Document Control

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Date	Author	Version	Status	Reason	Approver(s)
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This document has been distributed for information and comment to:

Title	Name	Date sent	Comments received
HRA - Solent Maritime SAC – Beam trawl (whitefish) & Light otter trawl (v1.4)	Natural England	08/02/2016	30/03/2016
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Southern Inshore Fisheries and Conservation Authority (IFCA)

Fisheries in EMS Habitats Regulations Assessment for amber and green risk categories

European Marine Site: Solent Maritime SAC (UK0030059)

Feature(s): Sandbanks slightly covered by seawater all the time

Generic Feature(s): -

Site Specific Sub-feature(s): Subtidal gravelly sand and sand; Subtidal muddy sand communities;

Generic Sub-feature(s): Subtidal gravel and sand, Subtidal muddy sand (Subtidal mixed sediments; Subtidal sand)[1]

Gear type(s) Assessed: Beam trawl (whitefish); Light otter trawl

[1] These are additional sub-features used in feature mapping provided by Natural England

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1. Introduction

1.1 Need for an HRA assessment

Southern IFCA has duties under Regulation 9(3) of the Conservation of Habitats and Species Regulations 2010 as a competent authority, with functions relevant to marine conservation to exercise those functions so as to secure compliance with the Habitats Directive. Article 6.2 of the Habitats Directive requires appropriate steps to be taken to avoid, in Natura 2000 sites, the deterioration of natural habitats and habitats of species as well as significant disturbance of the species for which the area has been classified.

Management of European Marine Sites is the responsibility of all competent authorities which have powers or functions which have, or could have, an impact on the marine area within or adjacent to a European Marine Site (EMS). Under section 36 of the Species and Habitats Regulations (2010):

“The relevant authorities, or any of them, may establish for a European marine site a management scheme under which their functions (including any power to make byelaws) are to be exercised so as to secure in relation to that site compliance with the requirements of the Habitats Directive.”

Within the Solent EMS such a management scheme has been developed in the form of the SEMS management scheme which was established in 2004. This resulted in the establishment of a framework for the effective management of the Solent EMS so that the conservation objectives are met. The key principles of the management scheme are included in Annex 2.

In the SEMs Management Group 2015 Monitoring Report, fishing activities have been flagged to be a high risk or (Tier 1) activity. High risk activities are considered as potentially representing a high risk and/or not having sufficient “systems in place to ensure they are managed in line with the Habitats Regulations” and, therefore, requiring further management consideration. During the 2015 consultation a request was made to reduce the risk of fishing activity from high to medium risk. The response from the group was that in order to do this a clear audit and evidence trail would be required to reduce the risk. This assessment, in line with Article 6.2 of the Habitats Directives, will form part of that audit trail, as will other assessments regarding the fishing activities within the Solent EMS. It is considered that some level of management will be required for high risk activities within the EMS.

This audit trail will be achieved through Southern IFCA’s responsibilities under the revised approach to the management of commercial fisheries in European Marine sites announced by the Department for Environment, Food and Rural Affairs (DEFRA).

The objective of this revised approach is to ensure that all existing and potential commercial fishing activities in European Marine Sites are managed in accordance with Article 6 of the Habitats Directive. Articles 4.1 and 4.2 of the Birds Directive also require that the Member States ensure the species mentioned in Annex I and regularly occurring migratory bird species are subject to special conservation measures concerning their habitat in order to ensure survival and reproduction in their area of distribution. This affords Special Protection Areas (SPAs) a similar protection regime to that of Special Areas of Conservation (SACs).

This approach is being implemented using an evidence-based, risk-prioritised, and phased approach. Risk prioritisation is informed by using a matrix of the generic sensitivities of the sub-features of the EMS to a suite of fishing activities as a decision making tool. These sub-feature-activity combinations have been categorised according to specific definitions, as red[2], amber[3], green[4] or blue[5].

Activity/feature interactions identified within the matrix as red risk have the highest priority for implementation of management measures by the end of 2013 in order to avoid the deterioration of Annex I features in line with obligations under Article 6(2) of the Habitats Directive.

Activity/feature interactions identified within the matrix as amber risk require a site-level assessment to determine whether management of an activity is required to conserve site features. Activity/feature interactions identified within the matrix as green also require a site level assessment if there are "in-combination effects" with other plans or projects.

Site level assessments are being carried out in a manner that is consistent with the provisions of Article 6(3) of the Habitats Directive, but are required to meet the 6(2) responsibilities of Southern IFCA as a competent authority. The aim of the assessment will be to consider if the activity could significantly disturb the species or deteriorate natural habitats or the habitats of the protected species and from this, a judgement can be made as to whether or not the conservation measures in place are appropriate to maintain and restore the habitats and species for which the site has been designated to a favourable conservation status (Article 6(2)). If measures are required, the revised approach requires these to be implemented by 2016.

The purpose of this site specific assessment document is to assess whether or not in the view of Southern IFCA the fishing activities 'Beam trawling (whitefish) and 'Light otter trawling' have a likely significant effect on 'Sandbanks slightly covered by seawater all the time' of the Solent Maritime SAC; and on the basis of this assessment whether or not it can be concluded that the beam trawling (whitefish) and light otter trawling will not have an adverse effect on the integrity of this EMS.

1.2 Documents reviewed to inform this assessment

- SEMs Annual Monitoring Report 2015
- SEMs Delivery Plan 2014
- Natural England's risk assessment Matrix of fishing activities and European habitat features and protected species[6]
- Reference list[7] (Annex 1)
- Natural England's Regulation 33 advice[8]/ Natural England's Interim Conservation Advice

[2] Where it is clear that the conservation objectives for a feature (or sub-feature) will not be achieved because of its sensitivity to a type of fishing, - irrespective of feature condition, level of pressure, or background environmental conditions in all EMSs where that feature occurs – suitable management measures will be identified and introduced as a priority to protect those features from that fishing activity or activities.

[3] Where there is doubt as to whether the conservation objectives for a feature (or sub-feature) will be achieved because of its sensitivity to a type of fishing, in all EMSs where that feature occurs, the effect of that activity or activities on such features will need to be assessed in detail at a site specific level. Appropriate management action should then be taken based on that assessment.

[4] Where it is clear that the achievement of the conservation objectives for a feature is highly unlikely to be affected by a type of fishing activity or activities, in all EMSs where that feature occurs, further action is not likely to be required, unless there is the potential for in combination effects.

[5] For gear types where there can be no feasible interaction between the gear types and habitat features, a fourth categorisation of blue is used, and no management action should be necessary.

[6] See Fisheries in EMS matrix: http://www.marinemanagement.org.uk/protecting/conservation/documents/ems_fisheries/populated_matrix3.xls

[7] Reference list will include literature cited in the assessment (peer, grey and site specific evidence e.g. research, data on natural disturbance/energy levels etc)

[8] Solent EMS Regulation 33 Conservation Advice: http://publications.naturalengland.org.uk/publication/3194402

- Site map(s) – sub-feature/feature location and extent (Annex 3)
- Fishing activity data (map(s), etc) (Annex 4)
- Fisheries Impact Evidence Database (FIED)

2. Information about the EMS

- Solent Maritime SAC (UK0030059)

2.1 Overview and qualifying features

- H1110. Sandbanks which are slightly covered by sea water all the time
    - Subtidal gravelly sand and sand
    - Subtidal muddy sand communities
    - Subtidal eelgrass *Zostera marina* beds
- H1130. Estuaries
- H1140. Mudflats and sandflats not covered by seawater at low tide
- H1150. Coastal lagoons*
- H1210. Annual vegetation of drift lines
- H1220. Perennial vegetation of stony banks; Coastal shingle vegetation outside the reach of waves
- H1310. *Salicornia* and other annuals colonising mud and sand; Glasswort and other annuals colonising mud and sand
- H1320. *Spartina* swards (*Spartinion maritimae*); Cord-grass swards
- H1330. Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)
- H2120. Shifting dunes along the shoreline with *Ammophila arenaria* ("white dunes"); Shifting dunes with marram
- S1016*. Vertigo moulinsiana*; Desmoulin`s whorl snail

Please refer to Annex 3 for a site feature map.

The Solent Maritime SAC is located in one of only a few major sheltered channels in Europe, lying between a substantial island (the Isle of Wight) and the mainland. The Solent and its inlets are unique in Britain and Europe for their complex tidal regime, with long periods of tidal stand at high and low tide, and for the complexity and particularly dynamic nature of the marine and estuarine habitats present within the area. There is a wide variety of marine sediment habitats influenced by a range of salinities, wave shelter and intensity of tidal streams, resulting in a uniquely complex site. Sediment habitats within the estuaries include extensive areas of estuarine flats, with intertidal areas often supporting eelgrass *Zostera sp.* and green algae, saltmarshes and natural shoreline transitions, such as drift line vegetation.

2.2 Conservation Objectives

The Conservation Objectives for the Solent Maritime SAC features:

- H1110. Sandbanks which are slightly covered by sea water all the time

Are to "ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the Favourable Conservation Status of its Qualifying Features, by maintaining or restoring;

- The extent and distribution of qualifying natural habitats and habitats of qualifying species
- The structure and function (including typical species) of qualifying natural habitats
- The structure and function of the habitats of qualifying species

- The supporting processes on which qualifying natural habitats and the habitats of qualifying species rely
- The populations of qualifying species, and,
- The distribution of qualifying species within the site."

The high level conservation objectives for the Solent Maritime SAC are available online at: http://publications.naturalengland.org.uk/publication/5762436174970880

3. Interest feature(s) of the EMS categorised as 'Red' risk and overview of management measure(s)

- Subtidal eelgrass *Zostera marina* beds

A red risk interaction between bottom towed gears and eelgrass/seagrass beds was identified and subsequently addressed through the creation of the 'Bottom Towed Fishing Gear' byelaw[9] and 'Prohibition of Gathering (Sea Fisheries Resources) in Seagrass Beds' byelaw[10]. The 'Bottom Towed Fishing Gear' prohibits the use any bottom towed fishing gear within sensitive areas (characterised by reef features or eelgrass/seagrass beds) in European Marine Sites throughout the district. The byelaw also states that if transiting through a prohibited area carrying bottom towed fishing gear, all parts of the gear are inboard and above the sea. Within the Solent EMS, which includes waters to the north of the Isle of Wight, all eastern harbours and Southampton Water, there are 20 prohibited areas. The 'Prohibition of Gathering (Sea Fisheries Resources) in Seagrass Beds' byelaw prevents digging, fishing for or taking any sea fisheries resource in or from prohibited areas containing eelgrass/seagrass beds in European Marine Sites throughout the District. Exceptions to the prohibition include if a net, rod and line or hook and line are used, in addition to the use of a vessel as long as the vessel's hull is not in contact with the seabed. It is also prohibited to carry a rake, spade, fork or any similar tool within specified areas. Within the Solent EMS, which includes north of the Isle of Wight, all eastern harbours and Southampton Water, there are 25 prohibited areas.

4. Information about the fishing activities within the site

4.1 Activities under Consideration/Summary of Fishery

Trawling, using beam trawl and light otter trawl, can take place all year round within the Solent Maritime SAC. 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. Trawling is also undertaken for bait, such as pout, that is subsequently used for longlining.

4.2 Technical Gear Specifications

Two types of demersal trawl are used to fish for a number of fish species within the Solent Maritime SAC. These are a beam trawl and light otter trawl.

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[9] Bottom Towed Fishing Gear Byelaw: https://secure.toolkitfiles.co.uk/clients/25364/sitedata/files/PDFbyelaw_bottomtowedfishi.pdf

[10] Prohibition of Gathering (Sea Fisheries Resources) in Seagrass Beds Byelaw: https://secure.toolkitfiles.co.uk/clients/25364/sitedata/files/PDFbyelaw_prohibitionofgat.pdf

4.2.1 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 1) (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 2) (Seafish, 2015). Lighter styles of beam, using fewer tickler chains and without a chain mat, are used to target shrimp (Seafish, 2015).

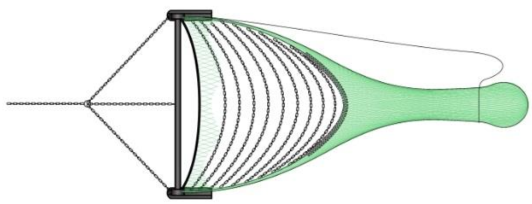


Figure 1. 'Open gear' beam trawl.

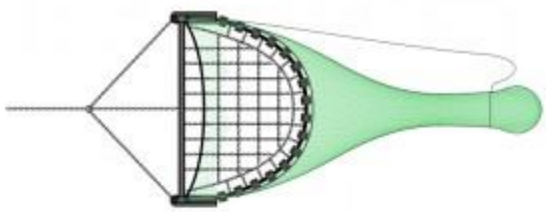


Figure 2. 'Chain mat gear' beam trawl.

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 size of trawls used in the Solent are approximately 3 m in width and weigh 650 kg with a chain matrix.

4.2.2 Light otter trawl

An otter trawl comprises of following design (see Figure 3). 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).

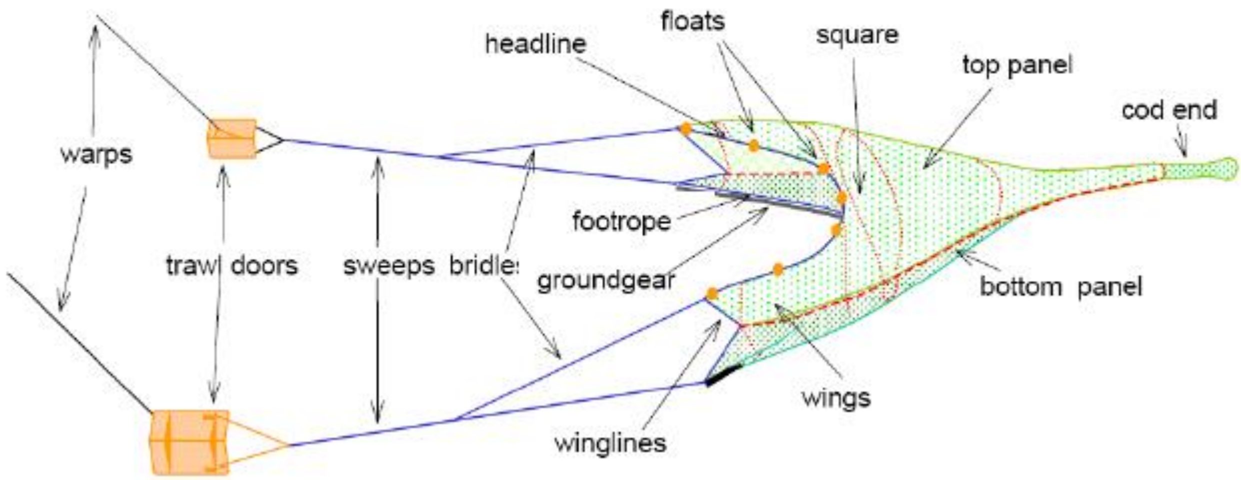


Figure 3. Key components of an otter trawl.
Source: www.seafish.org/upload/b2b/file/r_d/BOTTOM%20TRAWL_5a.pdf

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)[11]. 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).

4.3 Location, Effort and Scale of Fishing Activities

Trawling takes place subtidally and is generally focused in the central and eastern Solent, commonly between the Brambles to the end of Ryde pier on the north coast of the Isle of Wight (Annex 4). Trawling also occurs, albeit at lower levels, in the western Solent between Yarmouth and Cowes and up Southampton Water, although the latter is often for bait. Areas in which trawling are likely to occur within the Solent Maritime SAC include Yarmouth to Cowes and the area outside of Langstone and Chichester Harbours.

Sightings data in Annex 4 (split between 2005 to 2010 and 2011 to 2015) illustrates that trawling is focused subtidally in the central and eastern Solent, as well as into Southampton Water, although the latter may be more a reflection of patrol routes. The areas fished between 2005 and 2010 and 2011 and 2015 largely overlap and do not appear to significantly differ from one another. Having said this, the level of trawl sightings in the western Solent appears to be slightly higher between 2011 and 2015 and in the eastern Solent, the areas fished appears to have extended more eastwards, occurring outside the entrance to the harbours. 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. It is also worth noting that sightings data does not differentiate between the types of trawl used.

The total number of vessels operating within the fishery is approximately 10, 7 of which are regularly participating, with no more than 5 vessels operating at any one time (Southern IFCA Committee Member Pers. Comm). These vessels operate out of Portsmouth and Lymington. All vessels use light otter trawl and a number of switch between light otter trawl and beam trawl, although only a handful use a beam trawl (Southern IFCA Committee Member Pers. Comm).

Table 1 shows that the number of vessels sighted to be trawling is variable between years, with the average number of fishing vessels sighted per month showing a higher level of activity in 2014 and 2015 (so far). The maximum number of vessels sighted was in November 2014 at 12. Over the five years, there were only two instances where one vessel was sighted five or more times in one month. Overall, the sightings reflect a relatively low level of fishing activity within the Solent. Please note that Southern IFCA's sighting data is only indicative of fishing activity when land and sea patrols take place and therefore is likely to underestimate fishing activity.

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

Table 1. Trawling vessel sightings in the Solent from 2011 to 2015, from data collected during sea and land patrols.

Year	Month	No. of fishing vessels sighted	No. of fishing vessels sighted twice or more	No. of fishing vessels sighted 5 times or more
2011	Jan	0	0	0
	Feb	0	0	0
	Mar	0	0	0
	Apr	3	1	0
	May	3	1	0
	Jun	0	0	0
	Jul	0	0	0
	Aug	1	1	0
	Sep	3	0	0
	Oct	1	1	0
	Nov	4	3	1
	Dec	2	1	0
	Average	**1.4**	**0.7**	**0.1**
2012	Jan	2	0	0
	Feb	0	0	0
	Mar	1	0	0
	Apr	0	0	0
	May	0	0	0
	Jun	1	0	0
	Jul	0	0	0
	Aug	0	0	0
	Sep	1	0	0
	Oct	0	0	0
	Nov	0	1	0
	Dec	0	0	0
	Total	**1.4**	**0.1**	**0**
2013	Jan	0	0	0
	Feb	0	0	0
	Mar	0	0	0
	Apr	0	0	0
	May	1	0	0
	Jun	0	0	0
	Jul	0	0	0
	Aug	0	0	0
	Sep	0	0	0
	Oct	0	0	0
	Nov	1	0	0
	Dec	0	0	0
	Average	**0.2**	**0**	**0**
2014	Jan	0	0	0
	Feb	0	0	0
	Mar	1	0	0
	Apr	2	0	0
	May	3	2	0

	Jun	0	0	0
	Jul	2	1	0
	Aug	1	0	0
	Sep	10	4	1
	Oct	7	3	0
	Nov	12	1	0
	Dec	1	0	0
	Average	**3.3**	**0.9**	**0.1**
2015	Jan	0	0	0
	Feb	1	0	0
	Mar	0	0	0
	Apr	7	2	0
	May	0	0	0
	Jun	2	2	0
	Jul	3	0	0
	Aug	3	0	0
	Sep	1	0	0
	Oct			
	Nov			
	Dec			
	Average	**1.9**	**0.4**	**0**

Landings data provided by the Marine Management Organisation (MMO) show the greatest concentrations of all fish species between 2005 and 2014 were landed into Portsmouth (Table 2). Changes in overall landings for this period are variable and show no particular pattern for all species (Figure 3). The highest quantities of fish landed were of plaice, followed by sole and bass. Landings of both sole and plaice appear to be highest from 2005 to 2009, with landings of plaice peaking again in 2012 and 2013. Sole landings show an overall decline between 2005 and 2013, with higher catches in 2014. Bass landings appeared to peak in 2009, but landings thereafter showed a general decline. 2011 appears to have been a particularly poor year for all species. The high number of number of trawl vessel sightings (detailed in table 2) in 2014 is not reflected in the landings for this year. Please note that landings data should be viewed with caution, although reflective of the overall trends of the fishery. Exact figures are not always accurate; however this data represents the best available information to date.

Other notable species, which were also identified from the MMO landings data, include unidentified dogfish, cuttlefish and skates and rays. This highlights the large range of species caught through this activity.

Table 2. Landings (in tonnes) from 2005 to 2014 of key fish species (plaice, sole, bass) into ports located within the Solent European Marine Site (EMS) caught by UK vessels using a trawl (beam trawl, otter trawl (bottom), otter trawls (not specified)). Data was provided by the Marine Management Organisation (MMO).

