Marine Management Organisation

Spatial models of essential fish habitat (South Inshore and Offshore marine plan areas)

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Final Report

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Marine Management Organisation

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Glossary

Calibration (model -), adjustment of the selected mathematical model for the specific data to which the model is applied.

Connectivity, the exchange of individuals among geographically separated sub-populations that comprise a metapopulation.

Demersal, living and feeding on or near the sea bottom.

Essential Fish Habitats (EFH), aquatic habitats which are necessary to fish for spawning, feeding or growth to maturity (nursery grounds).

Pelagic, living near the surface or in the water column.

List of acronyms

BTS	Beam Trawl Survey
CHARM	Channel Integrated Approach for Marine Resource Management
CPUE	Catch Per Unit Effort
EUNIS	European Nature Information System
ICES	Institute of Estuarine and Costal Studies (University of Hull)
IFCA	Inshore Fisheries and Conservation Authorities
IHLS	International Herring Larval Survey
JNCC	Joint Nature Conservation Council
MCZ	Marine Conservation Zone
MMO	Marine Management Organisation
MPS	Marine Policy Statement
NERC	Natural Environment Research Council
TidE	Tidal Current Energy
WavE	Wave Energy
WGEGGS	Working Group on North Sea Cod and Plaice Egg Surveys

Executive Summary

The Marine Management Organisation (MMO) requires a robust understanding of the environmental assets and ecosystem services provided by the marine environment to develop effective marine plans. In particular, evidence based on the spatial distribution of ecologically important fish habitats is required to support marine planning in the South Inshore and South Offshore areas, thus allowing the management and protection of resources while contributing to the future of the fishing industry.

Ecologically important fish habitats are identified under the term of Essential Fish Habitats (EFH). These are aquatic habitats which are necessary to fish for spawning, feeding or growth to maturity (nursery grounds), hence their importance in ensuring viability of fish populations and provision of the associated ecosystem services. Existing data available to the MMO on the distribution of EFH (in particular, nursery and spawning areas) are insufficiently resolved (ICES rectangle) for the use in marine planning. The production of maps of EFH has been therefore identified as a key priority by MMO marine planners.

The Institute of Estuarine and Coastal Studies (IECS, University of Hull) was commissioned by the MMO a project to improve the spatial resolution of data on EFH for key fish species (both of commercial and ecological relevance) in the South Inshore and South Offshore Marine Plan Areas, and to assess the relative value of these fish habitats to the regional commercial fisheries productivity and the ecosystem function.

The project focused on developing a robust and reproducible methodology to address this aim by: (1) collating the relevant available datasets and data layers on fish species distribution and associated environmental variables; (2) applying statistical models to identify the quantitative relationships between the occurrence of a species life stage and the environmental conditions; (3) implementing the models in a GIS (geographic information system) environment in order to obtain spatial predictions of the species EFH in the study area; (4) assessing the relative ecological and socio-economic value of EFH, taking into account the provision of ecosystem services in these habitats; (5) identify the gaps in the data and limitations associated to the project outputs and provide suggestions to address these gaps within follow-up work.

The information on fish species distribution in the Channel, their commercial value and conservation importance was obtained from recent studies, and 10 fish species were selected for the project, namely plaice, sole, lemon sole, dab, red gurnard, common dragonet, solenette, thickback sole, thornback ray and herring. This selection took into account also the availability of data suitable for the application of predictive models.

Fish survey data were collated from different sources. In particular the UK Eastern English Channel Beam Trawl Survey (BTS), the ICES International Herring Larval Survey (IHLS) and ICES North Sea Cod and Plaice Egg Surveys in the North Sea (WGEGGS) were selected for the analysis. The BTS dataset provided data on

catches of juveniles and adults for most of the demersal species, whereas data on herring larvae and plaice eggs catches were obtained from the IHLS and WGEGGS datasets. Data within the time period between 2000 and 2012 were considered.

Based on the knowledge of the ecology of the selected species, the relevant environmental characteristics likely to affect to their distribution were identified and the correspondent available environmental data layers were collated. These included data on bathymetry and substratum type (EMODnet), energy levels at the seabed (EUSeaMap), mixing of the water column and presence of Annex I reef habitats (JNCC), sea surface temperature and a proxy for phytoplankton abundance (EU project MyOcean).

