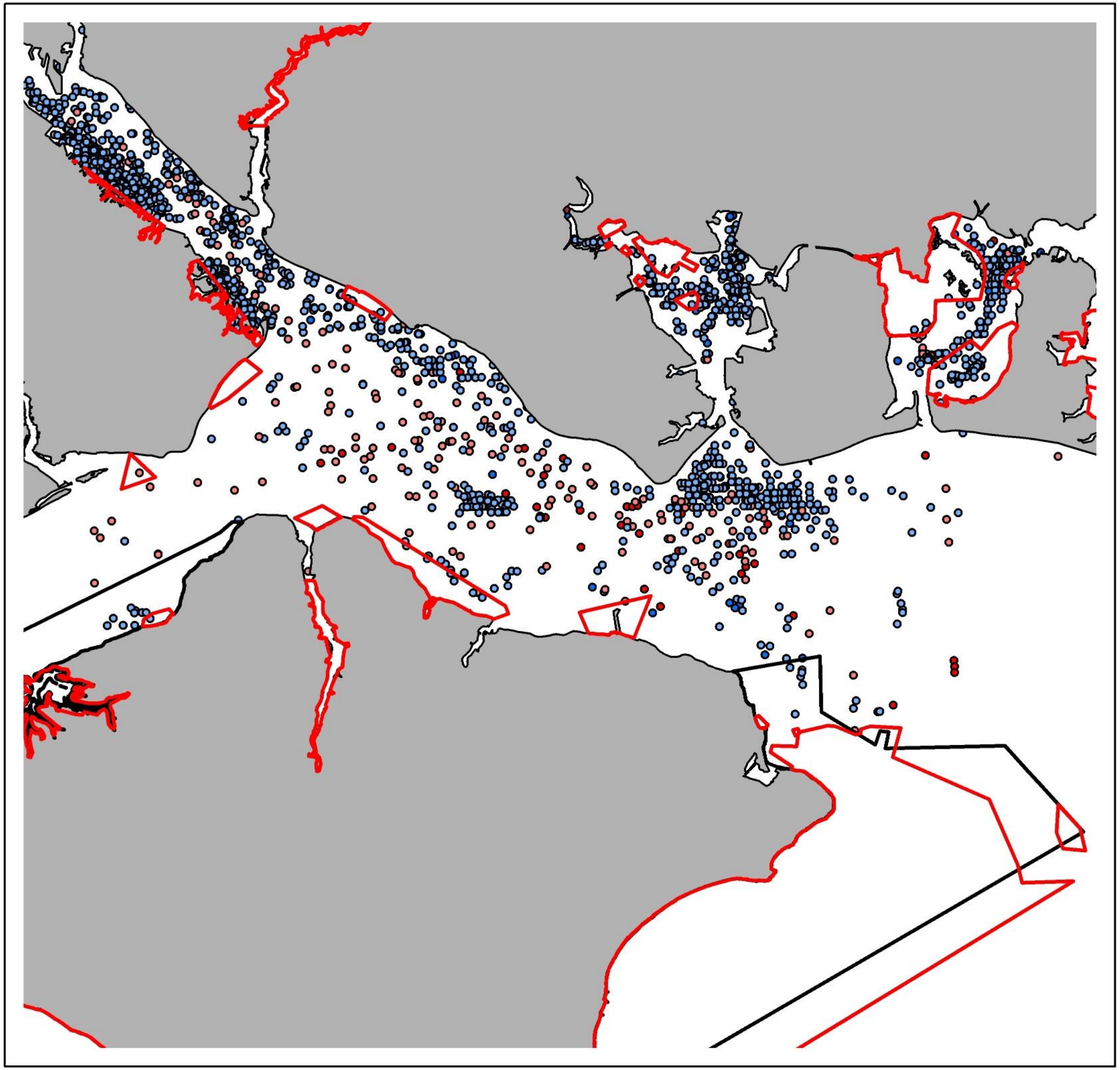
Visual disturbance		NS	

Annex 7 Advice on operations for commercial fishing activities in The West of Walney MCZ (Dredges only)

	Habitat		
Pressure Name	**Subtidal mud**	**Subtidal sand**	**Sea pens and burrowing megafauna**
Abrasion/disturbance of the substrate on the surface of the seabed	S	S	S
Changes in suspended solids (water clarity)	S	S	NS
Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion	S	S	S
Removal of non-target species	S	S	S
Removal of target species	NA	NA	
Smothering and siltation rate changes (Light)	S	S	NS
Visual disturbance		NS	
Deoxygenation	S	S	S
Hydrocarbon & PAH contamination	NA	NA	NA
Introduction of light	NS	S	NS
Introduction of microbial pathogens	IE	S	S
Introduction or spread of invasive non-indigenous species (INIS)	S	S	IE
Litter	NA	NA	NA
Nutrient enrichment	NS	NS	NS
Organic enrichment	S	S	S
Physical change (to another sediment type)	S	S	S
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	NA	NA	NA
Transition elements & organo-metal (e.g. TBT) contamination	NA	NA	NA
Underwater noise changes		NS	

Annex 8. Fishing activity maps using trawl and dredge sightings data from 2008-2019 in (a) Bembridge MCZ and (b) Eastern Solent.





Southern IFCA
Inshore Fisheries and Conservation Authority

Bottom Towed Fishing Gear Byelaw 2016
Marine Conservation Zone
Sightings-BTFG-2008-2019
Southern IFCA Sightings 2008-2019
- Trawling 2017 - 2019
- Trawling 2008-2016
- Dredging 2017-2019
- Dredging 2008-2016

Date Produced - 14/11/2019
Projected CRS - WGS1984 - UTM Zone 30N