		Landings (Tonnes)									
	Port of Landing	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Plaice	Cowes						0.212	0.780	0.744		
	Emworth			0.189	0.018						0.020
	Hamble			0.015							

	Isle of Wight	0.108	0.269	2.184	0.795	0.107	0.060	0.008	0.011		
	Lymington & Keyhaven	0.115	0.361	0.013	0.067	0.181	0.837	0.655	0.332	0.623	5.873
	Portsmouth	19.316	15.163	11.220	30.860	22.567	5.210	4.470	28.760	19.536	6.164
	Southampton		0.285	0.135	0.453	0.198	0.311	0.468	0.194	0.017	0.253
	Total	**77.825**	**63.128**	**50.1**	**126.626**	**91.619**	**24.616**	**22.045**	**117.384**	**80.064**	**43.074**
Sole	Cowes						1.078	2.745	0.120		
	Emworth		0.458	0.021							0.005
	Hamble			0.233							
	Isle of Wight	1.321	0.566	1.748	1.069	0.040	0.159	0.016	0.047		
	Lymington and Keyhaven	0.192	1.400	0.587	0.901	0.590	4.067	3.429	0.973	1.342	8.764
	Portsmouth	34.741	27.647	18.141	28.293	21.164	5.249	0.959	2.989	4.163	10.891
	Southampton		4.176	0.298	2.263	1.428	2.265	0.963	0.720	0.005	0.398
	Total	**72.508**	**68.494**	**42.289**	**65.052**	**46.444**	**24.558**	**13.479**	**9.578**	**11.020**	**40.116**
Bass	Cowes						0.316	1.072	0.060		
	Emworth		0.082	0.005							0.044
	Hamble		0.082								
	Isle of Wight	0.463	0.534	0.574	0.128	0.029	0.001	0.009	0.005		
	Lymington and Keyhaven	1.414	2.402	0.085	0.434	0.730	1.396	1.273	0.968	0.396	4.611
	Portsmouth	3.81	2.28	3.742	7.856	11.892	8.533	1.686	6.359	3.66	0.136
	Southampton		1.055	0.108	0.448	0.208		0.598	0.168	0.356	0.634
	Total	**14.721**	**15.507**	**12.299**	**25.908**	**37.789**	**28.708**	**10.479**	**21.582**	**12.84**	**11.576**

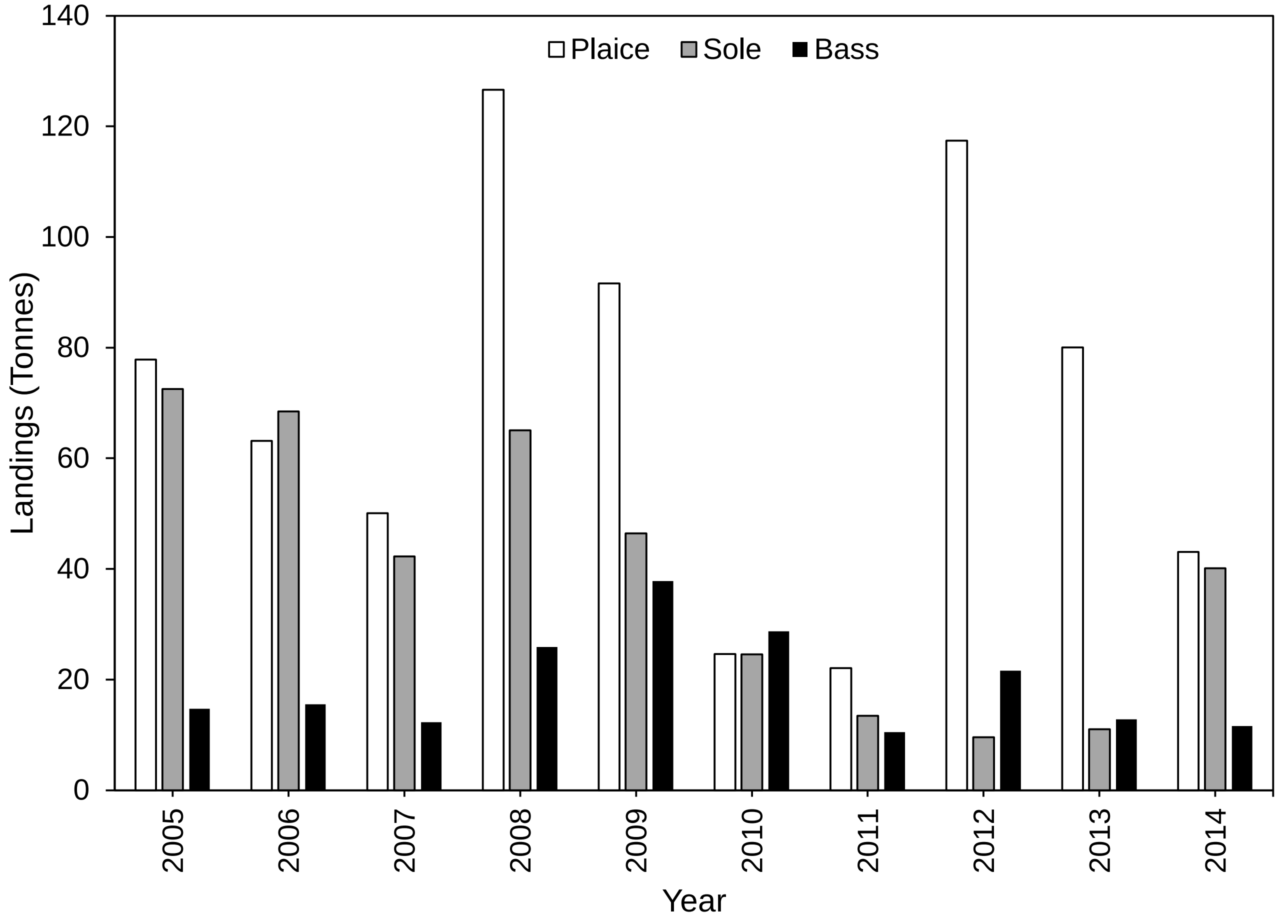


Figure 4. Total landings (in tonnes) from 2005 to 2014 of key fish species (plaice, sole, bass) into ports (Cowes, Emsworth, Hamble, Isle of Wight, Lymington & Keyhaven, Portsmouth, Southampton) located within the Solent European Marine Site (EMS) caught by UK vessels using a trawl (beam trawl, otter trawl (bottom), otter trawls (not specified)). Data was provided by the Marine Management Organisation (MMO).

5. Test of Likely Significant Effect (TLSE)

The Habitats Regulations assessment (HRA) is a step-wise process and is first subject to a coarse test of whether a plan or project will cause a likely significant effect on an EMS[12]. Each feature/sub-feature was subject to a separate TLSE, so the results are summarised in Table 3.

5.1 Table 3: Summary of LSE Assessment(s) – Subtidal gravel and sand

1. Is the activity/activities directly connected with or necessary to the management of the site for nature conservation?	No

[12] Managing Natura 2000 sites: http://ec.europa.eu/environment/nature/natura2000/management/guidance_en.htm

<table>
<tr><td rowspan="3">2. What potential pressures, exerted by the gear type(s), are likely to affect the feature(s)/sub-feature(s)?</td><td colspan="2">Regulation 33 CA/Interim CA:
1. Physical loss - removal
2. Physical loss - smothering
3. Physical damage – siltation/ Siltation rate changes (low), including smothering/ Siltation rate changes (high), including smothering
4. Physical damage – abrasion/ 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
5. Toxic contamination - introduction of synthetic/non-synthetic compounds
6. Non-toxic contamination - changes in nutrient loading/organic loading/ Organic enrichment
7. Non-toxic contamination - changes in turbidity/ Changes in suspended solids (water clarity)
8. Introduction of non-native species and translocation/ introduction or spread of non-indigenous species
9. Selective extraction of species/ Removal of non-target species
10. Interim CA only: Litter
11. Interim CA only: Physical change (to another seabed type)</td></tr>
</table>

<table>
<tr><td rowspan="3">3. Is the feature(s)/sub-features(s) likely to be exposed to the pressure(s) identified?</td><td>Pressure</td><td>Screening - Justification</td></tr>
<tr><td>3.</td><td>IN – This gear is known to cause the resuspension of finer sediments through disturbance to the seabed. Changes of siltation in areas of coarse sediment are highly unlikely to occur, however communities which inhabit areas of sand and gravel are sensitive to excessive inputs of fine material. Enhanced siltation rates and subsequent smothering may arise as an indirect effect of this activity occurring in adjacent sediment types (i.e. subtidal mud/subtidal muddy sand). Further investigation is needed on the magnitude of the pressure, including the effect of the gear and the spatial scale/intensity of the activity on different sediment types.</td></tr>
<tr><td>4.</td><td>IN – This gear type is known to cause abrasion and disturbance to the seabed surface, including potential changes in topography. Further investigation is needed on the magnitude of the pressure, including the effect of the gear and the spatial scale/intensity of the activity.</td></tr>
</table>

	9.	IN – Extraction of species can be limited by minimum landing sizes depending on the species. Typically, demersal fish species are targeted and removed and therefore is unlikely to have a significant impact on the biotope or communities associated with this feature type. Impacts on the associated community may however occur through the removal of larger epifaunal and potentially infaunal species, whilst smaller organisms are likely to pass through the gear. It is however likely to disturb smaller species through physical abrasion of the gear. Further investigation is needed as to the magnitude of removal and disturbance to associated communities/species.
4. What key attributes of the site are likely to be affected by the identified pressure(s)?	Regulation 33/Interim CA: - Topography - Sediment character/Sediment composition and distribution - Range and distribution of characteristic mud biotopes, for example: LMU biotopes/Presence and spatial distribution of intertidal mixed sediment communities/Presence and abundance of typical species/Species composition of component communities	
5. Potential scale of pressures and mechanisms of effect/impact (if known)	Refer to full LSEs.	
6. Is the potential scale or magnitude of any effect likely to be significant?	**Alone** Yes	**OR In-combination**[13] N/A
6. Have NE been consulted on this LSE test? If yes, what was NE's advice?	Please refer to letters from Natural England dated 12/01/2016 & 01/03/16.	

6. Appropriate Assessment

6.1 Co-location of Fishing Activity and Site Features/Sub-feature(s)

Maps of trawl sightings and site feature/sub-features can be found in Annex 5. These maps reveal where fishing activity occurs in relation to the designated features and sub-features of the site. Within the eastern Solent, trawling takes place within the Solent Maritime SAC outside the entrances of Langstone and Chichester Harbours in an area known as Hayling Bay, which is a predominantly an area of subtidal sand, as well as subtidal mixed sediment. Anecdotal evidence suggests that there has been a gradual change in seabed type in Hayling Bay from sand to mixed sediment with rocks and boulders (Southern IFCA Committee Member Pers. Comm). Such changes in substrate type make it undesirable for trawling (Southern IFCA Committee Member Pers. Comm). In Southampton Water, trawl sightings occur within the SAC on the fringes of

[13] If conclusion of LSE alone an in-combination assessment is not required.

intertidal zone, predominantly on the western side of the Solent. These sightings however are infrequent and the subtidal nature of the fishing activity is likely to limit this from occurring and may be explained by inaccurate reporting. In the western Solent, trawl sightings occur relatively infrequently and commonly on the fringes of the SAC, from Yarmouth to Cowes, and between Beaulieu and Lymington, which are areas of subtidal mixed sediment. Sightings data does not differentiate between the types of trawl used, however a lack of potential areas to deploy a beam trawl within the Solent EMS, due to the unsuitable nature of the substrate (i.e. soft sediments), is likely to limit the use of beam trawls within the site (Southern IFCA Committee Member Pers. Comm).

6.2 Table 4: Summary of LSE Assessment(s) – Subtidal muddy sand

<table>
<tr><td>1. Is the activity/activities directly connected with or necessary to the management of the site for nature conservation?</td><td colspan="2">No</td></tr>
<tr><td>2. What potential pressures, exerted by the gear type(s), are likely to affect the feature(s)/sub-feature(s)?</td><td colspan="2">Regulation 33 CA/Interim CA:
1. Physical loss - removal
2. Physical loss - smothering
3. Physical damage – siltation/ Siltation rate changes (low), including smothering/ Siltation rate changes (high), including smothering
4. Physical damage – abrasion/ 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
5. Toxic contamination - introduction of synthetic/non-synthetic compounds
6. Non-toxic contamination - changes in nutrient loading/organic loading/ Organic enrichment
7. Non-toxic contamination - changes in turbidity/ Changes in suspended solids (water clarity)
8. Introduction of non-native species and translocation/ introduction or spread of non-indigenous species
9. Selective extraction of species/ Removal of non-target species
10. Interim CA only: Litter
11. Interim CA only: Physical change (to another seabed type)</td></tr>
<tr><td rowspan="2">3. Is the feature(s)/sub-features(s) likely to be exposed to the pressure(s) identified?</td><td>Pressure</td><td>Screening - Justification</td></tr>
<tr><td>4.</td><td>IN – This gear type is known to cause abrasion and disturbance to the seabed surface. Intensive and persistent damage can be detrimental to the favourable condition of an interests feature structure and function. Further investigation is needed on the magnitude of the pressure, including the effect of the gear and the spatial scale/intensity of the activity.</td></tr>
</table>

	9.	IN – Extraction of species can be limited by minimum landing sizes depending on the species. Typically, demersal fish species are targeted and removed and therefore is unlikely to have a significant impact on the biotope or communities associated with this feature type. Impacts on the associated community may however occur through the removal of larger epifaunal and potentially infaunal species, whilst smaller organisms are likely to pass through the gear. It is however likely to disturb smaller species through physical abrasion of the gear. Further investigation is needed as to the magnitude of removal and disturbance to associated communities/species.
4. What key attributes of the site are likely to be affected by the identified pressure(s)?	Regulation 33/Interim CA: - Topography - Sediment character/Sediment composition and distribution - Range and distribution of characteristic mud biotopes, for example: LMU biotopes/Presence and spatial distribution of intertidal mixed sediment communities/Presence and abundance of typical species/Species composition of component communities	
5. Potential scale of pressures and mechanisms of effect/impact (if known)	Refer to full LSEs.	
6. Is the potential scale or magnitude of any effect likely to be significant?	**Alone** Yes	**OR In-combination**[14] N/A
6. Have NE been consulted on this LSE test? If yes, what was NE's advice?	Please refer to letters from Natural England dated 12/01/2016 & 01/03/16.	

[14] If conclusion of LSE alone an in-combination assessment is not required.

6.3 Potential Impacts

Bottom trawling is known to have a number of direct and indirect effects on the environment. Beam trawls, otter trawls and dredges are very similar in their effect, with heavier gear in contact with the seabed causing greater damage (Jones, 1992) and lighter towed gear (e.g. light demersal trawl) having less impact (Drabsch *et al* ., 2001). The effects vary depending on the level of gear in contact with the seabed, depth, seabed type and strength of currents and tides (Jones, 1992). It is therefore worth noting that the trawling effects reported in the studies discussed below will largely depend on the size of the gear used. Where possible the gear used within each study has been stated where available and any differences with the gear used in the Solent should be considered.

6.3.1 Physical disturbance

Physical disturbance is generally related to the direct effects of bottom towed fishing gear and 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).

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). Using a light beam trawl, of 700 kg with 15 tickler chains, disturbance was revealed to be restricted to the upper 1 cm in sandy sediments and 3 cm in muddy silt (Bridger, 1972). An average penetration depth of 40 to 70 mm was reported by de Groot *et al*. 1995. Experimental trawling, using a 3.5 tonne 4 m beam trawl with chain matrix, led to the flattening of sand ripples, suspension of fine materials and a reduction in the consolidation of sediments in areas of stable coarse sand and gravel and mobile sand in the eastern Irish sea (Kaiser & Spencer 1996, Kaiser *et al*. 1996, 1998, 1999). In the North Sea, experimental trawling, using a 7000 kg 12 m beam trawl with tickler chains, resulted in the physical penetration of the year to at least 6 cm in an area of medium hard sandy sediment (Bergman *et al*. 1990; Bergman & Hup, 1992).

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).

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).

Resuspension of sediment (general)

The resuspension of sediments is generated by turbulence from trawl doors (Main & Sangster, 1979; 1981). The sediment cloud which is created contributes to the capture of fish (Main & Sangster, 1979, 1981 in Jones, 1992). The increase in suspended sediment load reduces light levels and can smother benthos when the sediment settles out (Jones, 1992). The effects of sediment resuspension are site specific and depend on grain size, sediment type, water depth, hydrological conditions, sensitivity of fauna, currents, tides and water mass properties (Coen, 1995).

On Goote Bank, off Belgium and the Netherlands, Fonteyne (2000) examined the physical effects of a 4 m beam trawl with tickler chain matrix. In an area of densely packed fine sand overlaid with a silt layer, the upper 1 cm of the sediment was resuspended, resulting in a harder and less rough sediment surface. Sediments returned to pre-trawl conditions within 15 hours, whilst the tracks were visible for longer (see section 6.2.5).

Resultant sediment plumes from shellfish dredging can lead to areas of elevated turbidity up to 30 metres beyond the dredge zone (Manning, 1957; Haven, 1979; Manzi *et al*., 1985; Maier *et al*., 1998), potentially transporting and redistributing sediment into adjacent areas (Vining, 1978). In most cases however, the amount of suspended sediment rapidly returns to low levels with distance from the dredge activity (Kyte *et al*., 1976; Maier *et al*., 1998) with 98% resettling within 15 m (Mercaldo-Allen & Goldberg, 2011). Effects of sediment plumes and enhanced turbidity levels appear to be temporary, with the majority of sediment plumes disappearing within hours of dredging (Maier *et al*., 1998). Dispersed sediments may take 30 minutes to 24 hours to resettle (Lambert & Goudreau 1996; Northeast Region EFHSC 200). Shallow water environments with high silt and clay content are likely to experience larger plumes and greater turbidity (Ruffin 1995; Tarnowski 2006).

In areas of tide and current, the effects of sediment resuspension are short in duration and the effects of redeposition are not permanently, particularly with respect to those adapted to storm events and sediment transport by currents (Jones, 1992).

6.3.2 Biological disturbance

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 in Gubbay and Knapman, 1999; 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).

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 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).

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. Significant differences in abundance between fished and unfished areas were largely. 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 was decrease 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

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 in 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*., 1981) 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).

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).

Gear differences

A meta-analysis by Kaiser *et al*. (2006) revealed differences between beam trawling and otter trawling in the response of different functional biota groups to trawl disturbance. Otter trawling produced the least negative impacts, whilst the response to beam trawl disturbance is highly variable among habitat type (Kaiser *et al*., 2006). The impacts from beam trawls are thought to be greater than an otter trawl as they have more direct and prolonged contact with the seabed (Kaiser, 2014 in Goodchild *et al*., 2015).Typically, flatfish beam trawls disturb the seabed more intensively than otter trawls (Hall, 1994). Otter trawls have been shown to catch relatively more fish than invertebrates, whilst beam trawlers catch proportionally more invertebrates (Philippart, 1998).

6.3.3 Chemical disturbance

The vast majority of experimental studies investigate the physical and biological impacts of demersal trawling (Johnson *et al*. 2002). Information on the chemical effects of trawling is therefore very limited (Johnson *et al*. 2002). The chemistry of bottom sediments may be altered when the benthos are disturbed (Mercaldo-Allen & Goldberg, 2011).

Mayer *et al*. (1991) reported the mixing of surface organic material into subsurface layers. This led to the removal of organic matter from the surface metazoan-microbial aerobic chain to an anaerobic system (Jones, 1992). If subsurface layers of sediment are anoxic then further issues may occur and disturbing soft bottom may create anaerobic turbid conditions (Jones, 1992).

Riemann and Hoffman (1991) assessed the effects of otter trawling on the water column in a shallow (7.5-11 m) eutrophic sound (Limfjord) in Denmark using a small (6 m wide) commercial otter trawl. No information on sediment type was provided. Levels of suspended particulate matter, oxygen and nutrient levels were measured at a dredged and control site, before and after trawling. Immediately after trawling, average suspended particulate matter increased significantly at both sites, but returned to pre-trawl levels 60 minutes after. No significant effects were detected on oxygen and most nutrients, except for ammonia which significantly increased after trawling at one site. There were however marked differences between the control and experimental site which complicated the interpretation of this result.

The removal or disruption to benthic organisms that are involved in biogeochemical processes within the sediment, may alter the biogeochemistry of the sediment (Mercaldo-Allen & Goldberg, 2011). For example, the removal of large benthic bioturbators may affect sediment nutrient and oxygen fluxes ad influence whether the seafloor acts as a source or sink for certain nutrients (Olsgard *et al*., 2008).

6.3.4 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 organisms 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 is a dynamic area with strong tidal flows. 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 covers the Solent (Figure 5 & 6), 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 western Solent, is subject to relatively high levels of natural disturbance, with annual tidal bed stress ranging from 1.0-2.5 NM^2 in the eastern Solent, increasing to 5.0-7.5 NM^2 in the western Solent and kinetic energy at the seabed ranging from high in the western Solent to moderate to the eastern Solent.