Based on the data characteristics, classification tree models were applied to the presence- absence of the different species life stages in the datasets in order to identify the relationship with environmental variables. A total of 18 models were obtained that allowed to identify the environmental conditions associated to the presence of adult foraging habitats, nursery habitats or spawning grounds for the selected species based on the higher probability of occurrence of their adult, juvenile or eggs/larval stages, respectively.

The statistical models were implemented in a GIS environment by using environmental data layers as predictors for the occurrence of an EFH. Maps of the spatial distribution of EFH in the study area were thus obtained at a spatial resolution of 5 x 5km. A confidence value was associated to the obtained predictions, by combining the confidence attached to the input data (as assessed based on the associated metadata) and the predictive error of the statistical model used. The resulting spatial predictions are presented by species and EFH in Section 3

It is recognised that allocating a relative value to areas in the marine environment is of particular relevance to marine planning, as identifying the location of most valuable marine areas allows management of the marine space to be prioritised. A hotspot analysis was therefore applied to identify areas of higher ecological value within the study area based on the occurrence of EFH. EFH predicted with the highest confidence were taken into account for this purpose, and their frequency in an area was used as a proxy for ecological value. A confidence was associated with this value taking into account limitations in the predictive ability of the EFH models. As a result, areas of higher ecological value were identified in the eastern and western sides of the study area, in front of the coasts of Devon and of East Sussex and Kent, respectively. However, a higher confidence resulted attached to the eastern hotspot areas, whereas part of the western hotspots, as well as some areas of lower ecological value (in front of the Isle of Wight and inshore areas), showed a lower confidence in these estimates. This lower confidence is likely the result of gaps in the model predictions hence higher caution should be placed when considering the ecological value of these areas.

A socio-economic value was associated to these areas of higher value as EFH by using the ecosystem services framework as a reference. A non monetary value was associated to the EFH based on the most important ecosystem services these areas provide, depending on the habitat features (EUNIS habitat types) included in them. This assessment was informed by the recent literature assessing the importance of habitat features in providing ecosystem services in the marine environment. In order to attach a monetary value to the relevant ecosystem services provided by the EFH in the study area, possible valuation techniques were identified, with detailed description and requirements provided in particular for the valuation of those ecosystem services that are relevant to the identified ecological hotspots. An example of the methodology application was also provided by applying Market Analysis to assess economic value associated to the contribution of the EFH to regional commercial fishery. The economic value of these areas to fishery was calculated based on landing data, by using associated fishing effort within the EFH as a proxy to the associated landed value. The importance of the connectivity of EFH with fishing areas was highlighted in order to allow a more accurate assessment of the economic value of EFH while accounting for the transferability of their value to other areas.

The project involved the collation and analysis of a high amount of data and information. A number of gaps and limitations in the data, leading to limitations in the obtained results, were identified that should be taken into account by the MMO to address future studies. Key issues include: limitations in the species range and spatial coverage associated to the fish survey data used; high proportion of zeros in the fish catch data, leading to the modelling of presence-absence; limited availability in the datasets of environmental data recorded during the fish surveys; limited availability of raster data layers characterising certain abiotic (e.g., salinity) or biotic (e.g., prey abundance) variables that might be important in affecting species EFH distribution; confidence issues due to the inability of assessing confidence in certain input data layers (due to paucity of information/metadata).

Recommendations were formulated on how to address the limitations in future studies to allow improvement of the methodology and its application. These included: the need of integrating the analysis with additional fish datasets, in order to cover a wider range of species and a wider range of environmental variability, thus allowing improvement of the assessment of ecological value of EFH and of the associated confidence; the need of addressing shellfish species, as these are an important component of the ecological and fishery value of the study area; include fish abundance in the EFH assessment, by integrating the analysis with additional fish data and trialling alternative, more complex statistical models; use continuous raster data layer for salinity if extending the analysis into estuarine and inshore coastal areas, as salinity gradient is a relevant predictor of EFH in these environments; integrate the confidence assessment of the spatial outputs by validating the results with additional empirical evidence on the distribution of specie life stages in the marine areas.