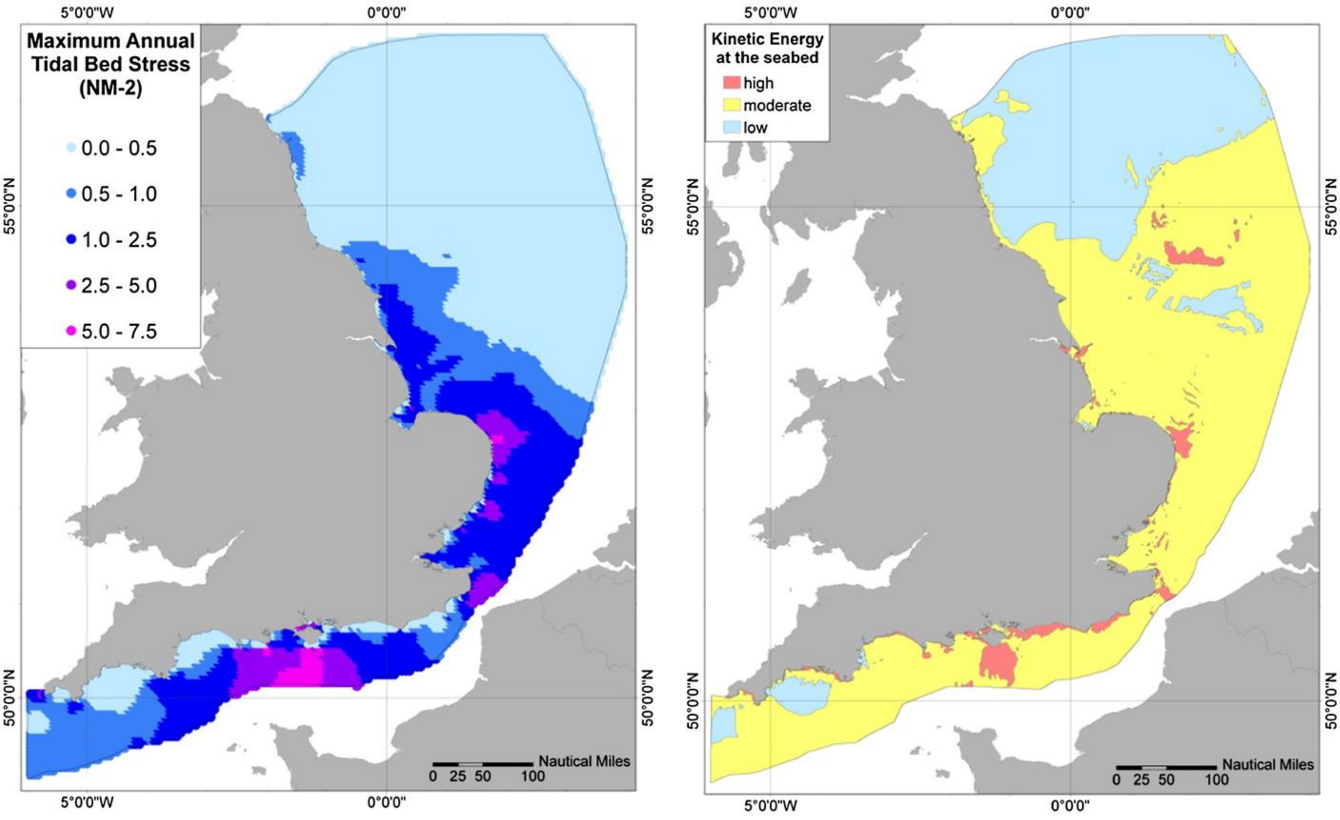


Figure 5. Maps of modelled natural disturbance of the seabed, represented by tidal bed stress (left) and kinetic energy (right). Source: Bolam *et al*., 2014

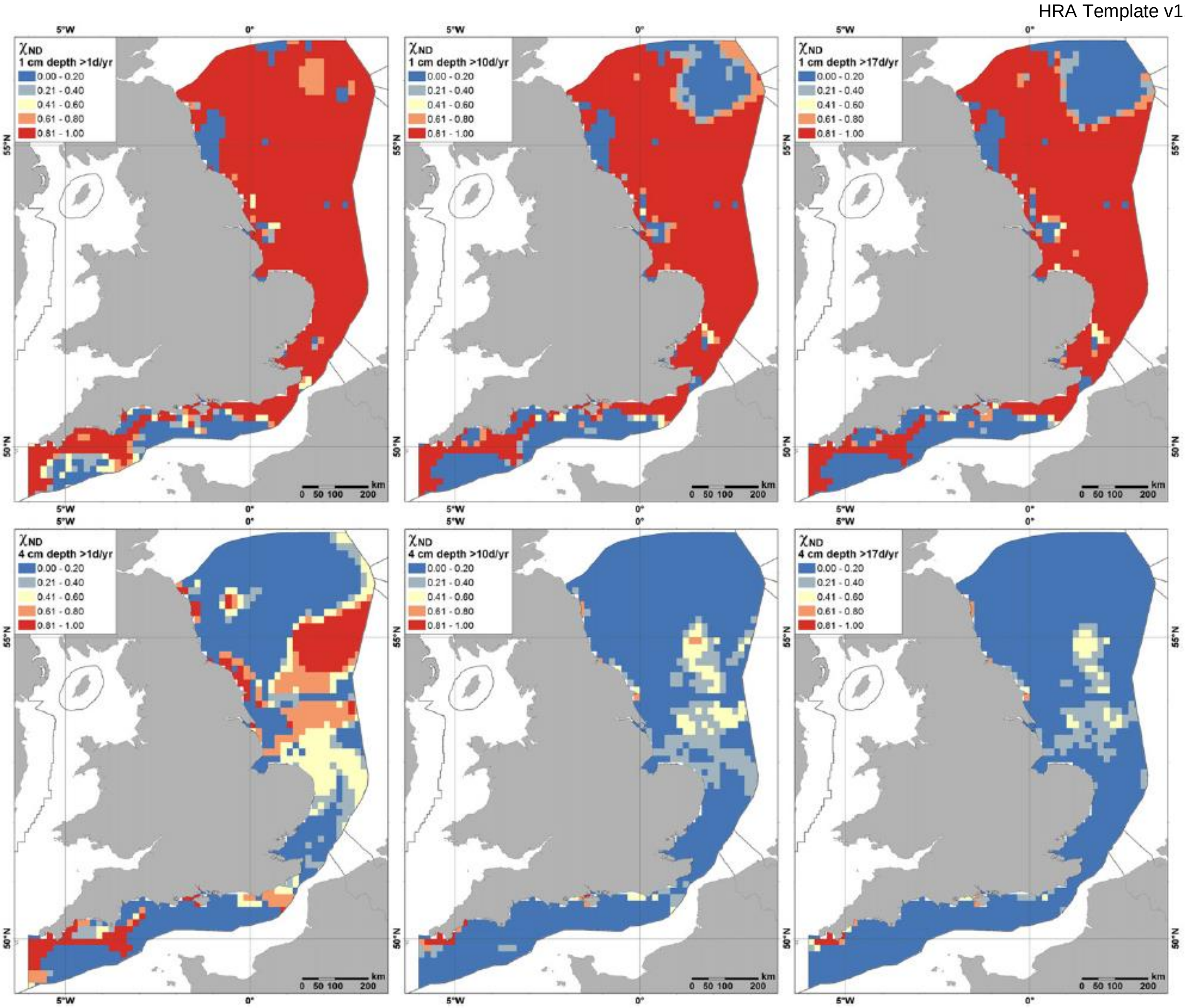


Figure 6. Maps of the modelled probability that natural forces disturb the seabed to different depths of 1 and 4 cm for a range of frequencies per year (once, 10 and 17 times). Source: Bolam *et al*., 2014

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)

6.3.4 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, 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 siltation rate changes, 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 5). Subtidal mixed sediments appear to be sensitive overall, 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 both gear types, except for demersal trawls in stable subtidal fine sands which has a medium sensitivity (Table 6). 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 and single pass gear intensities (Table 6).

Table 5. Sensitivity of SAC features to pressures identified by Tillin *et al*. (2010). Confidence of sensitivity assessment is included in brackets.

	Pressure				
Feature	Siltation rate changes (low) – 5 cm of final material added to the seabed in a single event	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 coarse sediment	Not Sensitive – Medium (Low)	Low – Medium (Low)	Low – Medium (Low)	Not Sensitive – High (Low)	Not Sensitive – Medium (Low)
Subtidal sand	Medium (Low)	Low – Medium (Low to Medium)	Not Sensitive - Medium (Low)	Not Sensitive – Medium (Low)	Not Sensitive – Medium (High)
Subtidal mixed sediment	Not Sensitive (Low)	High (Low)	High (Low)	Medium (Low)	Low (Medium)

Table 6. 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	**Subtidal stable muddy sands, sandy muds and muds**	High	High	Low	Low

dredges	**Stable subtidal fine sands**	High	Medium	Low	Low
	Dynamic, shallow water fine sands	Medium	Medium	Low	Low
	Stable spp. rich mixed sediments	High	High	Medium	Low
	Unstable coarse sediments – robust fauna	Medium	Medium	Low	Low
Demersal trawls	**Subtidal stable muddy sands, sandy muds and muds**	High	Medium	Low	Low
	Stable subtidal fine sands	Medium	Medium	Low	Low
	Dynamic, shallow water fine sands	Medium	Low	Low	Low
	Stable spp. rich mixed sediments	High	Medium	Medium	Low
	Unstable coarse sediments – robust fauna	Medium	Medium	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

6.3.5 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 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 the 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 7), 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 7 where the mean index of recovery exceeds 1).

Table 7. Recovery rates (days) of different habitats for different fishing gear types. ND: No Data. Source: Foden *et al*., 2010.

	Habitat Type				
Gear Type	Sand	Gravel	Muddy sand	Reef	Mud
Beam trawl	182[a]	ND	236[b]	ND	ND
Otter trawl	0[b]	365[d]	213[c]	2922[b]	8[b]
Scallop dredge	2922[b,e]	2922[b]	589[b]	1175[b]	ND

[a] Kaiser *et al*. (1998); [b] Kaiser *et al*. (2006); [c] Ragnarsson & Lindegarth (2009); [d] Kenchington *et al*. (2006); [e] Gilkinson *et al*. (2005)

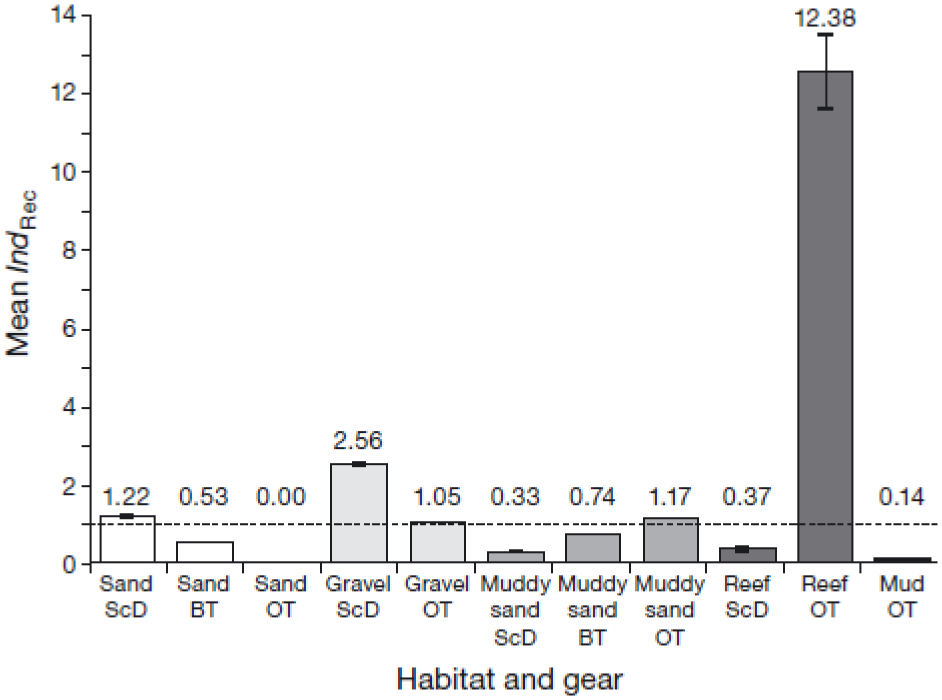


Figure 7. Mean index of recovery (Ind_{Rec}) for gear-habitat combinations using fishing intensity data derived from Vessel Monitoring Systems in 2007. At Ind_{Rec} Rec = 1, the recovery period is equal to fishing frequency (horizontal dashed line), at Ind_{Rec} <1 fishing frequency is less than the 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).

6.4 Site Condition

Natural England provides information on the condition of designated sites and describes the status of interest features. This is derived from the application of 'Common Standards Monitoring Guidance' which is applied to a subset of 'attributes' of site features as set out in the sites' Regulation 33/35 Conservation Advice document. Feature condition influences the Conservation Objectives in that it is used to determine whether a 'maintain' or 'recover' objective is needed to achieve the target level for each attribute. Natural England's current process for conducting condition assessments for marine features was developed due to requirements to report on condition of Annex 1 features at the national level in 2012/13 under Article 17 of the Habitats Directive. Since then, the methods have been reviewed and Natural England are actively working to revise this process further so that it better fulfils obligations to inform management actions within MPAs and allows them to report on condition. In light of this revision to the assessment methods, the condition assessments for the features of European Marine Sites have not been made available in the timeframe required under the revised approach.

An indication of the condition of site interest features can be inferred, if available, from assessments of SSSIs[15] that underpin the SAC. Unfortunately there are no relevant SSSI units which overlap with known areas of trawling as these areas occur subtidally, so these condition assessments cannot be used to inform this assessment.

6.5 Existing Management Measures

- **Bottom Towed Fishing Gear** byelaw – prohibits bottom towed fishing gear over sensitive features including reef features and seagrass within the Solent Maritime SAC 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.
- **Bass Nursery Areas** – fishing for bass or fishing for any fish using sand-eels as bait by any fishing boat within designated areas is prohibited between 30 April and 1 November. Designated areas include Southampton Water (Cadland foreshore to the Warsash foreshore, but excluding those waters above the Redbridge Causeway on the River Test) and Langstone Harbour (Gunnery Range Light at Eastney Point to Langstone Fairway Buoy, then to the foreshore east of Gunner Point) and all year round in a 556 m radius around the Fawley Power Station outfall.
- **Prohibition of Gathering (Sea Fisheries Resources) in Seagrass Beds** byelaw. This prohibits any person from digging for, fishing for or taking any sea fisheries resource in or

[15] SSSI Condition assessments: http://designatedsites.naturalengland.org.uk/.

from the prohibited areas and does not apply to fishing/taking fisheries resources by means of net, rod and line and hook and line. It also does not apply to fishing for/taking sea fisheries resources using a vessel, provided that no part of the vessels hull in contact with the seabed. No person shall carry a rake, spade, fork or any similar tool in prohibited areas

- 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** Southern Sea Fisheries District Committee legacy byelaw states the maximum number of dredges which can be towed at any time is twelve, provides details of dredge configuration and that no person shall fish for or take any scallop from any fishery on any day before 0700 and after 1900 local time
- Southern IFCA has a **Minimum Fish Sizes** byelaw, which states that no person shall take from the fishery any fish of the following species (black seabream, brill, dab, conger eel, flounder, lemon sole, red mullet, shad, turbot, witch flounder) that measures less than the size listed when measured from the tip of the snout to the end of the tail. The minimum size for flounder is 27 cm. The minimum sizes contained within this byelaw differ from that in EU legislation.
- 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 Council Regulation (EEC) 850/98 specify the minimum size for plaice is 27 cm and for bass is 42 cm.

6.6 Table 8: Summary of Impacts

The potential pressures, associated impacts, level of exposure and mitigation measures are summarised in table 8. Only relevant attributes identified through the TLSE process have been considered here.

Feature	Sub feature(s)	Attribute	Target	Potential Pressure(s) and Associated Impacts	Likelihood of Impacts Occurring/Level of Exposure to Pressure	Mitigation measures
Sandbanks slightly covered by water all the time	Subtidal gravelly sand and sand (Reg 33); Subtidal muddy sand communities (Reg 33); Subtidal gravel and sand (Generic); Subtidal muddy sand (Generic); Subtidal mixed sediments (feature data); Subtidal sand (feature data)	Topography	Depth should not deviate significantly from an established baseline, subject to natural change.	Abrasion, penetration and disturbance to the surface of the seabed and below the surface of the seabed were identified as potential pressures. Otter boards leave distinct tracks on the seafloor by ploughing grooves and creating berms (sediment mounds) (Jones, 1992; Gilkinson *et al*., 1998; Johnson *et al*., 2002; Thursh & Dayton, 2002). Berms can be up to 20 cm high (DeAlteris *et al*., 1999) and furrows can be up to 10 cm deep and 85 cm wide (Brylinsky *et al*., 1994; Nilsson & Rosenberg, 2003). The area directly affected by otter boards themselves is only 1/10 of the affected trawling area. Ground ropes and weights can scour and flatten the seabed. Beam trawls also flatten seabed features and leave trenches in soft sediment (Tuck *et al*., 1998). A light beam trawl (700 kg with 15 tickler chains) disturbance occurred to the upper 1 cm in sandy sediment and 3 cm in	Reports of trawling with the Solent from local IFCOs reveal the total number of vessels operating within the fishery is approximately 10, 7 of which regularly participate. Sightings data reveal a relatively low level of fishing effort within the Solent, with an average of 0.9 vessels sighted more than twice or more in a month in 2014. This was the highest average between 2011 and 2015. Trawling occurs subtidally and is focused in the central and eastern Solent, generally outside of the Solent Maritime SAC. Co-location maps of trawl sightings and site feature/sub-feature reveal that trawling within the Solent Maritime SAC is very limited. The areas where trawling does occur within the SAC is outside the entrances of Langstone and Chichester Harbours in an area known as Hayling Bay, which is a predominantly an area of subtidal sand, as well as subtidal mixed sediment. Over the ten year	Bottom Towed Fishing Gear byelaw prohibits bottom towed fishing gear over sensitive features including seagrass within the Solent Maritime SAC closing areas of the site to these activities. Southern IFCA is currently amending this byelaw to include an additional network of permanent closures areas to bottom towed fishing gear. These amendments are being made as part of a suite of new measures to manage shellfish dredging within the Solent EMS. The network of new closure areas is designed to protect good examples of low-energy SAC habitats, maintaining the integrity of the site, whilst also offering long-term stability to guard against the effects of fishing effort displacement. Additional spatial and temporal restrictions of shellfish dredging within the Solent EMS include a network of three dredge management fishing areas and a daily closure from 17:00 to 07:00. Within each dredge fishing management area, clam dredging

				muddy silt (Bridger, 1972). The physical recovery of sediments to such impacts largely depends on sediment type (Mercaldo-Allen & Goldberg, 2011). 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 in areas of faster water movement are likely to be filled in within a shorter period (Jones, 1992). 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). 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). 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).	period (2005-2015) covered by sightings, there were a total of three sightings within this area. In Southampton Water, trawl sightings occur within the SAC on the fringes of intertidal zone, predominantly on the western side of the Solent. These sightings however are infrequent and the subtidal nature of the fishing activity is likely to limit this from occurring. In other area, sightings show trawling to occur on the fringes of the Solent Maritime SAC, from Yarmouth to Cowes and Beaulieu to Lymington, both of which are areas of subtidal mixed sediment. Over the ten year period (2005-2015) covered by sightings, a total of 4 sightings occurred on the fringes of the SAC from Beaulieu to Lymington and 1 sighting from Yarmouth to Cowes. The infrequent nature of the activity within areas or on the fringes of the SAC are unlikely to cause any adverse effect on the topography of the subtidal sediment types mentioned. Furthermore, these subtidal sediment types are coarser and therefore any changes in topography that do occur are likely to recover rapidly (within days). The areas within the SAC where trawling takes place are also subject to high levels of energy as a result of strong tidal flows within these areas, thus supporting a rapid physical	will be prohibited for 35 weeks of the year during the spring, summer and autumn months. 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.

					recovery.	
Sandbanks slightly covered by water all the time	Subtidal gravelly sand and sand (Reg 33); Subtidal muddy sand communities (Reg 33); Subtidal gravel and sand (Generic); Subtidal muddy sand (Generic); Subtidal mixed sediments (feature data); Subtidal sand (feature data)	Sediment character (Reg 33); Sediment composition and distribution (Interim CA)	Average grain size parameter should not deviate significantly from an established baseline subject to natural change (Reg 33); The distribution of sediment composition types across the feature (and each of its sub-features)(presence/absence of areas mapped in GIS), compared to an established baseline, to ensure continued structural habitat integrity and connectivity (Interim CA)	Abrasion, penetration and disturbance to the surface of the seabed and below the surface of the seabed, as well as changes in siltation rates (for subtidal gravel and sand) were identified as potential pressures. 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). 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). 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). In Estero Bay of the Californian coast, 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) led to a slight increase in silt	Reports of trawling with the Solent from local IFCOs reveal the total number of vessels operating within the fishery is approximately 10, 7 of which regularly participate. Sightings data reveal a relatively low level of fishing effort within the Solent, with an average of 0.9 vessels sighted more than twice or more in a month in 2014. This was the highest average between 2011 and 2015. Trawling occurs subtidally and is focused in the central and eastern Solent, generally outside of the Solent Maritime SAC. Co-location maps of trawl sightings and site feature/sub-feature reveal that trawling within the Solent Maritime SAC is very limited. The areas where trawling does occur within the SAC is outside the entrances of Langstone and Chichester Harbours in an area known as Hayling Bay, which is a predominantly an area of subtidal sand, as well as subtidal mixed sediment. Over the ten year period (2005-2015) covered by sightings, there were a total of three sightings within this area. In Southampton Water, trawl sightings occur within the SAC on the fringes of intertidal zone, predominantly on the western side of the Solent. These sightings however are infrequent and the subtidal nature of the fishing activity is likely to limit this	Bottom Towed Fishing Gear byelaw prohibits bottom towed fishing gear over sensitive features including seagrass within the Solent Maritime SAC closing areas of the site to these activities. Southern IFCA is currently amending this byelaw to include an additional network of permanent closures areas to bottom towed fishing gear. These amendments are being made as part of a suite of new measures to manage shellfish dredging within the Solent EMS. The network of new closure areas is designed to protect good examples of low-energy SAC habitats, maintaining the integrity of the site, whilst also offering long-term stability to guard against the effects of fishing effort displacement. Additional spatial and temporal restrictions of shellfish dredging within the Solent EMS include a network of three dredge management fishing areas and a daily closure from 17:00 to 07:00. Within each dredge fishing management area, clam dredging will be prohibited for 35 weeks of the year during the spring, summer and autumn months. 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

				content and 2% decrease in the fine sand fraction, although post-trawl samples displayed the same grain size distribution as pre-trawl samples (Lindholm *et al*. 2013). There is limited information on resultant sediment plumes from trawling. The resuspension of sediment is known to occur through turbulence from trawl doors (Main & Sangster, 1979; 1981). Resultant sediment plumes from shellfish dredging can lead to areas of elevated turbidity up to 30 metres beyond the dredge zone (Manning, 1957; Haven, 1979; Manzi *et al*., 1985; Maier *et al*., 1998), although in most cases the amount of suspended sediment rapidly returns to low levels with distance from the dredge activity (Kyte *et al*., 1976; Maier *et al*., 1998) with 98% resettling within 15 m (Mercaldo-Allen & Goldberg, 2011). Dispersed sediments may take 30 minutes to 24 hours to resettle (Lambert & Goudreau 1996; Northeast Region EFHSC 2002). Shallow water environments with high silt and clay content are likely to experience larger plumes and greater turbidity (Ruffin 1995; Tarnowski 2006). In areas of tide and current, the effects of sediment resuspension are short in duration and the effects of redeposition are not permanently, particularly with respect to those adapted to storm events and sediment transport by currents (Jones, 1992).	from occurring. In other area, sightings show trawling to occur on the fringes of the Solent Maritime SAC, from Yarmouth to Cowes and Beaulieu to Lymington, both of which are areas of subtidal mixed sediment. Over the ten year period (2005-2015) covered by sightings, a total of 4 sightings occurred on the fringes of the SAC from Beaulieu to Lymington and 1 sighting from Yarmouth to Cowes. The infrequent nature of the activity within areas or on the fringes of the SAC are unlikely to cause any adverse effect on the sediment character of the subtidal sediment types mentioned. Changes in sediment occur particularly in muddy sand and mud habitat types, which are sediment types known to not affected by trawling within the Solent Maritime SAC. Furthermore, areas within the Solent Maritime SAC where trawling takes places are areas of tide and current and therefore the effects of sediment resuspension of sediment character are short in duration and temporary, with such areas being adapted to storm events and sediment transport by currents (Jones, 1992).	lighter towed gear.

				The physical recovery of sediments to such impacts largely depends on sediment type (Mercaldo-Allen & Goldberg, 2011). 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).		
Sandbanks slightly covered by water all the time	Subtidal gravel and sand (Generic); Subtidal gravelly sand and sand (Reg 33); Subtidal coarse sediment (Interim CA); Subtidal sand (Interim CA & feature data)	Distribution and extent of characteristic range of biotopes (Reg 33); Presence and spatial distribution of subtidal coarse sediment/subtidal sand sediment communities (Interim CA); Presence and abundance of typical species (Interim CA); Species composition of component communities (Interim CA)	Distribution and extent of characteristic biotopes should not deviate from an established baseline subject to natural change (Reg 33); The presence and spatial distribution of subtidal coarse sediment / subtidal sand communities according to the map (Interim CA); The abundance of listed typical species, to enable each of them to be a viable component of the habitat (Interim CA); The species composition of component communities (Interim CA)	The selection extraction of species and removal of non-target species, as well as changes in siltation rates were identified as potential pressures. In areas of gravel and sand, siltation and smothering of faunal communities is a key concern. Areas of sand and gravel are highly sensitive to siltation as the marine communities which are sensitive to inputs of fine material (English Nature, 2001). There is limited information on resultant sediment plumes from trawling. The resuspension of sediment is known to occur through turbulence from trawl doors (Main & Sangster, 1979; 1981). Resultant sediment plumes from shellfish dredging can lead to areas of elevated turbidity up to 30 metres beyond the dredge zone (Manning, 1957; Haven, 1979; Manzi *et al*., 1985; Maier *et al*., 1998), although in most cases the amount of suspended sediment rapidly returns to low levels with distance from the dredge activity (Kyte *et al*., 1976; Maier *et al*., 1998) with 98% resettling within 15 m (Mercaldo-Allen & Goldberg, 2011). Dispersed sediments may	Reports of trawling with the Solent from local IFCOs reveal the total number of vessels operating within the fishery is approximately 10, 7 of which regularly participate. Sightings data reveal a relatively low level of fishing effort within the Solent, with an average of 0.9 vessels sighted more than twice or more in a month in 2014. This was the highest average between 2011 and 2015. Trawling occurs subtidally and is focused in the central and eastern Solent, generally outside of the Solent Maritime SAC. Co-location maps of trawl sightings and site feature/sub-feature reveal that trawling within the Solent Maritime SAC is very limited. The areas where trawling does occur within the SAC is outside the entrances of Langstone and Chichester Harbours in an area known as Hayling Bay, which is a predominantly an area of subtidal sand, as well as subtidal mixed sediment. Over the ten year period (2005-2015) covered by sightings, there were a total of three sightings within this area.	Bottom Towed Fishing Gear byelaw prohibits bottom towed fishing gear over sensitive features including seagrass within the Solent Maritime SAC closing areas of the site to these activities. Southern IFCA is currently amending this byelaw to include an additional network of permanent closures areas to bottom towed fishing gear. These amendments are being made as part of a suite of new measures to manage shellfish dredging within the Solent EMS. The network of new closure areas is designed to protect good examples of low-energy SAC habitats, maintaining the integrity of the site, whilst also offering long-term stability to guard against the effects of fishing effort displacement. Additional spatial and temporal restrictions of shellfish dredging within the Solent EMS include a network of three dredge management fishing areas and a daily closure from 17:00 to 07:00. Within each dredge fishing management area, clam dredging will be prohibited for 35 weeks of the year during the spring, summer and autumn months.

				take 30 minutes to 24 hours to resettle (Lambert & Goudreau 1996; Northeast Region EFHSC 200). 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). The impact of otter trawls on benthic communities varies between studies, notably between sediment types. 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). Experimental fishing manipulations based on sandy sediments have reported mixed results. A number of studies report very little or no effect from trawling disturbance (Queirós *et al*. 2006; Lindholm *et al*., 2013), whilst others report significant reductions (Bergman & van Santbrink, 2000; Moran & Stephenson, 2000; Kenchington *et*	In Southampton Water, trawl sightings occur within the SAC on the fringes of intertidal zone, predominantly on the western side of the Solent. These sightings however are infrequent and the subtidal nature of the fishing activity is likely to limit this from occurring. In other area, sightings show trawling to occur on the fringes of the Solent Maritime SAC, from Yarmouth to Cowes and Beaulieu to Lymington, both of which are areas of subtidal mixed sediment. Over the ten year period (2005-2015) covered by sightings, a total of 4 sightings occurred on the fringes of the SAC from Beaulieu to Lymington and 1 sighting from Yarmouth to Cowes. Within the Solent Maritime SAC, they key biotopes associated with littoral gravels and sands, include burrowing amphipods and polychaetes (*Arenicola marina*) in clean sand shores, burrowing amphipods *Pontocrates* spp and *Bathyporeia* spp in lower shore clean sand and dense *Lanice conchilega* in tide swept lower shore sand. *Lanice conchilega* are highly incapable of movement in response to disturbance (Goss-Custard, 1977). Bergman and Hup (1992) reported reductions of 65% in the mean density of small *L. conchilega* (0.5-1.5 cm) after three-fold beam trawling on fine to hard medium hardy-sand, well packed sediments in the North	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.

				al., 2001). Bergman and van Santbrink (2000) reported direct mortality of 0-21% for bivalves, 12-16% for echinoderms and 19-30% for crustaceans after a single sweep with a commercial otter trawl in sandy areas 30-40 m deep in the North Sea. 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). Experimental fishing manipulations using a beam trawl have reported mortality levels ranging from 5-65% in sandy habitats (Bergman *et al*. 1990; Bergman & Hup, 1992; Bergman and van Santbrink, 2000; Kaiser & Spencer, 1996, Kaiser *et al*., 1996, 1998, 1999). 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	Sea. An increase of 15% in the mean density of large *L. conchilega* (1.5-5cm) however was also reported. Aside of *L. conchilega* and a number of other species, experimental fishing manipulations have shown that impacts of trawling disturbance on annelids are limited and in some instances may be positive. It is important to note the biotopes mentioned are those associated with littoral gravels and sands and may differ in subtidal areas. Whilst it is recognised that subtidal gravel and sand may support a sensitive polychaete species (*L. conchilega*), the infrequent nature of the activity within areas or on the fringes of the SAC means the activity is unlikely to cause an adverse effect on the benthic communities and biotopes associated with subtidal gravel and sand. Furthermore, the recovery periods for this sediment type are known to be relatively rapid (0-100 days) and therefore the infrequent nature of the activity will allow sufficient time for such recovery if the activity were to occur. Areas within the Solent Maritime SAC where trawling takes places are areas of strong tidal flows and communities within these areas are likely to be highly disturbed and adapted to such conditions. Any impacts from siltation or sediment resuspension are likely	

				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). The timescale for recovery largely depends on sediment type, associated fauna and rate of natural disturbance (Roberts *et al*., 2010). 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). In a 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). 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. Collie *et al*. (2000) reported recovery times of 100 days in sandy sediment communities from trawling disturbance. Effects of beam trawling in areas of mobile	to be very limited due to the infrequent nature of the activity and short-lived localised effects of sediment resuspension. Areas within the Solent Maritime SAC where trawling takes places are areas of tide and current and therefore the effects of sediment resuspension of sediment character are short in duration and temporary, with such areas being adapted to storm events and sediment transport by currents (Jones, 1992).	

				megaripple strucutures were not detectable (Kaiser *et al*., 1998).		
Sandbanks slightly covered by water all the time	Subtidal muddy sand (Generic); Subtidal muddy sand communities (Reg 33); Subtidal sand (Interim CA & feature data); Subtidal mixed sediments (Interim CA & feature data)	Range and distribution of characteristic subtidal sediment biotopes (Reg 33); Presence and spatial distribution of subtidal sand communities (Interim CA); Presence and abundance of typical species (Interim CA); Species composition of component communities (Interim CA)	Range and distribution should not deviate significantly from an established baseline subject to natural change (Reg 33); The presence and spatial distribution of subtidal sand communities according to the map (Interim CA); The abundance of listed typical species, to enable each of them to be a viable component of the habitat (Interim CA); The species composition of component communities (Interim CA)	The selection extraction of species and removal of non-target species, were identified as potential pressures. 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). The impact of otter trawls on benthic communities varies between studies, notably between sediment types. 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). 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). Experimental trawling, with a	Reports of trawling with the Solent from local IFCOs reveal the total number of vessels operating within the fishery is approximately 10, 7 of which regularly participate. Sightings data reveal a relatively low level of fishing effort within the Solent, with an average of 0.9 vessels sighted more than twice or more in a month in 2014. This was the highest average between 2011 and 2015. Trawling occurs subtidally and is focused in the central and eastern Solent, generally outside of the Solent Maritime SAC. Co-location maps of trawl sightings and site feature/sub-feature reveal that trawling within the Solent Maritime SAC is very limited. The areas where trawling does occur within the SAC is outside the entrances of Langstone and Chichester Harbours in an area known as Hayling Bay, which is a predominantly an area of subtidal sand, as well as subtidal mixed sediment. Over the ten year period (2005-2015) covered by sightings, there were a total of three sightings within this area. In Southampton Water, trawl sightings occur within the SAC on the fringes of intertidal zone, predominantly on the western side of the Solent. These sightings however are infrequent and the subtidal nature of the	Bottom Towed Fishing Gear byelaw prohibits bottom towed fishing gear over sensitive features including seagrass within the Solent Maritime SAC closing areas of the site to these activities. Southern IFCA is currently amending this byelaw to include an additional network of permanent closures areas to bottom towed fishing gear. These amendments are being made as part of a suite of new measures to manage shellfish dredging within the Solent EMS. The network of new closure areas is designed to protect good examples of low-energy SAC habitats, maintaining the integrity of the site, whilst also offering long-term stability to guard against the effects of fishing effort displacement. Additional spatial and temporal restrictions of shellfish dredging within the Solent EMS include a network of three dredge management fishing areas and a daily closure from 17:00 to 07:00. Within each dredge fishing management area, clam dredging will be prohibited for 35 weeks of the year during the spring, summer and autumn months. 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

				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). 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. Infaunal community structure became significantly altered after 5 months of fishing and remained so throughout the duration of the experimental. 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. No effects on total biomass were reported. Infaunal abundance lowered after trawling commenced and species diversity was lower in the fished site throughout the experiment, including prior to fishing. The timescale for recovery largely	fishing activity is likely to limit this from occurring. In other area, sightings show trawling to occur on the fringes of the Solent Maritime SAC, from Yarmouth to Cowes and Beaulieu to Lymington, both of which are areas of subtidal mixed sediment. Over the ten year period (2005-2015) covered by sightings, a total of 4 sightings occurred on the fringes of the SAC from Beaulieu to Lymington and 1 sighting from Yarmouth to Cowes. Within the Solent Maritime SAC, they key biotopes associated with subtidal muddy sand habitats include estuarine sublittoral muds containing *Aphelochaeta marioni* and *Tubificoides* spp invariable salinity infralittoral mud and *Nephtys hombergii* and *Tubificoides* spp in variable salinity infralittoral soft mud. *Nephtys* spp. have been shown to exhibit adverse responses to trawling disturbance (Kaiser *et al*., 1998; Tuck *et al*., 1998). Ball *et al*. (2000) however reported a decrease in abundance in most species following experimental trawling with a *Nephrops* otter trawl, except for a large proportion of polychaete species which exhibited an increase in abundance, including the large scavenger such as *Nephtys incisa* (16%). Generally speaking, experimental fishing manipulations have shown that impacts of trawling disturbance on	be used, with vessels often using lighter towed gear.

				depends on sediment type, associated fauna and rate of natural disturbance (Roberts *et al*., 2010). 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). 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. 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 the a rapid recovery of nematode abundance within 4 to 6 weeks following experimental flounder trawling on	annelids are limited and in some instances may be positive. Information on biotopes associated with subtidal mixed sediments is not provided in the Regulation 33 Advice package and it is therefore difficult to assess the sensitivity of this biotope of trawling. Littoral mixed sediment biotopes include *Mya arenaria* and polychaetes in muddy gravel shores and *Hediste diversicolor* and *Streblospio shrubsolii* in variable salinity gravelly mud. *Mya arenaria*, also known as the gaper clam, is a long-lived and takes several years to mature, so recovery times relatively long (Wheeler *et al*., 2014). This biotope however is typical of reduced salinity sheltered marine inlets where trawling is highly unlikely to occur. *Hediste diversicolor* and *Streblospio shrubsolii* on the other hand were not been identified as being sensitive to trawling disturbance in the studies examined. Trawling in the Solent Maritime SAC does not appear to occur over areas of subtidal mud (as per the co-location maps) but does infrequently occur over areas of subtidal mixed sediment (which is considered here). Subtidal muddy sand is not included in the feature mapping provided by Natural England. Information on biotopes associated with subtidal mixed	

				intertidal silty sediments in the Bay of Fundy.	sediments is not provided in the Regulation 33 Advice package but inferred from littoral mixed sediment biotopes (see above). The infrequent nature of the activity within areas or on the fringes of the SAC means the activity is unlikely to cause an adverse effect on the benthic communities and biotopes associated with subtidal mixed sediments. Furthermore, the recovery periods for this dynamic areas are known to be relatively rapid and therefore the infrequent nature of the activity will allow sufficient time for such recovery if the activity were to occur. Areas within the Solent Maritime SAC where trawling takes places are areas of strong tidal flows and communities within these areas are likely to be highly disturbed and adapted to such conditions.	

7. Conclusion[16]

Research into the impacts of trawling reveal the activity has the potential to cause physical and biological disturbance. The extent of the impact however largely depends on sediment type and physical regime within the area considered. In areas subject to dynamic physical regimes with coarser sediments the evidence of impacts from trawling are either undetectable or negligible and short-lived.

Using Southern IFCA sightings data and feature mapping data (provided by Natural England), trawling is shown to occur infrequently in the Solent Maritime SAC, with sightings mainly occurring on the fringes of the site and in an area known as Hayling Bay. Within these areas, the sediment type consists of subtidal mixed sediment and subtidal sand. These subtidal sediment types form part of the 'Sandbanks slightly covered by seawater all the time' interest feature.

Having reviewed a wide range of evidence, including scientific literature, sightings data and feature mapping, it has been concluded that beam trawling (whitefish) and light otter trawling (excluding that which takes place for sandeels) is unlikely to have a significant adverse effect on sub features which occur under the 'Sandbanks slightly covered by seawater all the time' interest feature. The level of trawling within the Solent Maritime SAC is limited and is shown to occur infrequently. The areas in which it does occur in or fringe onto within the site are physically dynamic areas which are characterised by strong tidal flows and therefore are likely to support faunal communities which are adapted to highly disturbed conditions. Experimental fishing manipulations suggest that recovery from any trawling impacts within these areas is likely to be rapid, with physical recovery taking up to 4 days in sandy habitats and biological recovery estimated to take up to 100 days, although it is likely to be less. Kaiser *et al*. (2006) predicted recovery of biota in highly energetic, shallow, soft-sediment habitats of sand and muddy sand to be less than 50 days. Kaiser et al. (1998) reported no detectable impacts of beam trawling on megafaunal communities in recovery rates of sand habitats from light otter trawling activity in areas of mobile megaripple structures. The infrequent nature of trawling within the SAC would therefore likely allow for any recovery if necessary. It is important to note that we do not have site level assessment of recoverability and so a review of the existing literature has been used to assess risk. In addition, whilst it has been recognised that experimental fishing manipulations have a number of drawbacks, including not being reflective of the true level of trawling disturbance, the level of fishing simulated within these studies is likely to be similar to the level of activity that occurs within the Solent Maritime SAC.

Based on the infrequent nature, concentrated on the fringes of the site; the low level of trawling within the Solent Maritime SAC; its limited potential to cause adverse effect on the sediment types over which it occurs; and the rapid recoverability of these sediment types, it is deemed that trawling using a light otter trawl and occasionally a beam trawl within the Solent Maritime SAC is unlikely to have an adverse effect on the features considered and will not hinder the site from achieving its conservation objectives. It is Southern IFCA's duty as the competent and relevant authority to manage damaging activities that may affect site integrity and lead to deterioration of the site. The levels and location of the activity considered is such that it is not believed to lead to the deterioration of the site and that it is compatible with the sites conservation objectives.

In order to ensure that the management of trawling remains consistent with the conservation objectives of the site, Southern IFCA will continue to monitor fishing effort through sightings data and information from IFCOs. In the short term a change in the status of the fishery is unforeseen, however it is recognised that the status of a fishery may change. On this basis, the management

[16] If conclusion of adverse effect alone an in-combination assessment is not required.

of trawling will be reviewed as appropriate should new evidence on activity levels and/or gear-habitat interaction become available.

8. In-combination assessment

No adverse effect on the intertidal or subtidal sediment feature/sub-features of the Solent Maritime SAC was concluded for the effect of beam trawling and light otter trawling for whitefish alone within the SAC. Trawling activities currently occur in the Solent Maritime SAC alongside other fishing activities and commercials plans and projects and therefore require an in-combination assessment.

Commercial plans and projects that occur within or may affect the Solent Maritime SAC are considered in section 8.1. The impacts of these plans or projects require a Habitats Regulations Assessment in their own right, accounting for any in-combination effects, alongside existing fisheries activities.

There is the potential for trawling to have a likely significant effect when considered in-combination with other fishing activities that occur within the site. These are outlined in section 8.2. Any fishing activities that were screened out as part of the revised approach assessment process will not be considered (see Solent Maritime SAC screening summary for details of these activities). In the Solent Maritime SAC, commercially licensed fishing vessels are known to utilise a number of different gear types and can be engaged in multiple fishing activities and this, whilst dividing effort between gear types, may lead to cumulative impacts different to those of a single fishing activity.

8.1 Other plans and project

Project details	Status	Potential for in-combination effect
Kendall Wharf extension	In planning	Relevant impact pathways identified in relation to this project include loss of intertidal habitat and increase in suspended sediment concentrations. Loss of intertidal habitat – As part of this project, the total area subject to capital dredging is expected to be 0.33 ha. Following dredging, 0.073 ha of intertidal mudflat would be removed. The total intertidal area lost or altered is 0.148 ha which equates to 0.01% of the total intertidal habitat in Langstone Harbour. The impact significance of intertidal habitat loss was concluded to be minor[17]. Increase in suspended sediment concentrations – It is estimated that during capital dredge operations suspended sediment concentrations could reach a maximum of 196 mg/l. Naturally occurring suspended sediment concentrations reach up to 200 mg/l within Langstone Harbour. The impact significance of increases in suspended sediment concentration was concluded to be not significant[18]. In addition, a back-

[17] When an effect will be experienced but the effect magnitude is sufficiently small and well within accepted standards and/or receptor is of low sensitivity.

[18] An impact that, after assessment, was found not to be significant in the context of the environmental statement objectives.

		hoe dredger will be used to minimise sediments suspended. At a tLSE level for trawling, physical damage from siltation and abrasion were screened in and it was recognised that trawling causes disturbance to the seabed but does result not in the physical loss of the extent of the feature. Common impact pathways with the project therefore include an increase in suspended sediment concentrations. The level of increase in suspended sediment concentrations associated with the project have been shown to be at the same magnitude as those which occur naturally and are likely to far exceed those caused by trawling. The resuspension of sediment is known to occur through turbulence from trawl doors and/or through contact of components of the trawl with the seafloor (Main & Sangster, 1979; 1981). Studies on shellfish dredging have reported suspended sediment rapidly returns to low levels with distance from the dredge activity (Kyte *et al*., 1976; Mairer *et al*., 1998), with 98% resettling within 15 m (Mercaldo-Allen & Goldberg, 2011). The project and its relevant impact pathways were considered from not significant to negligible and are likely to be of small scale and localised in their nature. The impact pathways include the loss of intertidal, which does not overlap with impact pathways of trawling. Furthermore, trawling activity is largely concentrated within the subtidal zone, occasionally fringing on intertidal areas. Knowledge of trawling activity reveals that the area of the project and surrounding areas is not subject to the activity, further limiting the potential for in-combination effects due to a lack of spatial overlap. Based on the limited significance and small scale of the project impact pathways and locality of the activity in relation to the project, it is unlikely the project and activity will lead to in-combination effects.
Queen Elizabeth aircraft carrier capital dredge	Consented and underway	Relevant impact pathways identified in relation to the project include an increase in suspended sediment concentrations and increase in sedimentation rates (as identified by the appropriate assessment). The capital dredging operation in Portsmouth Harbour and approach channel will result in resuspension of sediment into the water column and potentially result in smothering of sensitive habitats. A likely significant effect on the Solent Maritime SAC was concluded for the estuaries, mudflats and sandflats, Salicornia and sandbanks features for project element and associated impact pathways.