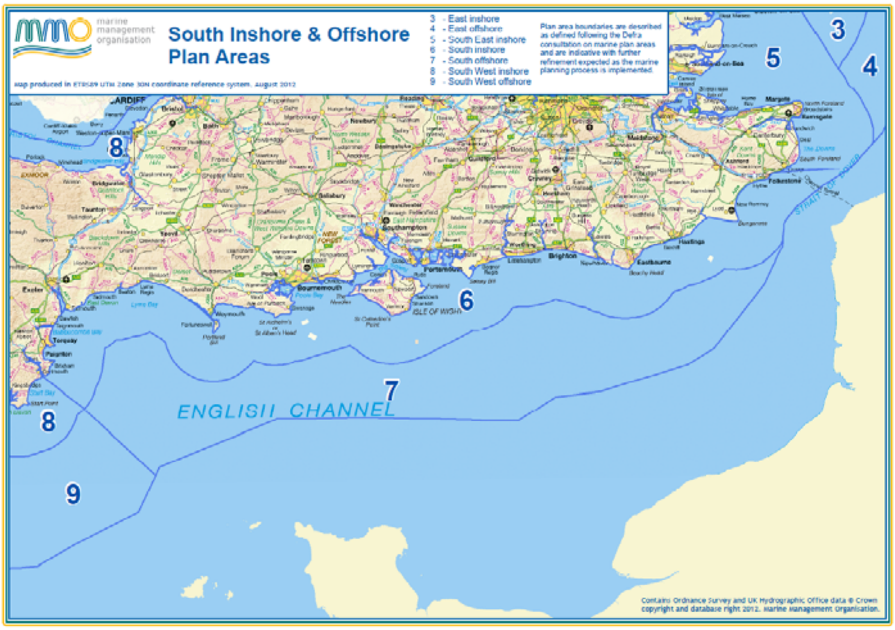
1. Introduction

1.1 Project background

One of the core functions of the Marine Management Organisation (MMO) is marine planning, as established by the Marine and Coastal Access Act 2009. Marine planning provides an approach to the management of the activities, resources and assets in England's waters which aims at ensuring sustainable development in the marine environment. High level policy context to marine planning is given by the UK Marine Policy Statement (MPS)[1].

In order to develop marine plans on a manageable scale, English waters have been divided into 10 plan areas. After developing the first plans for the East Inshore and East Offshore areas, the South Inshore and South Offshore areas have been selected as the next areas in England for marine planning. These plan areas stretch from Dover in Kent to the River Dart in Devon, and extend out to the limit of the UK exclusive economic zone (Figure 1).

Figure 1: South Inshore and South Offshore Marine Plan Areas.



The South marine plan areas have been identified as one of the busiest marine areas in Europe, and a significant increase in the levels of activity over the next 20 years has been predicted for various sectors, including potentially new sectors such as offshore renewable energy, as well as oil and gas production, aggregate extraction, ports and shipping, leisure and recreation (MMO, 2013). Relatively high levels of fishing activity also occur in the area (MMO, 2012a). In addition, this marine environment supports a particularly high biological diversity as a result of the variety of geophysical features present in the area. Therefore, there is a strong need for marine planning in order to ensure that current activities and future plans of all

[1] https://www.gov.uk/government/publications/uk-marine-policy-statement

relevant sectors are taken into account in managing the marine space, whilst guaranteeing the protection of the natural resources.

Understanding the environmental assets and ecosystem services provided by the marine environment is important for the MMO to develop effective marine plans and a robust evidence base is essential to this purpose. In particular, the MMO requires a robust fisheries evidence base to support marine planning in the South Inshore and South Offshore areas.

Scenario planning is identified as a useful tool for the development of marine plans. If data is available in a consistent format and resolution, a rules-based multicriteria analysis can be applied in a GIS (geographic information system) environment to suggest potential spatial 'options' which can meet specific plan objectives. This approach to plan development was trialled by the MMO for the East Inshore and East Offshore Marine Plans (MMO, 2012b).

The approach of developing plan options with a spatial element is likely to be utilised by the MMO in the development of future marine plans. An evidence-based understanding of the distribution of ecologically important fish habitats would ideally be used as a consideration in these options to inform the management and protection of resources while contributing to the future of the fishing industry.

1.2 Essential fish habitats and their management

Ecologically important fish habitats are identified under the term of Essential Fish Habitats (EFH). These are aquatic habitats which are necessary to fish for spawning, feeding or growth to maturity (nursery grounds), hence their importance in ensuring viability of fish populations and provision of the associated ecosystem services. These habitats can be characterised by the physical, chemical and biological properties of their waters and substrata. Therefore, these properties can be used to predict the occurrence and location of EFH for a species in relation to the distribution of the species life stages, hence providing support to marine planning.

Fish species have different modes of reproduction (Elliott *et al*., 2007; Franco *et al*., 2008). The production of large numbers of small sized pelagic eggs and an extended pelagic planktotrophic larval period typically characterise marine species, this strategy being advantageous in the marine environment (Balon, 1984; Wootton, 1999; Elliott and Hemingway, 2002). The distribution of spawning adults (mature fish with ripe gonads) can provide a direct indication of the spawning grounds, but these data are not often available. The distribution of fish eggs and larvae in the water column can therefore be indicative of spawning areas. A more accurate indication of spawning grounds can be obtained by considering egg and earlier larval stages, as later development stages are more likely to be hydrographically advected further from the spawning areas, due to the lack of or reduced mobility at these stages.

The nursery value of a habitat is measured by the higher density of juveniles that is produced by that habitat in a certain amount of time and that eventually recruit to the adult population (Beck *et al*., 2001). This is the result of the combination of different factors, such as higher density, growth and survival of juveniles in the nursery compared to other habitats. However, a broader definition is often applied in many fish studies, with the nursery grounds being identified as those habitats where juveniles are found with high frequency and abundance. Ellis *et al*. (2010) distinguished primary nursery grounds, identified by considering recently-settled and 0-group (<1 year old) fish, and secondary nursery grounds, indicating the habitat that may be utilised by a wider range of juveniles.

By providing the environment required by fish populations throughout different stages of the species life cycle, these EFH provide support to a sustainable fishery and reflect a healthy ecosystem. An important aspect that characterises the contribution of EFH to the fishery stocks is associated to their connectivity with adult habitats, i.e. the exchange of individuals among geographically separated sub-populations of marine organisms (Cowen *et al*., 2002). In fact, although EFH can be identified by particular environmental conditions reflecting the ecological requirements of a species life stage, hence showing a spatial distribution limited to where these conditions occur, the mobility of these life stages (e.g. through larval dispersal, or juvenile fish movements) determines the exchange of individuals with other areas where adult occur. This role of EFH as source habitats for adult populations is of particular importance to maintain viable stocks hence to contribute to the sustainability of their exploitation.

The spatial distribution of these areas of ecological value needs to be taken into account to allow a fair and proportionate management of sectors operating in the marine environment whilst ensuring sustainable use of its resources. In fact, management issues may arise from the possible impacts of marine activities on the functioning of EFH, with the magnitude of the resulting effects being dependent on the sensitivity of the EFH (e.g., due to its extent, distribution, connectivity).

Management measures are currently adopted to ensure protection of EFH in the marine environment. Defra regards sectoral measures as the most effective tools in conserving widely dispersed and mobile species and their habitats (Defra, 2010). These include fisheries management, like restrictions and closures to fishing grounds to maintain healthy fish stocks, and can be temporary, for example to protect spawning and nursery grounds. Other measures are by-catch mitigation measures and protected species licensing. For example, the assessment of benthic fish spawning grounds (e.g., for herring and sandeel) is often a condition on licences for dredging for aggregates. These measures are managed and enforced by Defra, Inshore Fisheries and Conservation Authority, MMO and Natural England.

Also MPA designations (under the Marine and Coastal Access Act 2009) can be a useful tool to protect wide ranging fish species and their EFH. For example, fisheries-based closures or designation of spawning and nursery grounds, where species are more restricted in mobility, may be effective (Defra, 2012). As a result, some of the MCZs recommended by the Regional MCZ Projects include area considered important to fish species, i.e. breeding, spawning and nursery grounds, meaning MCZs could provide a valuable contribution to the protection of EFH. It is of note, however, that considerable proportions of species distributions within English waters fall outside proposed European designations, and a need for better consideration of the areas that might be worthy of protection as nationally important sites has been identified (Defra, 2012).

Within this context, the MMO marine plans add value to existing management of EFH. Being based on robust spatial evidence, these will allow co-existence of activities in the marine environment with the protection of ecological resources. However, existing data available to the MMO on the distribution of EFH (in particular, nursery and spawning areas; Ellis *et al*., 2010) are insufficiently resolved (ICES rectangle) for the use in marine planning. The production of maps of EFH has been therefore identified as a key priority by MMO planners.

1.3 Project aims and objectives

The Institute of Estuarine and Coastal Studies (IECS, University of Hull) was commissioned by the MMO a project to improve the spatial resolution of data on essential fish habitat for key fish species (both of commercial and ecological relevance) in the South Inshore and South Offshore Marine Plan Areas (from here on termed the study area), and to assess the relative value of these fish habitats to the regional commercial fisheries productivity and the ecosystem function.