		Modelling of suspended sediment concentrations found changes would be temporary and largely confined to the area of the approach channel and Harbour, with levels reducing significantly to the west of the channel due to mixing and dispersal and any redeposition of sediment would be concentrated with the immediate vicinity. Generally coastal waters would be unaffected by significant increases in suspended sediment concentrations above natural background levels and the concentration of suspended sediments was shown to cease after 7 days post dredging. Modelling also concluded that predicted sediment accumulations will be confined to a number of small areas away from the intertidal area within Portsmouth Harbour. A more detailed appropriate assessment concluded the approach channel dredge would not result in an adverse effect on the integrity of the site, with no direct implications anticipated for designated features. At a tLSE level for trawling, physical damage from siltation was screened in. Increases in suspended sediment concentrations from trawling are localised and temporary in nature. The resuspension of sediment is known to occur through turbulence from trawl doors and/or through contact of components of the trawl with the seafloor (Main & Sangster, 1979; 1981). Studies on shellfish dredging have reported suspended sediment rapidly returns to low levels with distance from the dredge activity (Kyte *et al*., 1976; Mairer *et al*., 1998), with 98% resettling within 15 m (Mercaldo-Allen & Goldberg, 2011). When this is combined with the very low levels of suspended sediments and lack of impact thought to occur as a result of the project, it is unlikely that there will be in-combination effects.
Royal Pier phase 2 reclamation and capital dredge	In planning	Relevant impact pathways identified in relation to the project include an increase suspended sediment concentrations and increase in sedimentation rates. Increases in suspended sediment concentrations and subsequent increases in sedimentation rates may arise from a number of different pathways including dredging, reclamation works and piling works. The area of proposed dredging will extend to 18,700 metres and will remove around 37,000 cubic metres of material. The area to be dredged is one of low flow speeds and sediments disturbed during dredging will return to the bed in the vicinity of the dredging site. Any sediment release within the dredging site is most likely to occur in the bottom metre of the water column, increasing to suspended sediment concentrations to around 10,000 mg/l, reducing to a

		few hundred mg/l through the water column before resettling to the seabed. The predicted sediment plume will be largely confined to the dredge area due to very flows. Modelling estimates the suspended sediment concentrations of 10-20 mg/l could occur in the water column up to 50 to 100 m from the source. Increases of more than 10 mg/l are not expected beyond 250 m up and down estuary in the direction of the main channel and within 100 m of the outer extent of the dredge. Accumulation will be in the order of 0.1-0.2 m over the dredge area. The proposed dredging works are predicted to lead to a negligible increase in suspended sediment concentrations in and around the site and are predicted to not be significant. Dewatering activities associated with the proposed land reclamation will have the potential to create a sediment plume, resulting in sediment dispersion and deposition in the vicinity of the site. This will be minimised by the use of silt busters and/or sediment filters. Dewatering activities will last between 3 and 5 days. Proposed piling works have the potential to release sediments from the seabed a result of minor disturbance to sediments surrounding the piles. Suspended sediment concentrations are predicted to increase by 10-30 mg/l around each pile being driven. As a result of the low tidal flows, the maximum extent of dispersion will be no greater than 100 m up and down estuary from the site and no further than the north eastern edge of the navigation channel. The relatively small areas of piling and demolition mean the effects will be negligible and not significant. It was concluded that the small scale of the works and distance from designated nature conservation sites, like the Solent Maritime SAC, mean the proposed land reclamation and dredging will not significantly affected features of the site. Similarly, the impacts resulting from piling work were considered negligible and not significant. At a tLSE level for trawling, physical damage from siltation was screened in. Increases in suspended sediment concentration from trawling are localised and temporary in nature. The resuspension of sediment is known to occur through turbulence from trawl doors and/or through contact of components of the trawl with the seafloor (Main & Sangster, 1979; 1981). Studies on shellfish dredging have reported

		suspended sediment rapidly returns to low levels with distance from the dredge activity (Kyte *et al*., 1976; Mairer *et al*., 1998), with 98% resettling within 15 m (Mercaldo-Allen & Goldberg, 2011). When this is combined with the small scale of the work, localised impacts and distance from the SAC, it is unlikely that there will be in-combination effects with trawling.
Portchester to Emsworth Coastal Defence Strategy	In planning	Relevant impact pathways identified in relation to the project include the loss of intertidal habitat. The Portsea Island Coastal Strategy Study [PICSS] was approved in 2011 and covers the whole of Portsea Island. The strategy confirms the North Solent Shoreline Management Plan [SMP] policy (2010) for Portsea Island of ‘Hold the Line’ and splits Portsea Island into 7 discrete flood cells. Under the North Portsea Island scheme, covering 8.4 km of coastline from Tipner through to Milton, works have been identified including raising of seawalls and improving seawalls structural integrity. These proposed works are planned over the first ten years and these follow a phased approach, including Phase 1, Ports Creek Railways Bridge to Kendall’s Wharf Northern Boundary, and Phase 2, Milton Common and Great Salterns Quay. Coastal squeeze loss of 11.69 ha of intertidal will be caused by sea level rise and the delivery of the delivery of the strategic policy option of ‘Hold the Line’. An appropriate assessment concluded that because of the calculated coastal squeeze losses, that implementation of the strategy would have an adverse effect on designated sites. The AA however also concluded there is justification for these adverse effects as there is no alterative policy and there is an over-riding public need to protect life and property and so an Imperative Reasons of Overriding Public Interest statement was made. Environmental compensation will be achieved through the Regional Habitat Creation Programme which promotes the realignment of defences elsewhere in the Solent to create new intertidal habitats. This was signed off by Defra in April 2011. The phases that are currently underway or in planning have a small working footprint during their construction which is strictly controlled by a Construction and Environment Management Plan. Direct disturbance to the sediment is minimal and in discrete locations at any one time. For phase 1 there was an access footprint of 15m and in phase 2 a maximum access footprint of 10 m along the Milton Common Frontage and 20 m around Great Salterns Quay. No LSE is expected as any disturbance to

		discrete working areas is minimal, temporary and must follow good working practices as outlined in the Construction and Environment Management Plan. Phase 2 works will lead to the gain of 2,460m^2 mudflat habitat within Langstone Harbour from the removal of Great Salterns Quay. At a tLSE level for trawling, physical damage from siltation and abrasion were screened in and it was recognised that trawling causes disturbance to the seabed but does not result in the physical loss of the extent of the feature. The combined impacts of phased small scale coastal defence works and trawling will not lead to in-combination effects due to the small scale and localised nature of the impacts, a lack of overlapping impact pathways and spatial interaction. The general loss of intertidal from the overall strategy has been signed off by Defra under an Imperative Reasons of Overriding Public Interest statement.
Wightlink – Fishbourne to Portsmouth	In planning	Relevant impact pathways identified in relation to the project include the loss of intertidal habitat. The project involves the installation of three piles below MHWST, each with a diameter of 1.2 m and installation depth of 25 m below the seabed, is estimated to displace approximately 25.5m^3 of sediment. Drill operations will lead to the release of sediment and an increase in scour around the installed piles. The total volume of material eroded is estimated to be 60m^3. The area directly affected by piling works is approximately 13.6m^2 with a further 77m^2 affected by scour. Scour has the potential to locally alter the nature of the seabed in the vicinity of each pile structure, especially in terms of its composition. Although in relatively close proximity, the planned works are actually outside of the SAC boundary, so designated habitats are not directly affected by pile placement or associated scour. At a tLSE level for trawling, physical damage from siltation and abrasion were screened in and it was recognised that trawling causes disturbance to the seabed but does not result in the physical loss of the extent of the feature. Impacts surrounding the installation of three piles are small scale and localised, affecting a very limited area which occurs outside of the SAC and therefore cannot lead to in-combination affects with trawling. It

		is also important to point out that impact pathways of the project and activity do not overlap.
Cowes breakwater (Shrape extension), marine and capital dredge	In planning	The environmental statement or habitats regulation assessment is currently not available (as of 06/04/2016) and so there is a lack of information regarding the impact pathways which may arise from this project, thus making it hard to assess. Potential and relevant impact pathways are likely to include increases in suspended sediment concentrations and increase in sedimentation rates. These impact pathways are likely to arise from dredging of the new Eastern Channel. The dredging is likely to be small scale and as such increases in suspended sediment and sedimentation rates are likely to be limited, localised and temporary in nature. At a tLSE level for trawling physical damage from siltation was screened in. The resuspension of sediment is known to occur through turbulence from trawl doors and/or through contact of components of the trawl with the seafloor (Main & Sangster, 1979; 1981). Studies on shellfish dredging have reported suspended sediment rapidly returns to low levels with distance from the dredge activity (Kyte *et al*., 1976; Mairer *et al*., 1998), with 98% resettling within 15 m (Mercaldo-Allen & Goldberg, 2011). It is therefore not anticipated that the project and activity will lead to any in-combination effects.
IFA2 Cable	In planning	The environmental statement or habitats regulation assessment is currently not available (as of 05/04/2016) and so there is a lack of information regarding the impact pathways which may arise from this project, thus making it hard to assess. The interconnector is made up of undersea cables which will enter a converter station based at Daedalus airfield in Stubbington and a substation near Chilling in Warsash. There will be a need for undersea cables to run from Daedalus to Chilling to connect the two sites. Where the cable comes ashore there are two options available in order to bury the cable; trenching and drilling. Trenching involves digging a trench to bury the cable and drilling involves using horizontal directional drilling, the latter of which involves drilling underneath the beach. Potential and relevant impact pathways are likely to include increase in suspended sediment concentrations, increase in sedimentation rate and

		loss of intertidal. If drilling is used then there is unlikely to be a loss of intertidal. If trenching is used there is likely to be a loss of some intertidal habitat, although this is likely to be limited in extent when compared with the rest of the SAC. Increases in suspended sediment concentrations and sedimentation rates are likely to be small scale, temporary (one off events) and localised to each area. At a tLSE level for trawling, physical damage from siltation was screened in. The resuspension of sediment is known to occur through turbulence from trawl doors and/or through contact of components of the trawl with the seafloor (Main & Sangster, 1979; 1981). Studies on shellfish dredging have reported suspended sediment rapidly returns to low levels with distance from the dredge activity (Kyte *et al*., 1976; Mairer *et al*., 1998), with 98% resettling within 15 m (Mercaldo-Allen & Goldberg, 2011). Although in relatively close proximity, both sites are outside of the SAC boundary and therefore will not be affected by a loss of intertidal. Based on the small scale, temporary and localised nature of the impacts of the project and activity with respect to suspended sediments and sedimentation rates, it is anticipated that the combination of both will not lead to in-combination effects.

8.2 Other fishing activities

Fishing activity	Potential for in-combination effect
Clam dredging	Common impact pathways were identified at a tLSE level and these include physical damage – siltation, physical damage – abrasion and selective extraction of species. The two activities target different species and therefore there will be no in-combination effects with respect to selective extraction of species. Clam dredging is often focused in areas of softer sediment in distinct, small spatial areas where shellfish beds exist and where fishing is permitted. These largely include the north eastern quarter of Langstone Harbour, the western upper reaches of Southampton Water, outside the entrance to the river Hamble and Ashlett Creek. These sites occur intertidally (fished at high tide) and subtidally, with vessels often operating in very shallow waters. Trawling is generally focused subtidally in the central and eastern Solent, occurring at lower levels in the western Solent. The level of trawling occurring within the SAC is limited and sightings data shows it occurs on an infrequent basis. Sightings data presented in Annex 6 demonstrate a very limited spatial

	overlap between recent clam dredging sightings (indicative of current levels) and trawl sightings (split between 2005-2011 and 2012-2015) within the SAC, with limited spatial overlap occurring in Southampton Water and the north eastern quarter of Langstone Harbour where the number of recent (2012-2015) trawl sightings are low in both areas. Based on this lack of spatial overlap, and low level of trawling within the SAC, it is unlikely the two activities will lead to any significant in-combination effects through physical damage (siltation and abrasion).
Oyster dredging	Common impact pathways were identified at a tLSE level and these include physical damage – siltation, physical damage – abrasion and selective extraction of species. The two activities target different species and therefore there will be no in-combination effects with respect to selective extraction of species. Oyster dredging is concentrated takes place in distinct, small spatial areas where shellfish beds exist. In recent years these areas include the channels running up into the north eastern quarter of Langstone Harbour and an area known as Sword Sands, located fairly centrally within the harbour. Trawling is generally focused subtidally in the central and eastern Solent, occurring at lower levels in the western Solent. The level of trawling occurring within the SAC is limited and sightings data shows it occurs on an infrequent basis. Sightings data presented in Annex 6 demonstrate a very limited overlap between recent oyster sightings data (indicative of current levels) and trawl sightings (split between 2005-2011 and 2012-2015) within the SAC, with the only spatial overlap occurring in the north eastern quarter of Langstone Harbour where the number of recent (2012-2015) trawl sightings are low. Based on this lack of spatial overlap, and low level of trawling within the SAC, it is unlikely the two activities will lead to any significant in-combination effects through physical damage (siltation and abrasion).
Light otter trawling (for sandeels)	Common impact pathways were identified at a tLSE level and these include; physical damage – siltation, physical damage – abrasion and selective extraction of species. The two activities target different species and therefore there will be no in-combination effects with respect to selective extraction of species. Light otter trawling for sandeels occurs in one area of Langstone Harbour known as Sword Sands located in the main channels in the southern and central parts of the harbour. Trawling on the other hand is generally focused subtidally in the central and eastern Solent, occurring at lower levels in the western Solent. The level of trawling occurring within the SAC is limited and sightings data shows it occurs on an infrequent basis. There is no spatial overlap between the two activities and therefore there are likely to be no in-combination effects for any of the impact pathways identified.
Demersal netting	No impact pathways were identified at a tLSE level for demersal netting. The activity is low impact and unlikely to lead to any in-combination effects. In addition, static gear types such as netting and mobile gear types such as oyster dredging are not compatible and often occur in different areas, thus largely eliminating any spatial overlap between the two activities.
Demersal	No impact pathways were identified at a tLSE level for demersal longlining.

longlining	The activity is low impact and unlikely to lead to any in-combination effects. In addition, static gear types such as longlining and mobile gear types such as oyster dredging are not compatible and often occur in different areas, thus largely eliminating any spatial overlap between the two activities.
Potting	No impact pathways were identified at a tLSE level for potting within the Solent Maritime SAC. The activity is low impact and unlikely to lead to any in-combination effects. In addition, static gear types such as potting and mobile gear types such as oyster dredging are not compatible and often occur in different areas, thus largely eliminating any spatial overlap between the two activities.

9. Summary of consultation with Natural England

Consultation	Date submitted	Response from NE	Date received
First draft (v1.4)	08/02/2016	Recommended amendments	30/03/2016
Revised draft in response to NE recommendations (v1.6)	21/04/2016	Accepted amendments	12/05/2016

10. Integrity test

It can be concluded that the activities in this Habitats Regulations Assessment (light otter trawling and beam trawling), alone or in-combination, do not adversely affect the designated Sandbanks slightly covered by seawater all the time features/ sub-features of the Solent Maritime SAC; and that future activity, if it remains similar to current levels, will not foreseeably have an adverse effect on the Sandbanks slightly covered by seawater all the time features/ sub-features and their supporting habitats of the SAC. The mitigation measures detailed in table 8 are therefore considered sufficient.

Annex 1: Reference list

Ball, B., Munday, B., & Tuck, I.D. 2000. Effects of otter trawling on the benthos and environment in muddy sediments. In Kaiser, M.J. & de Groot, S.J. (Eds). *The Effects of Fishing on Non-target Species and Habitats*. Blackwell Science. pp. 69-82

Bergman, M.J.N, Fonds, M., Hup, M. & Stam, A. 1990. Direct effects of beam trawl fishing on benthic fauna in the North Sea. ICES C.M. 1990/MINI:11.

Bergman, M.J.N. & van Santbrink, J.W. 2000. Mortality in megafaunal benthic populations caused by trawl fisheries on the Dutch continental shelf in the North Sea in 1994. *ICES J. Mar. Sci*., **57**, 1321-1331.

Bergman, M.J.N., & Hup, M. 1992. Direct effects of beam trawling on macrofauna in a sandy sediment in the southern North Sea. *ICES J. Mar. Sci*., **49**, 5-11.

Bolam, S.G., Coggan, R.C., Eggleton, J., Diesing, M. & Stephens, D. 2014. Sensitivity of microbenthic secondary production to trawling in the English sector of the Greater North Sea: A biological trait approach. *J. Sea Res*., **85**, 162-177.

Bridger, J. P. 1972. Some observations on the penetration into the sea bed of tickler chains on a beam trawl. ICES CM 1972/B:7, 9 pp.

Brylinsky, M., Gibson, J. & Gordon, D.C. 1994. Impacts of flounder trawls on the intertidal habitat and community of the Minas Basin, Bay of Fundy. *Can. J. Fish Aquat*. *Sci*., **51**, 650-61.

Callaway, R., Engelhard, G.H., Dann, J., Cotter, J. & Rumohr, H. 2007. A century of North Sea epibenthos and trawling: comparison between 1902–1912, 1982–1985 and 2000. *Mar. Ecol. Prog. Ser*., **346**, 27-43.

Coen, L.D. 1995. A review of the potential impacts of mechanical harvesting on subtidal and intertidal shellfish resources. SCDNR-MRRI, 46 pp.

Collie, J.S., Hall, S.J., Kaiser, M.J. & Poiner, I.R. 2000. A quantitative analysis of fishing impacts on shelf-sea benthos. *J. Anim. Ecol*., **69**, 785-798.

de Groot, S.J. & Lindeboom, H.J. 1994. Environmental impact of bottom gears on benthic fauna in relation to natural resources management and protection of the North Sea. Texel, Netherlands. Netherlands Institute for Sea Research.

DeAlteris, J., Skrobe, L. & Lipsky, C. 1999. The significance of seabed disturbance by mobile fishing gear relative to natural processes: a case study in Narragansett Bay, Rhode Island. In Benaka, L (Ed). *Fish habitat: essential fish habitat and rehabilitation*. American Fisheries Society, Symposium 22, Bethesda, Maryland, pp. 224-237

Depestele, J., Courtens, W., Degraer, S., Haelters, J., Hostens, K., Houziaux, J.S., Merckz, B., Polet, H., Rabaut, M., Stienen, E.W.M., Vandendriessche, S., Verfaillie, E. & Vincx, M. 2012. An integrated impact assessment of trammel net and beam trawl fisheries "WAKO II" - Final Report. Project SD/NS/O8A. Brussels: Belgian Science Policy Office. 234 pp.

Dernie, K.M., Kaiser, M.J. & Warwick, R.M. 2003. Recovery rates of benthic communities following physical disturbance. *J. Anim. Ecol*., **72**, 1043-1056.

Drabsch, S. L., Tanner, J. E. & Connell, S. D. 2001. Limited infaunal response to experimental trawling in previously untrawled areas. *ICES J. Mar. Sci*., **58**, 6, 161.

Engel, J. & Kvitek, R. 1998. Effects of otter trawling on benthic community in Monterey Bay National Marine Sanctuary. *Cons. Biol*., **12**, 6, 1204-214.

English Nature. 2001. Solent European Marine Site. English Nature's advice given under Regulation 33(2) of the Conservation (Natural Habitats &c.) Regulations 1994. 129 pp.

Foden, J., Rogers, S.I. & Jones, A.P. 2010. Recovery of UK seabed habitats from benthic fishing and aggregate extraction – towards a cumulative impact assessment. *Mar. Ecol. Prog. Ser*., **411**, 259-270.

Fonteyne, R. 2000. Physical impact of beam trawls on seabed sediments. In Kaiser, M.J. & de Groot, S.J. (Eds). *The Effects of Fishing on Non-target Species and Habitat*. Blackwell Science. pp. 15-36

Freeman, S. M., Richardson, C.A. & Seed, R. 2001. Seasonal abundance, spatial distribution, spawning and growth of *Astropecten irregularis* (Echinodermata: Asteroidea). *Estuar. Coast. Shelf. Sci*., **53**, 39–49.

Gilkinson, K.D., Gordon, Jr D.C., MacIsaac, K.G., McKeown, D.L., Kenchington, E.L.R., Bourbonnais, C. & Vass, W.P. 2005. Immediate impacts and recovery trajectories of macrofaunal communities following hydraulic clam dredging on Banquereau, eastern Canada. *ICES J. Mar. Sci*., **62**, 925–947

Gilkinson, K., Paulin, M., Hurley, S. & Schwinghamer, P. 1998. Impacts of trawl door scouring on infaunal bivalves: results of a physical trawl door model/dense sand interaction. *J.Exp.Mar.Biol. & Ecol.*, **224**, 291-312.

Goodchild, R., Brutto, D., Snaith, E., Frost, N., Kaiser, M. & Salmon, P. 2015. Analysis of existing data to study effects of towed fishing gears on mobile sediments against a background of natural variability. Funded by Department for Environment, Food and Rural Affairs (Defra). 65 pp.

Goss-Custard, J.D. 1977. The ecology of the Wash. III. Density-related behaviour and the possible effects of a loss of feeding grounds on wading birds (Charadrii). *J. Anim. Ecol*., **14**, 721-739.

Grieve, C., Brady, D.C. & Polet, H. 2014. Best practices for managing, measuring and mitigating the benthic impacts of fishing – Part 1. *Marine Stewardship Council Science Series*, 2, 18 – 88.

Groot S.J. de. 1995. On the penetration of the beam trawl into the sea bed. ICES C.M. 1995/B:36

Gubbay, S. & Knapman, P.A. 1999. A review of the effects of fishing within UK European marine sites. UK Marine SACs Project. 134 pp.

Hall, S.J. 1994. Physical disturbance and marine benthic communities: life in unconsolidated sediments. *Oceanogr. Mar. Biol. Annu*. *Rev*., **32**, 179–239

Hall, K., Paramor, O.A.L., Robinson, L.A., Winrow-Giffin, A., Frid, C.L.J., Eno, N.C., Dernie, K.M., Sharp, R.A.M., Wyn, G.C. & Ramsay, K. 2008. Mapping the sensitivity of benthic habitats to fishing in Welsh Waters: development of a protocol. CCW (Policy Research) Report No: 8/12. 85 pp.

Haven, D.S. 1979. A study of hard and soft clam resources of Virginia. US Fish Wildl. Serv.,Comm. Fish. Res. Devel. Act Final Report Contract Nos. 3-77-R-1, 3-77-R-2, 3-77-R-3, 69 pp.

Hiddink, J.G. 2003. Effects of suction-dredging for cockles on non-target fauna in the Wadden Sea. *J. Sea. Res*., **50**, 315-323

Hiddink, J.G., Jennings, S., Kaiser, M.J., Queirós, A.M., Duplisea, D.E. & Piet, G.J. 2006a. Cumulative impacts of seabed trawl disturbance on benthic biomass, production and species richness in different habitats. *Can. J. Fish. Aquat. Sci*., **63**, 721-736.

Hiddink, J. G., S. Jennings, and M. J. Kaiser. 2006b. Recovery status as an indicator of the large scale ecological impact of bottom trawling. *Ecosystems*, **9**, 1190–1199.

Hinz, H., Prieto, V. & Kaiser, M.J. 2009. Trawl disturbance on benthic communities: chronic effects and experimental predictions. *Ecol. Appl*., **19**, 3, 761-773.

Howell, B.R. & Shelton, R.G.J. 1970. The effect of china clay on the bottom fauna of St Austell and Mevagissey Bays. *J. Mar. Biol. Assoc. U. K*., **50**, 3, 593-607.

Humborstad, O.-B., Nøttestad, L., Løkkeborg, S. & Rapp, H.T. 2004. RoxAnn bottom classification system, sidescan sonar and video-sledge: spatial resolution and their use in assessing trawling impacts. *ICES J. Mar. Sci*., **61**, 53-63.

ICES. 1992. Report of the study group on ecosystem effects of fishing activities. ICES C.M.1992/G:11.

Jennings, S., Dinmore, T.A., Duplesea, D.E., Warr, K.J. & Lancaster, J.E. 2001. Trawling disturbance can modify benthic production processes. *J. Anim. Ecol*., **70**, 459–475.

Jennings, S. & Kaiser, M.J., 1998. The effects of fishing on marine ecosystems. *Adv. Mar. Biol*., **34**, 201–352.

Jennings, S., M.D. Nicholson, T.A. Dinmore & J. Lancaster, 2002. Effects of chronic trawling disturbance on the production of infaunal communities. *Mar. Ecol. Prog. Ser*., **243**, 251–260.

Johnson, K.A. 2002. A review of national and international literature on the effects of fishing on benthic habitats. NOAA Tech. Memo. NMFS-F/SPO-57. 72 pp.

Jones, J.B. 1992. Environmental impact of trawling on the seabed: a review. *New Zeal. J. Mar. Freshwat. Res*., **26**, 59-67.

Kaiser, M.J., Ramsay, K., Richardson, C.A., Spence, F.E., Brand, A.R. 2000. Chronic fishing disturbance has changed shelf sea benthic community structure. *J. Anim. Ecol*., **69**, 494–503.

Kaiser, M.J. & Spencer, B.E. 1996. The effects of beam-trawl disturbance on infaunal communities in different habitats. *J. Anim. Ecol*., **65**, 348-58.

Kaiser, M.J. 2014. The conflict between static gear and mobile gear in inshore fisheries – In depth analysis. Policy Department B: Structural and Cohesion Policies. European Parliament. B-1047 Brussels.

Kaiser, M.J., Clarke, K.R., Hinz, H., Austen, M.C.V., Somerfield, P.J. & Karakassis, I. 2006. Global analysis of response and recovery of benthic biota to fishing. *Mar. Ecol. Prog. Ser*., **311**, 1-14.

Kaiser, M.J., Collie, J.S., Hall, S.J., Jennings, S. & Poiner, I.R. 2002. Modification of marine habitats by trawling activities: prognosis and solutions. *Fish and Fisheries*, **3**, 1-24.

Kaiser, M.J., D.B. Edwards & Spencer, B.E. 1996. Infaunal community changes as a result of commercial clam cultivation and harvesting. *Aquat. Living Resour*., 9, 57-63
.

Kaiser, M.J., Edwards, D.B., Armstrong, P.J., Radford, K., Lough, N.E.L., Flatt, R.P. & Jones, H.D. 1998. Changes in megafaunal benthic communities in different habitats after trawling disturbance. *ICES J. Mar. Sci*., **55**, 353-361.

Kaiser, M.J., Cheney, K., Spence, F.E., Edwards, D.B. & Radford, K. 1999. Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. VII. The effects of trawling disturbance on the fauna associated with the tubeheads of serpulid worms. *Fish. Res*., **40**, 195-205.

Kenchington, E.L.R., Gilkinson, K.D., MacIsaac, K.G., Bourbonnais- Boyce, C., Kenchington, T.J., Smith, S.J. & Gordon, D.C. Jr. 2006. Effects of experimental otter trawling on benthic assemblages on Western Bank, northwest Atlantic Ocean. *J. Sea Res*., **56**, 249–270

Kenchington, E. L. R., Prena, J., Gilkinson, K. D., Gordon Jr, D. C., Macisaac, K., Bourbonnais, C., Schwinghamer, P. J., Rowell, T. W., McKeown, D. L. & Vass, W. P., 2001. Effects of experimental otter trawling on the macrofauna of a sandy bottom ecosystem on the Grand Banks of Newfoundland. *Can. J. Fish. Aquat. Sci*., **58**, 6, 1043-1057.

Kyte, M.A., Averill. P. & Hendershott, T. 1976. The impact of the hydraulic escalator shellfish harvester on an intertidal soft-shell clam flat in the Harraseeket River, Maine. Maine Dep. Mar. Res. 31 pp.

Lambert, J. & Goudreau, P. 1996. Performance of the New England hydraulic dredge for the harvest of Stimpson's surf clams (*Mactromeris polynyma*). Can. Ind. Rep. Fish. Aquat. Sci., 235. 28 pp.

Leth J.O. & Kuijpers A. 1996. Effects on the seabed sediment from beam trawling in the North Sea. ICES 1996. Annual Science Conference. Mini-symposium: "Ecosystem Effects of Fisheries". ICES C.M. 1996/Mini 3.

Lindeboom, H.J. & S.J. de Groot, 1998. Impact II. The effects of different types of fisheries on the North Sea and Irish Sea bent hic ecosystems. NIOZ Rapport 1998-1. 404 pp.

Lindholm, J., Gleason, M., Kline D., Clary, L., Rienecke, S., Bell, M. & Kitaguchi, B. 2013. Central Coast Trawl Impact and Recovery Study: 2009-2012 Final Report. Report to the California Ocean Protection Council. 49 pp.

Løkkeborg, S. 2005. Impacts of trawling and scallop dredging on benthic habitats and communities. FAO Fisheries Technical Paper 472. Food and Agriculture Organisation of the United Nations. 69 pp.

Maier, P.P., Wendt, P.H., Roumillat, W.A., Steele, G.H., Levisen, M.V. & Van Dolah, R. 1998. Effects of subtidal mechanical clam harvesting on tidal creeks. SCDNR-MRD. 38 pp.

Main, J. & Sangster, G. I. 1979: A study of bottom trawling gear on both sand and hard ground. Scottish fisheries research report 14, 15 pp.
Main, J.; Sangster, G. I. 1981: A study of the sand clouds produced by trawl boards and their possible effect on fish capture. Scottish fisheries research report 20, 20 pp.

Manning, J.H. 1957. The Maryland softshell clam industry and its effects on tidewater resources. Md. Dep. Res. Educ. Resour. Study Rep. 11, 25 pp.

Manzi, J.J., Burrell, V.G., Klemanowicz, K.J., Hadley, N.H. & Collier, J.A. 1985. Impacts of a mechanical harvester on intertidal oyster communities in South Carolina. Final Report: Coastal Energy Impact Program Contract # CEIP-83-06. Governor's Office, Columbia (SC). 31 pp.

Maurer, D., Keck, R.T., Tinsman, J.C., Leathem, W.A. 1982. Vertical migration and mortality of benthos in dredged material: Part 111 - Polychaeta. *Mar. Environ. Res*., **6**, 49-68.

Mayer, L.M., Schick, D.F., Findlay, R.H. & Rice, D.L. 1991. Effects of commercial dragging on sedimentary organic matter. *Mar. Environ. Res*., **31**, 249-261.

McConnaughey, R.A., Mier, K.L. & Dew, C.B. 2000. An examination of chronic trawling on soft bottom benthos of the eastern Bering Sea. *ICES J. Mar. Sci*., **57**, 1388-1400.

Mercaldo-Allen, R. & Goldberg, R. 2011. Review of the Ecological Effects of Dredging in the Cultivation and Harvest of Molluscan Shellfish. NOAA Technical Memorandum NMFS-NE-220. 84 pp.

MMO. 2014. Fishing gear glossary for the matrix (by gear type). Available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/314315/gearglossary_gear.pdf [Accessed 2016, 5th January].

Moran, M.J. & Stephenson, P.C. 2000. Effects of otter trawling on macrobenthos and management of demersal scalefish fisheries on the continental shelf of north-western Australia. *ICES J. Mar. Sci*., **57**, 510-516.

Nilsson, H.C. & Rosenberg, R. 2003. Effects on marine sedimentary habitats of experimental trawling analysed by sediment profile imagery. *J. Exper. Mar. Biol. Ecol*., **285**, 453-463.

Northeast Region EFHSC (Northeast Region Essential Fish Habitat Steering Committee). 2002. Workshop on the effects of fishing gear on marine habitats off the Northeastern United States October 23-25, 2001 Boston, MA. Northeast Fish. Sci. Cent. Ref. Doc. 02-01. 86 pp.

Olsgard, F., Schaanning, M.T., Widdicombe, S., Kendall, M.A. & Austen, M.C.V. 008. Effects of bottom trawling on ecosystem functioning. *J. Exper. Mar. Biol. Ecol*., **66**, 123-133.

Pearson, T. H. & Barnett, P. R. O. 1987: Long-term changes in benthic populations in some west European coastal areas. *Estuaries*, **10**, 220-226.

Philippart, C.J.M. 1998. Long-term impact of bottom fisheries on several bycatch species of demersal fish and benthic invertebrates in the southeastern North Sea. *ICES J. Mar. Sci*., **55**, 342-352.

Prena, J., Schwinghamer, P., Rowell, T.W., Gordon, Jr. D.C., Gilkinson, K.D., Vass, W.P. & McKeown, D.L. 1999. Experimental otter trawling on a sandy bottom ecosystem of the Grand

Banks of Newfoundland: analysis of trawl bycatch and effect on epifauna. *Mar. Ecol. Prog. Ser.*, **181**, 107-124.
Queirós, A.M., Hiddink, J.G., Kaiser, M.J. & Hinz, H. 2006. Effects of chronic bottom trawling disturbance on benthic biomass, production and size spectra in different habitats. *J. Exp. Mar. Biol. Ecol.,* **335**, 91-103.

Ragnarsson, S.A. & Lindegarth, M. 2009. Testing hypotheses about temporary and persistent effects of otter trawling on infauna: changes in diversity rather than abundance. *Mar. Ecol. Prog. Ser.,* **385**, 51–64

Rees, H. L. & Eleftheriou, A. 1989. North Sea benthos: A review of field investigations into the biological effect of man's activities. *Journal du Conseil. Conseil international pour l'exploration de la mer*, **45**, 284-305.

Riemann, B. & Hoffman, E., 1991. Ecological consequences of dredging and bottom trawling in the Limfjord, Denmark. Marine ecology progress series. *Oldendorf*, **69**, 1, 171-178.

Roberts, C., Smith, C., Tillin, H. & Tyler-Walters, H. 2010. Review of existing approaches to evaluate marine habitat vulnerability to commercial fishing activities. Report: SC080016/R3.Environment Agency, Bristol. 150 pp.

Ruffin, K.K. 1995. The effects of hydraulic clam dredging on nearshore turbidity and light attenuation in Chesapeake, MD. MS Thesis. University of Maryland. 97 pp.

Sanchez, P., Demestre, M., Ramon, M. & Kaiser, M. J. 2000. The impact of otter trawling on mud communities in the northwestern Mediterranean. *ICES J. Mar. Sci*., **57**, 1352–1358.

Schratzberger, M., Dinmore, T.A. & Jennings, S. 2002. Impacts of trawling on the diversity, biomass and structure of meiofauna assemblage. *Mar. Biol*., **140**, 83-93.

Schwinghamer, P., Gordon, Jr., D.C., Rowell, T.W., Prena, J., McKeown, D.L., Sonnichsen, G. & Guigne, J.Y. 1998. Effects of experimental otter trawling on surficial sediment properties of a sandy-bottom ecosystem of the Grand Banks of Newfoundland. *Cons. Biol*., **12**, 6, 1215-1222.

Schwinghamer, P., Guigne, J.Y. & Siu, W.C. 1996. Quantifying the impact of trawling on benthic habitat structure using high resolution acoustics and chaos theory. *Can. J. Fish. Aquat. Sci*., **53**, 2, 288-296.

Seafish. 2015. Basic fishing methods. A comprehensive guide to commercial fishing methods. August 2015. 104 pp.

Smith, C.J., Banks, A.C. & Papadopoulou, K.N., 2007. Improving the quantitative estimation of trawling impacts from sidescan-sonar and underwater-video imagery. *ICES J. Mar. Sci.*, **64**, 1692–1701.

Smith, C.J., Papadopoulou, K.N. & Diliberto, S. 2000. Impact of otter trawling on an eastern Mediterranean commercial trawl fishing ground. *ICES J. Mar. Sci*., **57**, 1340–1351.

Smith, C.R. & Brumsickle, S.J. 1989. The effects of patch size and substrate isolation on colonization modes and rates in an intertidal sediment. *Limnol. Oceanogr*., **34**, 1263–1277.

Tarnowski, M. 2006. A literature review of the ecological effects of hydraulic escalator dredging. Fish. Tech. Rep. Ser. 48. 30 pp.

Thrush, S.F. & Dayton, P.K. 2002. Disturbance to marine benthic habitats by trawling and dredging: implications for marine biodiversity. *Annu. Rev. Ecol. Syst*., **33**, 449-473.

Tillin, H.M., Hull, S.C. & Tyler-Walters, H. 2010. Development of a Sensitivity Matrix (pressures-MCZ/MPA features). Report to the Department of Environment, Food and Rural Affairs (DEFRA) from ABPMer, Southampton and the Marine Life Information Network (MarLIN) Plymouth: Marine Biological Association of the UK. Defra Contract No. MB0102 Task 3A, Report No. 22. 947 pp.

Trimmer, M., Petersen, J., Sivyer, D.B.,Mills, C., Young, E. & Parker, E.R. 2005. Impact of long-term benthic trawl disturbance on sediment sorting and biogeochemistry in the southern North Sea. *Mar. Ecol. Prog. Ser*. **298**, 79–94.

Tuck, I.D., Hall, S.J., Robertson, M.R., Armstrong, E. & Basford, D.J. 1998. Effects of physical trawling disturbance in a previously unfished sheltered Scottish sea loch. *Mar. Ecol. Progr. Ser*., **162**, 227-42.

Van Dolah, R. F., Wendt, P. H. & Levisen, M. V., 1991. A study of the effects of shrimp trawling on benthic communities in two South Carolina sounds. *Fish. Res*., **12**, 2, 139-156.

Vining, R. 1978. Final Environmental Impact Statement for the Commercial Harvesting of Subtidal Hardshell Clams with a Hydraulic Escalator Shellfish Harvester. WA Dep. Fish.,Dep. Nat. Resour. 55 pp.

Wallace, D.H. & Hoff, T.B. 2005. Hydraulic clam dredge effects on benthic habitat off the northeastern United States. American Fisheries Society Symposium 41, Bethesda, MD, pp. 691-693.

Wheeler, R., Stillman, R.A.S. & Herbert, R.J.H. 2014. Ecological impacts of clam and cockle harvesting on benthic habitats and waterfowl. Report to Natural England. Bournemouth University. 42pp.

Annex 2: The Key Principles of the SEMS Management Scheme (http://www.solentems.org.uk/sems/management_scheme/)

Principle 1 - Favourable Condition

The SEMS has qualified for designation against the background of current use and there is a working assumption that the features for which the site is designated are in favourable condition from the time of designation. The Management Scheme and the monitoring to be carried out by 2006 will test this assumption.

Principle 2 - Sustainable Development

The aim of the Management Scheme is not to exclude human activities from SEMS, but rather to ensure that they are undertaken in ways which do not threaten the nature conservation interest, and wherever possible, in ways that support it. The Management Scheme should ensure a balance of social, economic and environmental objectives when considering the management of activities within the Solent.

Principle 3 - Regulatory Use of Bye-laws

New bye-laws may be used as a regulatory mechanism for the SEMS. These should only be introduced into the Management Scheme when all other options have been considered and it is the only effective solution.

Principle 4 - Links to Existing Management and Other Plans/Initiative

Where appropriate the SEMS Management Scheme will directly utilise management actions from other existing management plans. The actions identified in the Management Scheme will therefore serve to inform and support existing management effects rather than duplicate them. The management measures identified in other plans will remain the mechanism through which these are to be implemented.

Principle 5 - Onus of Proof

The wording for principle 5 is based on the following three-stage process:

- Stage 1 - Evidence must be established that a site feature is in deterioration. This evidence must be scientific, credible and unambiguous but it need not originate from English Nature itself. It is acknowledged that other Relevant Authorities will be undertaking monitoring regimes and if their programmes flag up something of interest, it would be expected that they would present it to English Nature for further comment and verification.
- Stage 2 - English Nature, as the Government's body with responsibility for nature conservation, must believe that a site feature is in deterioration. If the evidence to support this view has come from their own monitoring - or if it has come from an external, authoritative source - EN should act as a conduit to demonstrate this fact to the Relevant Authority with responsibility for the management of the activity suspected of having detrimental effect.
- Stage 3 - English Nature and the Relevant Authority (ies) involved should work together to establish any cause and effect relationship. From this, changes to management actions may be made.

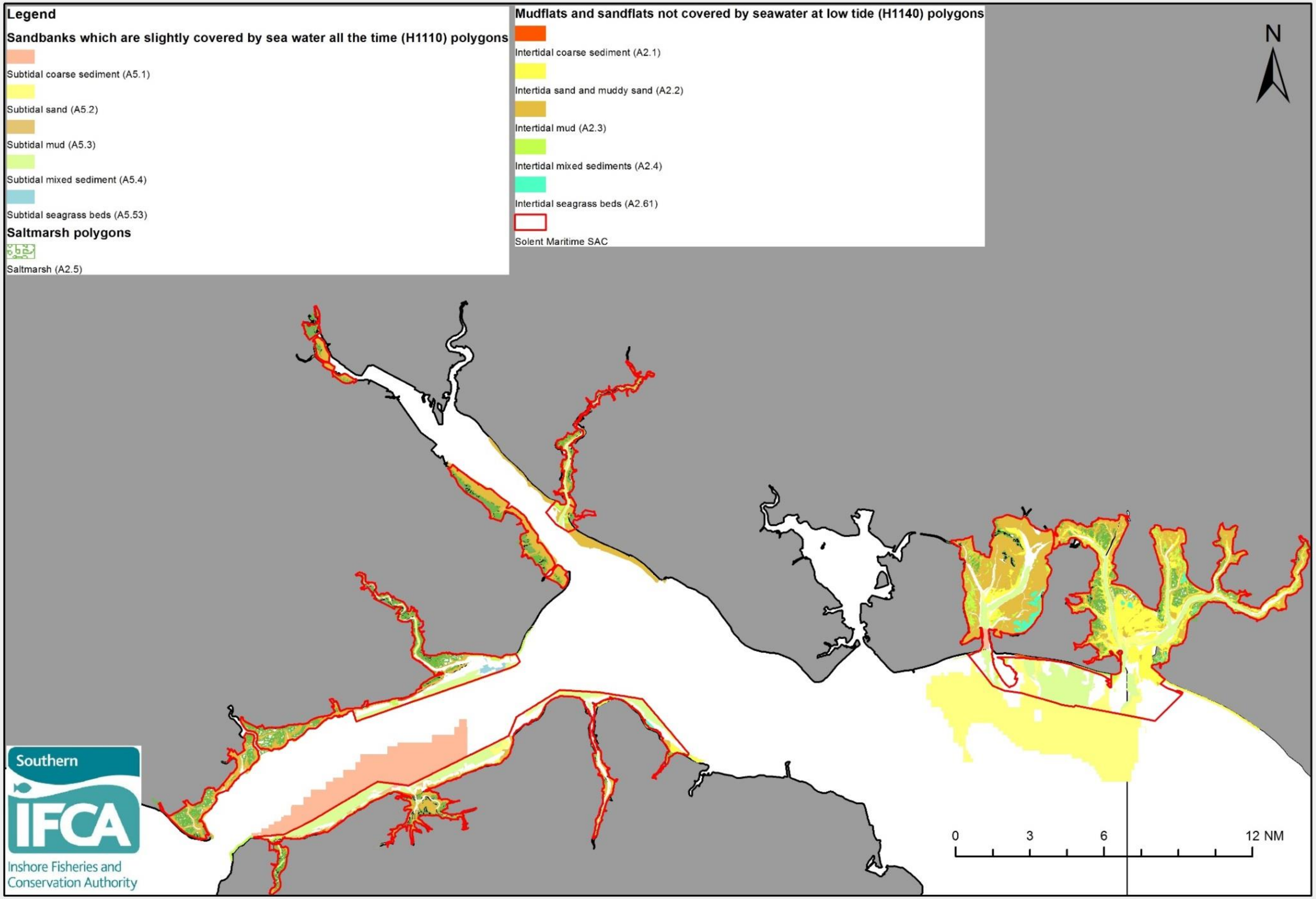
Consideration of this process had led to the following definition of onus of proof: If through their own site condition monitoring programme or that of another Relevant Authority, English Nature can demonstrate that they have reasonable evidence to indicate that a deterioration in the condition of a SEMS feature or species exists, then English Nature and the Relevant Authorities concerned will work together to identify any cause and effect relationship.