This project has focused on developing a robust and reproducible methodology which can be continuously improved. This is a methodology whereby: (1) statistical models are applied to data obtained from fish surveys and environmental data in order to identify the combination of environmental conditions associated to the occurrence of a species life stage; (2) a GIS spatial analysis is applied to combine environmental data layers accordingly, in order to predict the spatial distribution of the species EFH in the wider study area.

The specific objectives of the project were to:

1. develop a methodology to improve the spatial resolution of distribution and connectivity of EFH for key commercially important species using modelling including a validation approach estimation of the value of those habitats

2. produce guidelines for fish data collection and processing

3. identify the commercially or otherwise important species on which to base the study

4. implement the methodology developed in objectives 1 and 2 to the species identified as important in objective 3 in order to create data layers in ESRI ArcGIS 10.0 (compatible with v.9.3) vector format

5. geo-process the data following the MMO template and provide a flow diagram describing the process

6. consult with the MMO and relevant stakeholders to validate the findings of the modelling

7. produce a detailed final report with methodology, data sources, and modelling approach, including also limitations, problems encountered and recommendations and, where possible, a quantitative confidence in the findings.

Rather than being definitive, the project findings and outcomes constitute a first step in the process of evidence provision to support the marine spatial planning in the South Coast plan areas.

1.4 Report contents

The report comprises the following sections addressing the objectives listed above:

Section 2 presents information on the methods and approach used in the project, with technical details and relevant references given in a separate annex (Technical Annex). These methods include initial selection of fish species, data collation and processing, geo-statistical modelling and confidence assessment (methods on EFH validation and evaluation are described in stand-alone annexes providing information on these phases of the project).

Section 3 presents the outputs obtained from the implementation of the methodology developed within the project, including fish habitat models, EFH maps and confidence values associated with these outputs.

The ecological value of marine areas as essential habitats for fish was estimated by combining the results obtained for the different species, in order to highlight 'hotspot' areas of higher potential value in supporting marine fish populations. Also the value of marine areas within the study area and in the identified EFH was assessed taking into account their contribution in provision of ecosystem services. Methods were identified for the economic valuation of these services, based on available literature. The main results of value assessment of the identified EFH are presented in Section 4, with detailed methodology and results given in a separate Annex ('Assessing EFH Value').

A major outcome of the project is also to identify the main gaps and issues arising from the fish habitat prediction in the study area in order to provide suggestions on how to address the gaps and issues within follow-up work. These aspects are reported in Section 5. As the consultation with stakeholders on the project outputs contributed to highlight gaps and possible additional sources of information, the main results of this validation exercise are also included in this section, with detailed methods and results given in a separate Annex ('Stakeholder Validation').

Additional support data (metadata, confidence assessment with MMO template, geo-processing following the MMO template, flow diagram describing the process) are provided in separate files.

2. Methods and Approach

2.1 Fish species selection

An initial list of fish species to be considered in the project was compiled based on criteria of commercial and ecological importance. Data collation was based on this list.

Commercial interest was assessed taking into account marine fisheries, with particular attention given to the information regarding specifically the English Channel. This was obtained from previous projects, including the MMO project 1011, assessing the distribution, trends and value of inshore and offshore fisheries in England (MMO, 2012a) and the European project “Channel Integrated Approach for Marine Resource Management” (CHARM), providing an integrated overview on the fisheries in the English Channel. Information on the species commercial relevance in the study area was obtained also from the Sussex Inshore Fisheries and Conservation Authority (IFCA) (Vause and Clark, 2011).

The commercial interest of a species was considered to be:

- high when the species is among most valuable species for English vessels by landed value over 2008-2011 from the English Channel (source: MMO, 2012a)
- moderate for species reported as relevant to commercial fishery in the English Channel (source: European project CHARM; Vause and Clark 2011)
- low for species of general commercial interest, but not reported as relevant commercial species in the English Channel.

Ecological importance was determined based on the listing of the species as threatened and declining by OSPAR (OSPAR Commission, 2008).

The resulting initial list of fish species identified as relevant to the project (Table 1) includes 35 species, of which 29 are teleosts (bony fish) and 6 elasmobranchs (sharks and rays). Information on the ecology of these species was also obtained from various sources (Dipper, 1987; Miller and Loates, 1997; Coull *et al*., 1998; Ellis *et al*., 2012; MMO, 2012a; Froese and Pauly, 2013; NERC knowledge transfer project ZIMNES, http://192.171.193.133/index.php; JNCC, www.jncc.defra.gov.uk). In particular, the timing of the species spawning was taken into account (Table 1b). This information was used to inform the assessment of the confidence on the collated fish data in regard to the ability of the fish survey design/method to capture a species/life stage depending on the matching between season of sampling and seasonality of occurrence of life cycles/spawning period (see Section 2.2.1 and Technical Annex).