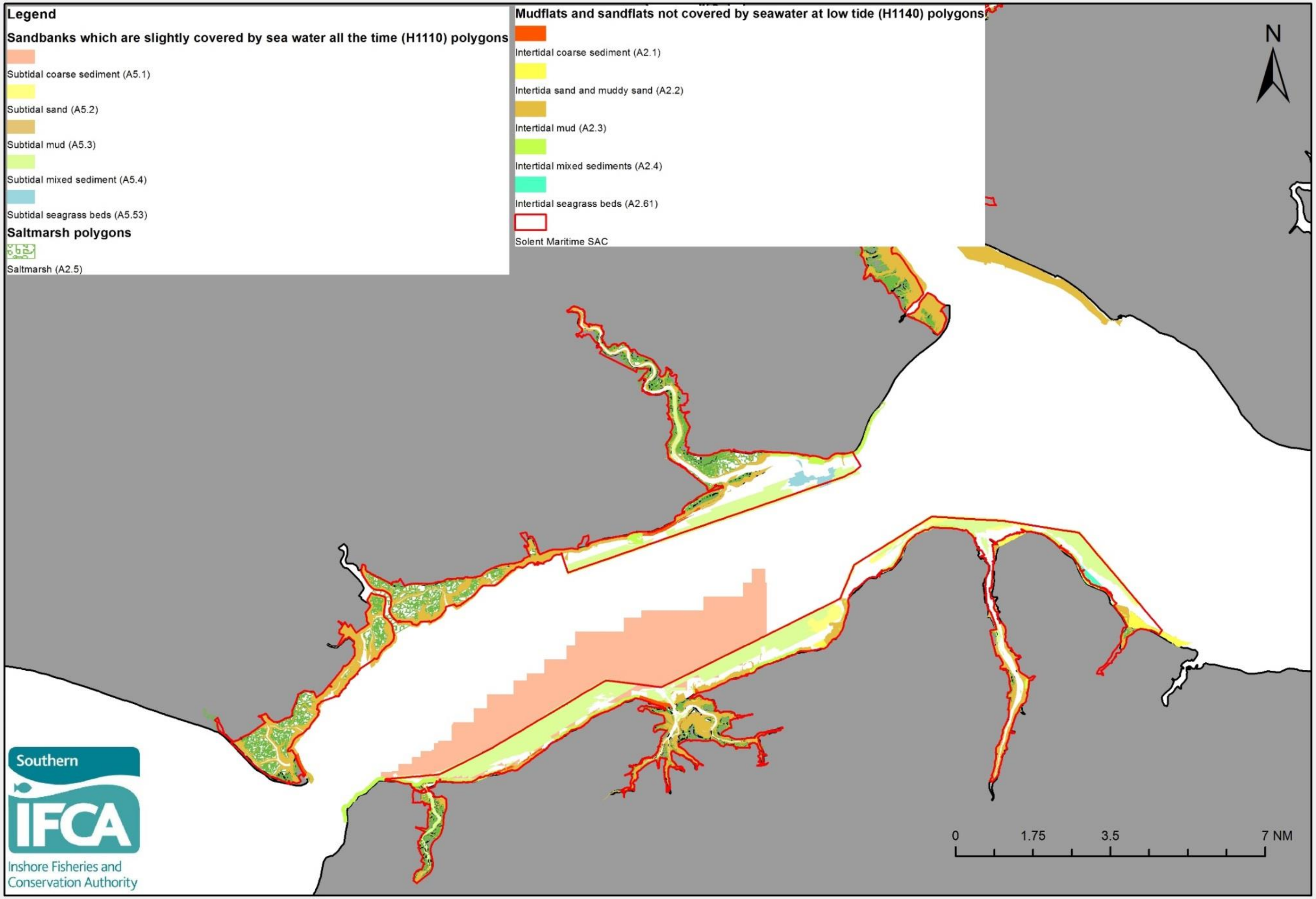
Principle 6 - Management Actions

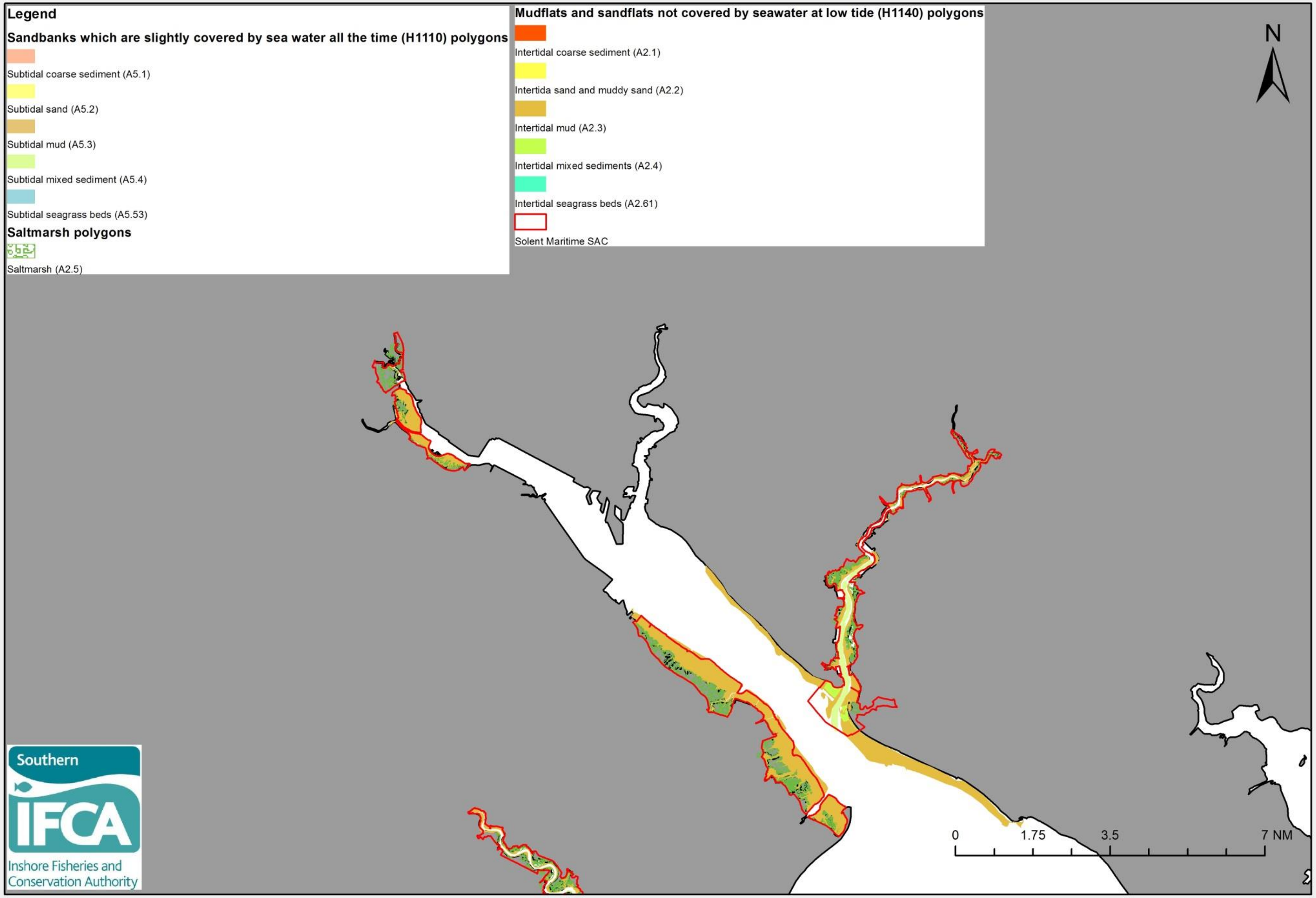
Where reasonable evidence is found to clearly demonstrate the cause and effect relationship the Relevant Authorities involved will instigate changes to the management of the activity, which will be within a RAs statutory obligations and will provide a solution that is in accordance with the Regulations and be fair, balanced, proportionate and appropriate to the site and the activity. Where the cause and effect relationship is uncertain but deterioration in the condition is still significant the Relevant Authorities should consider any potential changes in management practices in light of the precautionary principle* and the cost effectiveness of proposed measures in preventing damage. However, the precautionary principle should not be used to prevent existing management actions continuing where there is no evidence of real risk of deterioration or significant disturbance to site features.

All forms of environmental risk should be tested against the precautionary principle which means that where there are real risks to the site, lack of full scientific certainty should not be used as a reason for postponing measures that are likely to be cost effective in preventing such damage. It does not however imply that the suggested cause of such damage must be eradicated unless proved to be harmless and it cannot be used as a licence to invent hypothetical consequences. Moreover, it is important, when considering whether information available is sufficient, to take account of the associated balance of likely costs, including environmental costs, and benefits." (DETR & the Welsh Office, 1998).

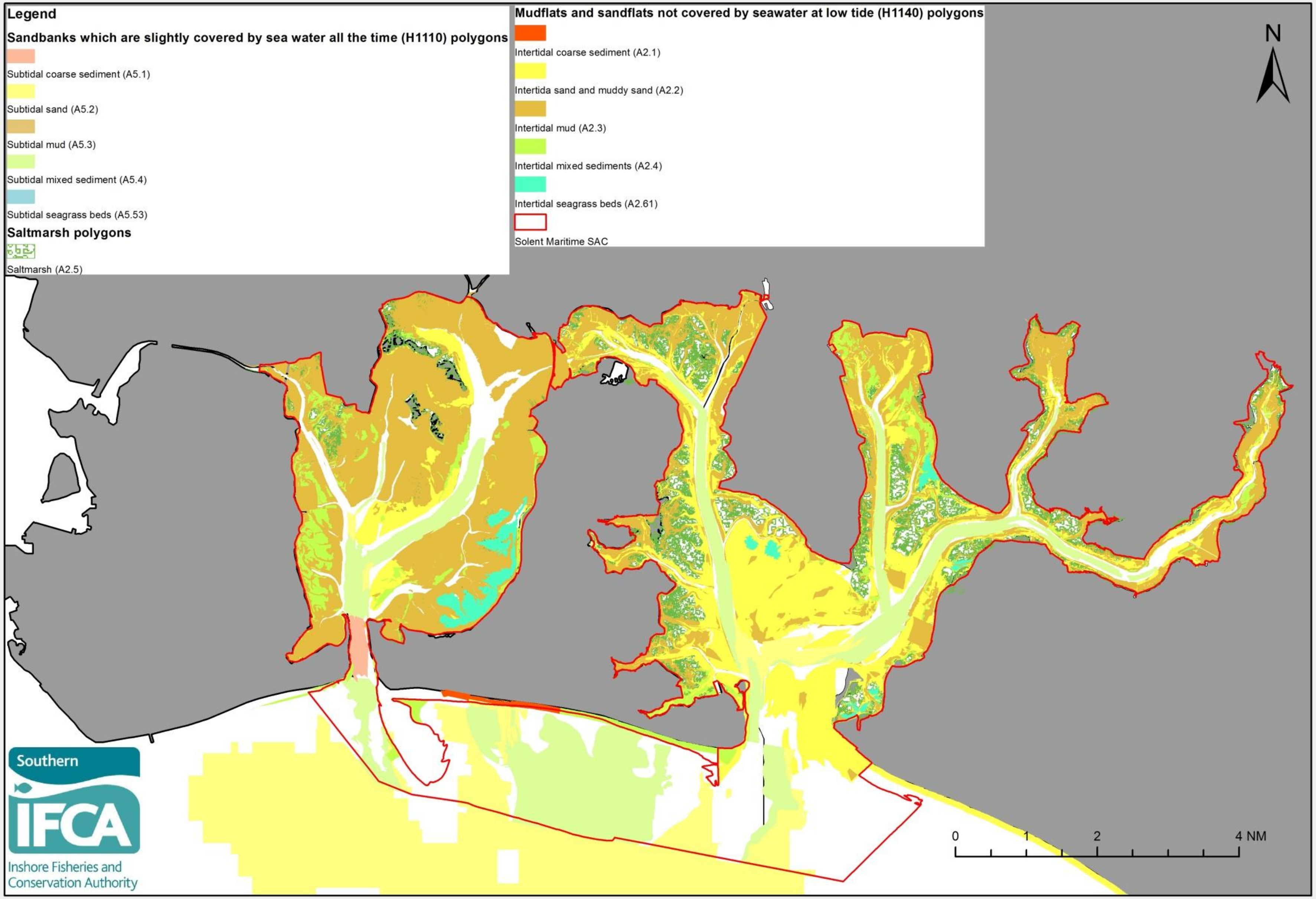
Annex 3: Site Feature/Sub-feature Map(s) for Solent Maritime SAC (Whole Solent Maritime SAC, Western Solent, Southampton Water and Langstone and Chichester Harbour)


Legend
Sandbanks which are slightly covered by sea water all the time (H1110) polygons
Subtidal coarse sediment (A5.1)
Subtidal sand (A5.2)
Subtidal mud (A5.3)
Subtidal mixed sediment (A5.4)
Subtidal seagrass beds (A5.53)
Saltmarsh polygons
Saltmarsh (A2.5)
Mudflats and sandflats not covered by seawater at low tide (H1140) polygons
Intertidal coarse sediment (A2.1)
Intertida sand and muddy sand (A2.2)
Intertidal mud (A2.3)
Intertidal mixed sediments (A2.4)
Intertidal seagrass beds (A2.61)
Solent Maritime SAC
N
0
3
6
12 NM
Southern
IFCA
Inshore Fisheries and
Conservation Authority

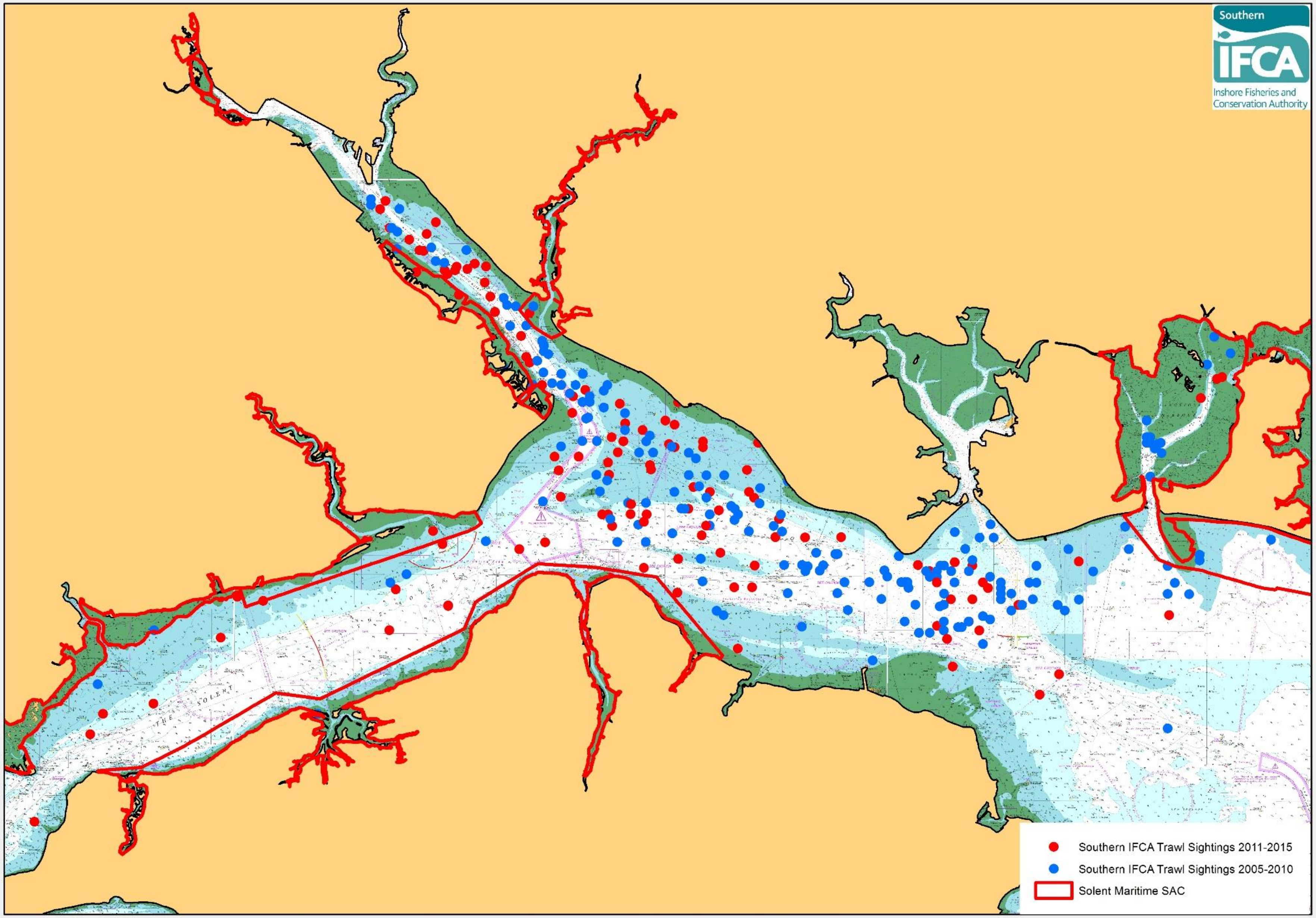

Legend
Sandbanks which are slightly covered by sea water all the time (H1110) polygons
Subtidal coarse sediment (A5.1)
Subtidal sand (A5.2)
Subtidal mud (A5.3)
Subtidal mixed sediment (A5.4)
Subtidal seagrass beds (A5.53)
Saltmarsh polygons
Saltmarsh (A2.5)
Mudflats and sandflats not covered by seawater at low tide (H1140) polygons
Intertidal coarse sediment (A2.1)
Intertida sand and muddy sand (A2.2)
Intertidal mud (A2.3)
Intertidal mixed sediments (A2.4)
Intertidal seagrass beds (A2.61)
Solent Maritime SAC
N
0
1.75
3.5
7 NM
Southern
IFCA
Inshore Fisheries and Conservation Authority