Table 1: a) Taxonomic list of the species considered in the project. The species commercial fishery interest in the study area and its dominant habitat (for juveniles/adults) are indicated. When eggs and/or larval stages are found in a different habitat, this is indicated in parenthesis. Species listed as threatened and declining by OSPAR are denoted *.

Common name	Scientific name	Habitat	Commercial interest
Teleosts			
Plaice	*Pleuronectes platessa*	Demersal (pelagic eggs/larvae)	High
Sole	*Solea solea*	Demersal (pelagic eggs/larvae)	High
Lemon sole	*Microstomus kitt*	Demersal (pelagic eggs/larvae)	High
Dab	*Limanda limanda*	Demersal (pelagic larvae)	Moderate
Thickback sole	*Microchirus variegatus*	Demersal (pelagic eggs/larvae)	Moderate
Solenette	*Buglossidium luteum*	Demersal (pelagic eggs/larvae)	Moderate
Flounder	*Platichthys flesus*	Demersal (pelagic eggs/larvae)	Moderate
Brill	*Scophthalmus rhombus*	Demersal (pelagic larvae)	Moderate
Turbot	*Scophthalmus maximus*	Demersal (pelagic eggs/larvae)	Moderate
Cod *	*Gadus morhua*	Demersal (pelagic eggs/larvae)	Moderate
Whiting	*Merlangius merlangus*	Demersal (pelagic larvae)	Moderate
Blue whiting	*Micromesistius poutassou*	Demersal (pelagic eggs/larvae)	Minor
Pollack	*Pollachius pollachius*	Demersal (pelagic eggs/larvae)	High
Anglerfish	*Lophius piscatorius/L. budegassa*	Demersal	High
Sea bass	*Dicentrarchus labrax*	Demersal (pelagic eggs/larvae)	High
Red gurnard	*Chelidonichthys cuculus*	Demersal (pelagic larvae)	Moderate
Lesser weeverfish	*Echiichthys vipera*	Demersal (pelagic eggs/larvae)	Moderate
Common dragonet	*Callionymus lyra*	Demersal (pelagic eggs/larvae)	Moderate
Sandeels *	Ammodytidae (5 species)	Demersal (pelagic larvae)	Moderate
Ling *	*Molva molva*	Demersal (pelagic larvae)	Minor
European hake	*Merluccius merluccius*	Demersal (pelagic eggs/larvae)	Minor
Horse mackerel	*Trachurus trachurus*	Demersal (pelagic eggs/larvae)	Minor
Mackerel	*Scomber scombrus*	Pelagic	Moderate
Herring	*Clupea harengus*	Pelagic (demersal eggs)	Moderate
Salmon *	*Salmo salar*	Pelagic (demersal eggs)	Minor
European eel *	*Anguilla anguilla*	Demersal (pelagic eggs/larvae)	Minor
Sea Lamprey *	*Petromyzon marinus*	Demersal	
River Lamprey	*Lampetra fluviatilis*	Demersal	
Seahorses *[1]	*Hyppocampus spp.* (2 species)	Demersal	
Elasmobranchs			
Spurdog *	*Squalus acanthias*	Demersal	
Tope shark	*Galeorhinus galeus*	Demersal	Moderate
Common skate *	*Dipturus batis* (species complex) [2]	Demersal	
Thornback ray *	*Raja clavata*	Demersal	Moderate
Spotted ray *	*Raja montagui*	Demersal	Moderate
Undulate ray	*Raja undulata*	Demersal	

Notes: [1] Two species (*H. guttulatus* and *H. hyppocampus*), both listed as threatened and declining by OSPAR. [2] In 2009, research showed that common skate is comprised of two distinct species. As available data cannot be disaggregated between these species, *Dipturus batis* is referred to as a species complex.

b: Spawning periods of the initial species considered in the project.

Common name	J	F	M	A	M	J	J	A	S	O	N	D	source
Teleosts													
Plaice													[1]
Sole													[1]
Lemon sole													[2]
Dab													[3]
Thickback sole													[3]
Solenette													[3]
Flounder													[3]
Brill													[4, 5]
Turbot													[3, 4]
Cod *													[1]
Whiting													[1]
Blue whiting													[1]
Pollack													[6]
Anglerfish													[1]
Sea bass													[6]
Red gurnard													[3]
Lesser weeverfish													[7]
Common dragonet													[3]
Sandeels *													[1]
Ling *													[1]
European hake													[1]
Horse mackerel													[1]
Mackerel													[1]
Herring													[1]
Salmon *						(FW)							[8]
European eel *													[3]
Sea Lamprey *					(FW)								[3]
River Lamprey				(FW)									[3]
Seahorses * [2]													[3]
Elasmobranchs													
Spurdog *													[1]
Tope shark													[1]
Common skate *	?	?	?	?	?	?	?	?	?	?	?	?	[1]
Thornback ray *													[1]
Spotted ray *				?				?					[1]
Undulate ray	?	?	?	?	?	?	?	?	?	?	?	?	[1]

Sources: [1] Ellis *et al*., 2012; [2] Coull *et al*., 1998; [3] Froese and Pauly, 2013; [4] Miller and Loates, 1997; [5] Dipper, 1987; [6] MMO, 2012a; [7] NERC knowledge transfer project ZIMNES, http://192.171.193.133/index.php; [8] JNCC, www.jncc.defra.gov.uk

2.2. Input data and processing

Three different types of data have been collated, based on their use in the project:

1. data used for the calibration of the statistical model, including fish survey data and associated environmental variables
2. spatial data layers to be used for the model implementation in GIS
3. data used for the assessment of the value of the identified EFH in terms of their contribution to regional fisheries and ecosystem functioning.

2.2.1. Fish survey data

The criteria for the fish data collation for the model calibration included the following aspects:

- data from scientific fish surveys using standard fishing methods and including species catches (CPUE), fish size (length), information on the sampling method and strategy (e.g., gear, seasonality), and associated environmental data recorded during survey (e.g., depth, temperature, salinity)
- data availability for the species included in Table 1
- distribution of fishing stations within the study area, and, if possible, in the wider English Channel[2]
- data available for the period 2000-2012
- information available on survey methods and design
- comparability of data from different datasets based upon the use of similar survey strategies (e.g., gear, seasonality).

The collation of fish data was focused on scientific fish surveys, whereas fishery-dependent data (reported landings) were not considered suitable for the purpose of this project, due to their bias towards commercially relevant species and fish size, possible issues associated with the taxonomic identification of the catches, and also due to the low resolution (ICES rectangle) at which these data are available as well as inaccuracy as the data relate to port at which they are taken rather than the precise place of capture (Ellis *et al*., 2010a).

Relevant fish survey data were identified based on the information obtained from recent projects (Defra project MB5301, Cefas 2010, Ellis *et al*., 2012; CHARM project) and enquiries made with relevant data providers (ICES, Cefas, Ifremer, Environment Agency) (a full list of these datasets is given in the Technical Annex). Multiple datasets were explored, as no single scientific ship-based survey is currently carried out to cover consistently both the Eastern and Western English Channel. This is partly the result of differences in habitat characteristics between the two areas (with irregular and rocky bottom habitats more frequent in the Western channel) posing limitations to the use of certain sampling gear (Stephens *et al*., 2010).

Data selection for the project was aimed at obtaining consistent datasets (in terms of survey method and strategy) with the widest spatial coverage within the study area.

[2] The study area covers the South Inshore and Offshore Marine Plan areas but data collation extended into adjacent areas due to the connectivity and mobility of fish species. Extending data collation to the Channel area allowed also to cover a wider range of environmental conditions and to increase the size of the fish datasets used in the analysis, thus increasing the power of the model, hence the confidence in its results.

In addition, the availability of data for the different species and their life stages (eggs, larvae, juveniles and adults) was considered.

Although data for the same species/life stage could be derived from different survey datasets, data from different surveys were not combined into a single dataset (hence preventing a single analysis) for a certain species as the use of different sampling gear and strategies made these data not comparable[3]. Therefore, the best dataset for a species/life stage was selected from among those available based on the dataset size (number of observations) and on considerations about the confidence on the species catch data related to the sampling method employed and its sampling selectivity and efficiency with respect to the species/life stage under consideration.