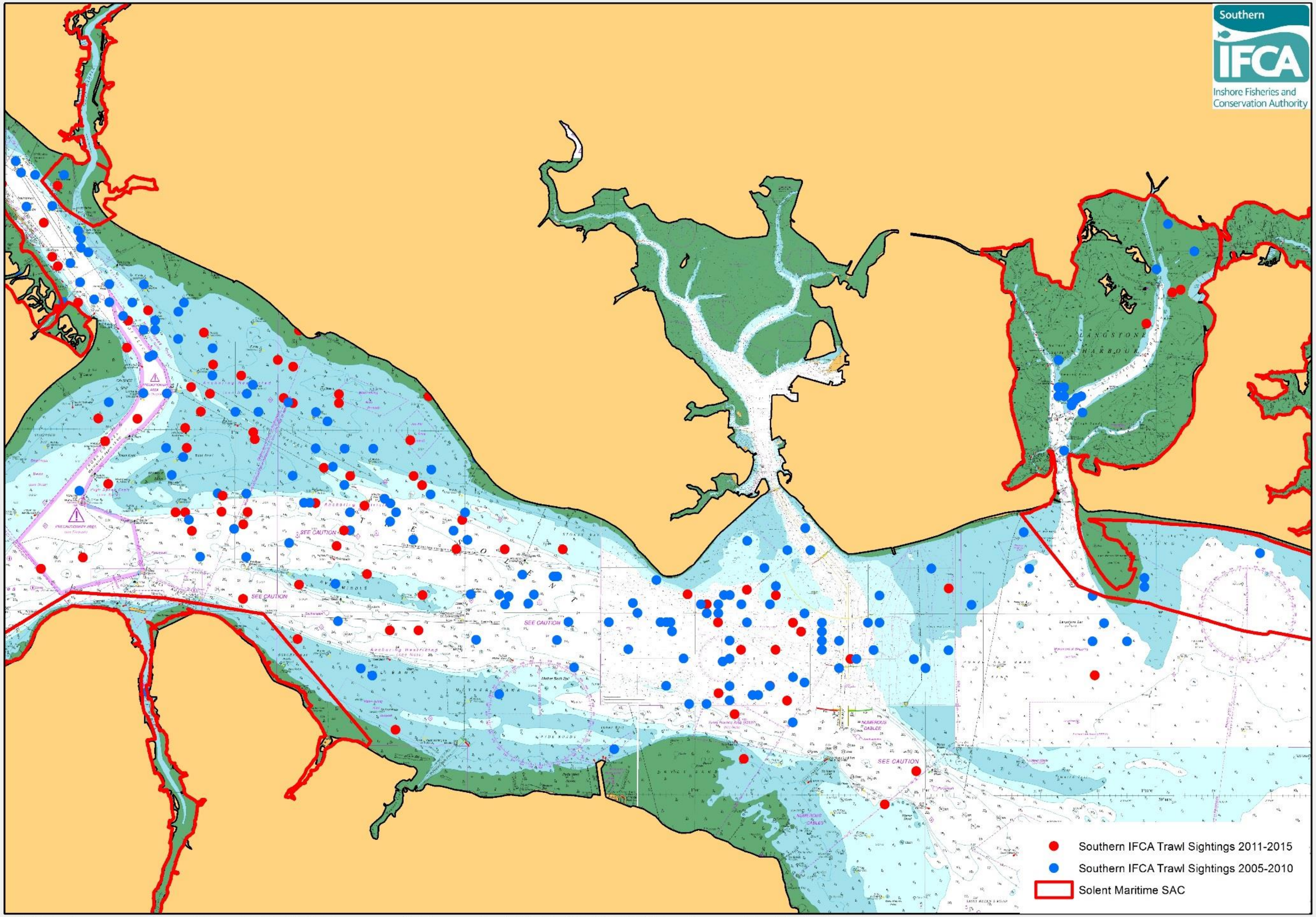


 SIFCA Reference: SIFCA/HRA/06/003

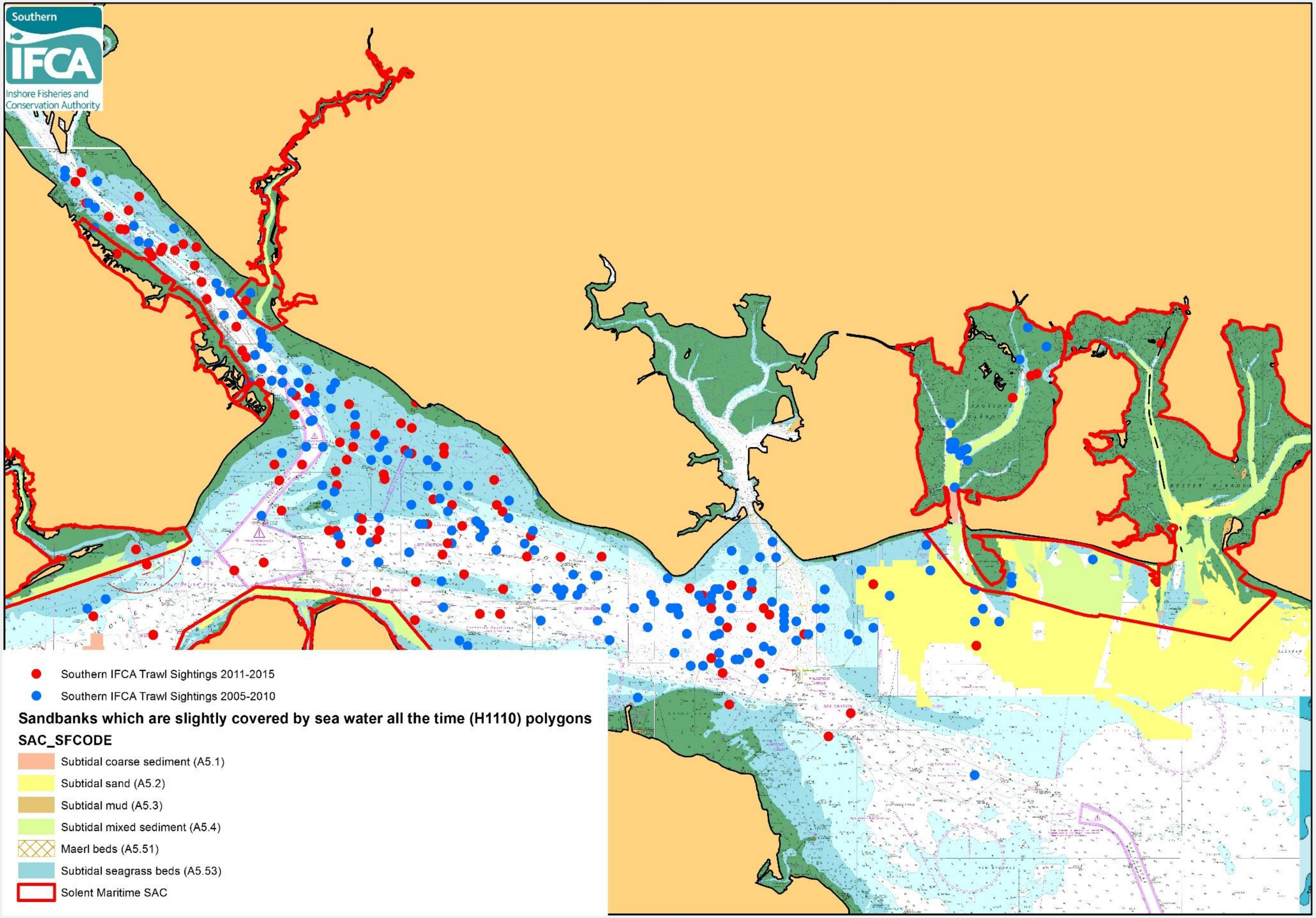

Legend
Sandbanks which are slightly covered by sea water all the time (H1110) polygons
Subtidal coarse sediment (A5.1)
Subtidal sand (A5.2)
Subtidal mud (A5.3)
Subtidal mixed sediment (A5.4)
Subtidal seagrass beds (A5.53)
Saltmarsh polygons
Saltmarsh (A2.5)
Mudflats and sandflats not covered by seawater at low tide (H1140) polygons
Intertidal coarse sediment (A2.1)
Intertida sand and muddy sand (A2.2)
Intertidal mud (A2.3)
Intertidal mixed sediments (A2.4)
Intertidal seagrass beds (A2.61)
Solent Maritime SAC
N
0
1
2
4 NM
Southern
IFCA
Inshore Fisheries and
Conservation Authority

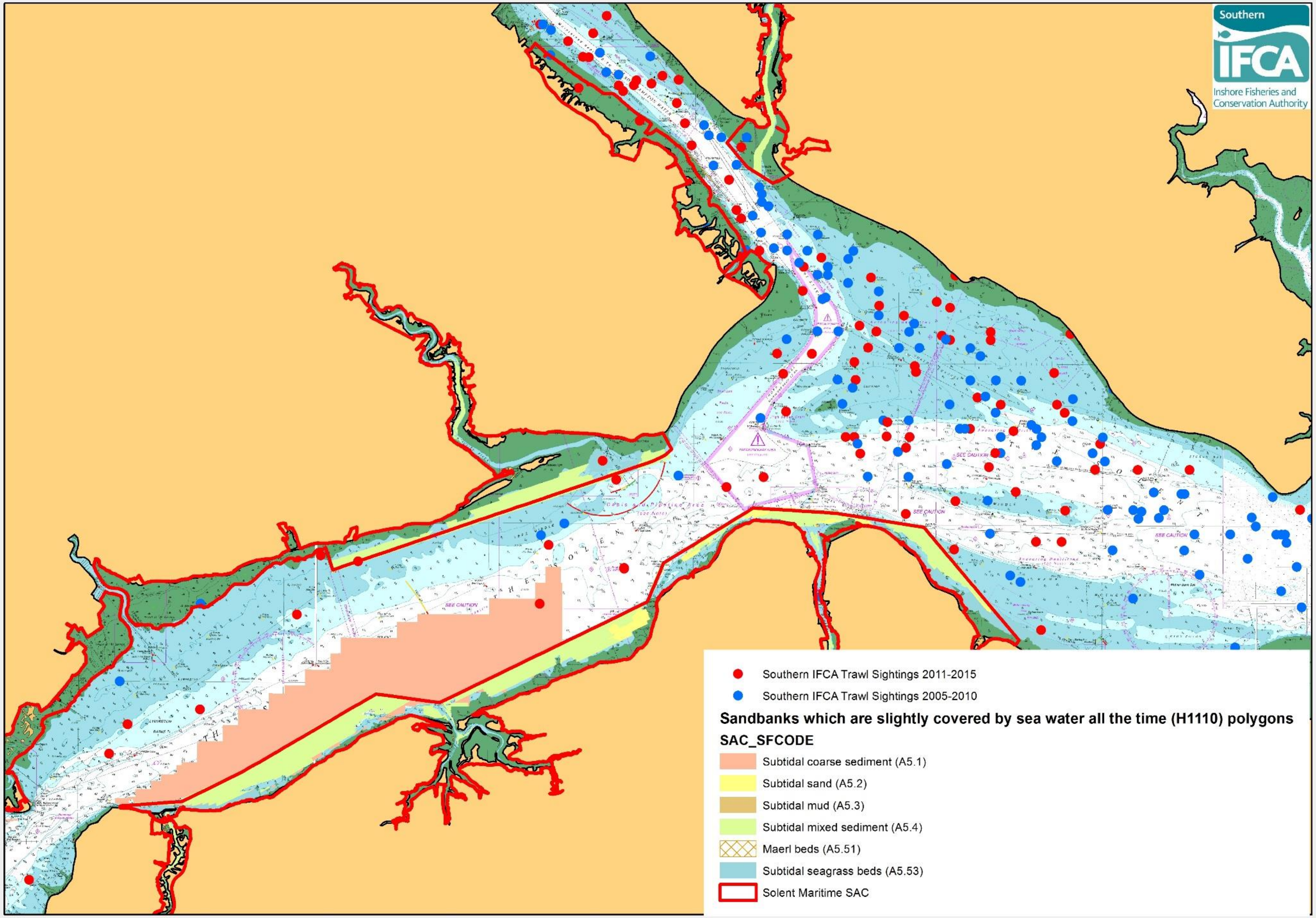
Annex 4: Fishing Activity Map(s) using Trawl Sightings Data from 2005-2015 (2005-2010 & 2011-2015) in the entire and eastern Solent.


Southern
IFCA
Inshore Fisheries and Conservation Authority
Southern IFCA Trawl Sightings 2011-2015
Southern IFCA Trawl Sightings 2005-2010
Solent Maritime SAC

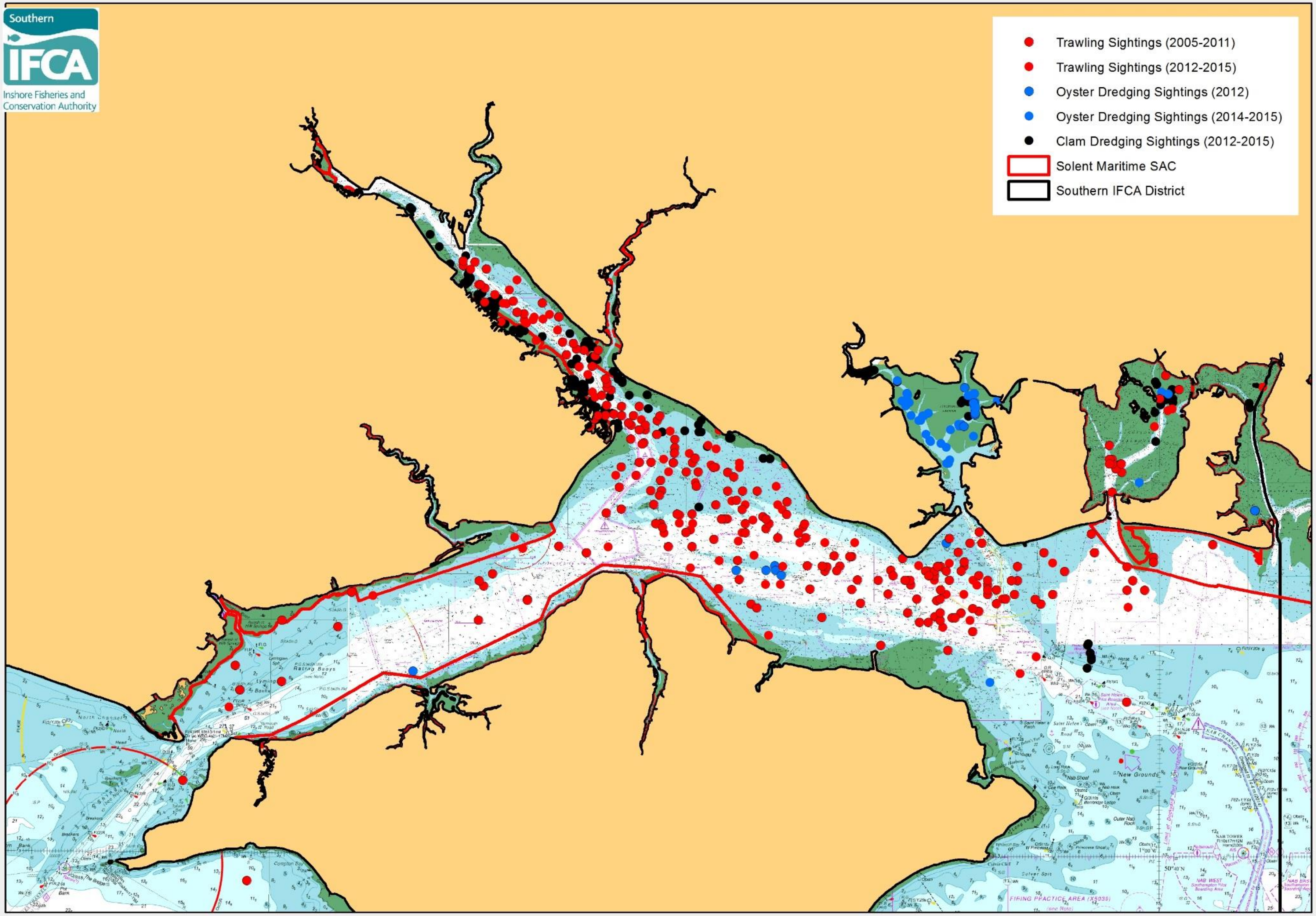

Southern
IFCA
Inshore Fisheries and Conservation Authority
Southern IFCA Trawl Sightings 2011-2015
Southern IFCA Trawl Sightings 2005-2010
Solent Maritime SAC

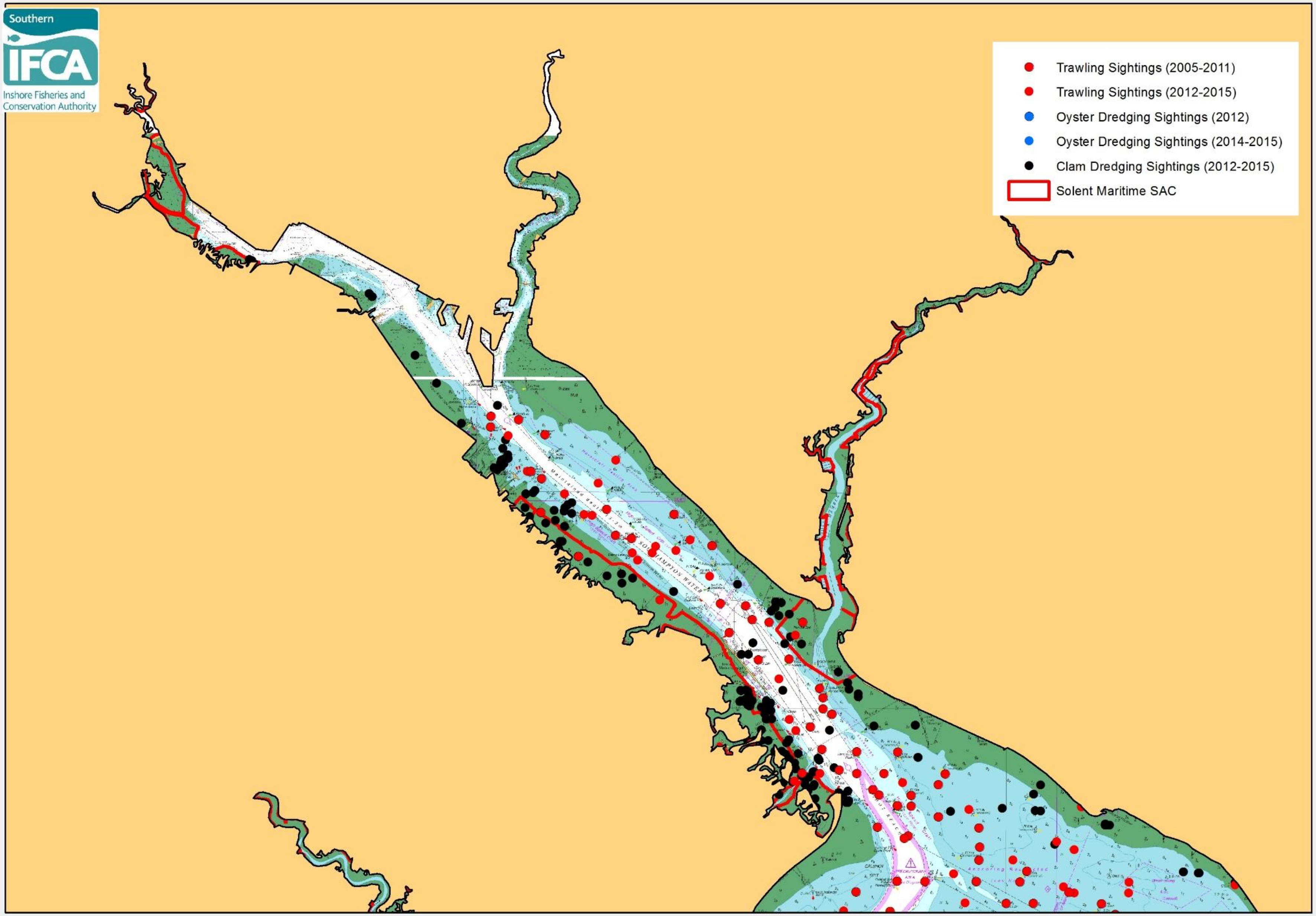
Annex 5: Co-Location of Fishing Activity using Trawl Sightings (2005 to 2015, broken down by 2005-2010 & 2011-2015) and Site Feature(s)/Sub-feature(s) (eastern and western Solent)

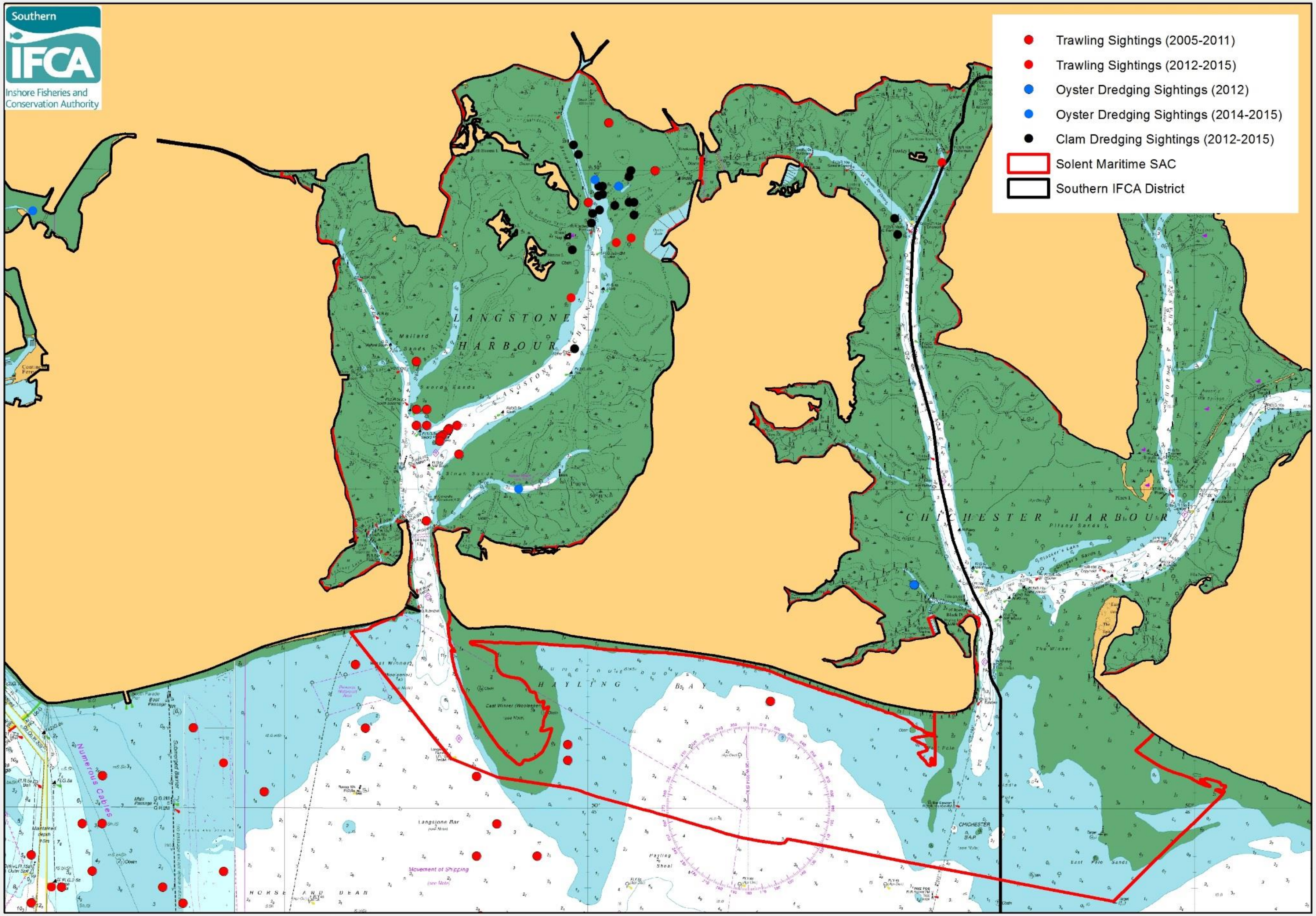

Southern
IFCA
Inshore Fisheries and Conservation Authority
Southern IFCA Trawl Sightings 2011-2015
Southern IFCA Trawl Sightings 2005-2010
Sandbanks which are slightly covered by sea water all the time (H1110) polygons
SAC_SFCODE
Subtidal coarse sediment (A5.1)
Subtidal sand (A5.2)
Subtidal mud (A5.3)
Subtidal mixed sediment (A5.4)
Maerl beds (A5.51)
Subtidal seagrass beds (A5.53)
Solent Maritime SAC


Southern
IFCA
Inshore Fisheries and Conservation Authority
Southern IFCA Trawl Sightings 2011-2015
Southern IFCA Trawl Sightings 2005-2010
Sandbanks which are slightly covered by sea water all the time (H1110) polygons
SAC_SFCODE
Subtidal coarse sediment (A5.1)
Subtidal sand (A5.2)
Subtidal mud (A5.3)
Subtidal mixed sediment (A5.4)
Maerl beds (A5.51)
Subtidal seagrass beds (A5.53)
Solent Maritime SAC

Annex 6: Co-location of Historic Trawl Sightings (2005-2011, 2012-2015), Clam Dredging (2012-2015) Oyster Dredging (2012, 2014-2015) Sightings in the entire Solent Maritime SAC and Southampton Water and the Langstone and Chichester portions of the Solent Maritime SAC


Southern
IFCA
Inshore Fisheries and Conservation Authority
Trawling Sightings (2005-2011)
Trawling Sightings (2012-2015)
Oyster Dredging Sightings (2012)
Oyster Dredging Sightings (2014-2015)
Clam Dredging Sightings (2012-2015)
Solent Maritime SAC
Southern IFCA District


Southern
IFCA
Inshore Fisheries and Conservation Authority
Trawling Sightings (2005-2011)
Trawling Sightings (2012-2015)
Oyster Dredging Sightings (2012)
Oyster Dredging Sightings (2014-2015)
Clam Dredging Sightings (2012-2015)
Solent Maritime SAC


Southern
IFCA
Inshore Fisheries and Conservation Authority
Trawling Sightings (2005-2011)
Trawling Sightings (2012-2015)
Oyster Dredging Sightings (2012)
Oyster Dredging Sightings (2014-2015)
Clam Dredging Sightings (2012-2015)
Solent Maritime SAC
Southern IFCA District
LANGSTONE HARBOUR
CHICHESTER HARBOUR
HAYLING BAY