The main datasets that have been selected for the habitat modelling have been identified as those obtained from the UK Eastern English Channel Beam Trawl Survey (BTS, Eastern Channel), the ICES International Herring Larval Survey (IHLS) and ICES North Sea Cod and Plaice Egg Surveys in the North Sea (WGEGGS) (Table 2), as these provide a greater deal of information on several species. Although the selected data were those with the widest coverage of the study area (Figure 2), it is of note that there is still poor coverage of western areas. This spatial limitation might affect the ability of the model calibrated on these data to predict the distribution of EFH in the wider study area. This aspect was taken into account when assessing the confidence in the data hence in the model predictions.

Table 2: Fish survey data used for EFH modelling.

Fish data	Source	Survey/data information
UK Eastern English Channel Beam Trawl Survey (BTS)	ICES, online fish trawl surveys database (DATRAS) (public access)	Survey series starting in 1989 and ongoing, carried out by Cefas. Fishing during July/August (Quarter 3) over an allocated area of the Southern North Sea and Eastern English Channel using a standard grid. Station, catch, length (all species) and biological data (selected species) for each of the annual surveys covering the Southern North Sea and Eastern English Channel using research vessels and 4m beam trawl in support of EU data regulations and as part of a research program coordinated by ICES. The primary aim was to assess the relative abundance of prerecruit plaice and sole in ICES Division VIId (with extension to southern North Sea in 1995); consequently most of the sampling is concentrated in areas that are nursery grounds for these species. Additional aims include collection of water temperature and salinity and acoustic data. Selected data 2000-2012 within English Channel (dataset name BTS 2000-12, N=854)

[3] The difficulty in comparing datasets is likely to be reduced when considering only presence/absence data rather than fish abundance. However differences in selectivity of the methods can still lead to biases in the assessment of the occurrence of a species, particularly when different life stages are distinguished, thus introducing an error in the model results.

Fish data	Source	Survey/data information
ICES International Herring Larval Survey (IHLS)	ICES, online fish eggs and larvae database (public access)	Survey series starting in 1967 and ongoing, with combined effort of different countries (UK, France, Germany, Netherlands), as part of a research program coordinated by ICES. Surveys carried out in specific periods and areas, following autumn and winter spawning activity of herring from north to south (December/January in the English Channel), with double oblique hauls of high-speed plankton sampler deployed on a fixed stations grid from research vessels. Data on herring larvae CPUE (individuals per square meter) per haul per length class (small, medium, large larvae), sampling methods (e.g., gear type, hauling duration) and environmental conditions measured during sampling (e.g., depth, water temperature, salinity) . The main purpose of the international herring larval surveys (IHLS) programme is to provide quantitative estimates of herring larval abundance, which are used as a relative index of changes of the herring spawning-stock biomass in the assessment. Selected data 2000-2011 within English Channel (dataset name IHLS 2000-11, N=1503)
ICES North Sea Cod and Plaice Egg Surveys in the North Sea (WGEGGS)	ICES, online fish eggs and larvae database (public access)	Survey series conducted in winter (December/January) 2003/04 and 2008/09, with combined effort of different countries (France, Germany, Netherlands), as part of a research program coordinated by ICES. Use of different sampling strategies (e.g., double oblique hauls of high-speed plankton sampler, surface sampling with continuous underway fish egg sampler) Station, egg abundance (eggs per haul per species), egg stage (all species) and length (selected species) data for each of the annual surveys covering the North Sea, down to Eastern English Channel using research vessels and different sampling gears. The database contains also the haul information data, position, time , duration, filtered water volume, depth, temperature and salinity. The surveys were originally directed at cod and plaice, but also supply data of other winter spawning North Sea fish. Selected data 2003/4 and 2008/09 within English Channel obtained with high-speed plankton sampler 280um mesh (dataset name WGEGGS 2003/4 and 2008/9, N=172)

Based on the sampling methods used in these surveys and, in particular, taking into account the spatial coverage of a single fishing event (based on information on sampling strategy and effort), a spatial grid of 5x5 km was identified as the minimum scale of validity of the fish data. This scale was adopted as the maximum spatial resolution of data layers for the model calibration and EFH mapping in the project.

The selected fish datasets were explored, fish catch and size data were combined to distinguish catches of different life stages of a same species. Ten species (19 life stages) were selected for the modelling analysis (Table 3). This selection took into account the relevance of species for commercial and conservation purposes (Table 1a), the confidence in the data (based on the information on the gear selectivity, survey seasonality, taxonomic standards, suitability of the considered life stage as an indicator of the EFH; Table 1b and 4), as well as the data availability and frequency of occurrence for the species/life stage in the dataset (Table 3).

Figure 2: Station distribution in the selected survey data.

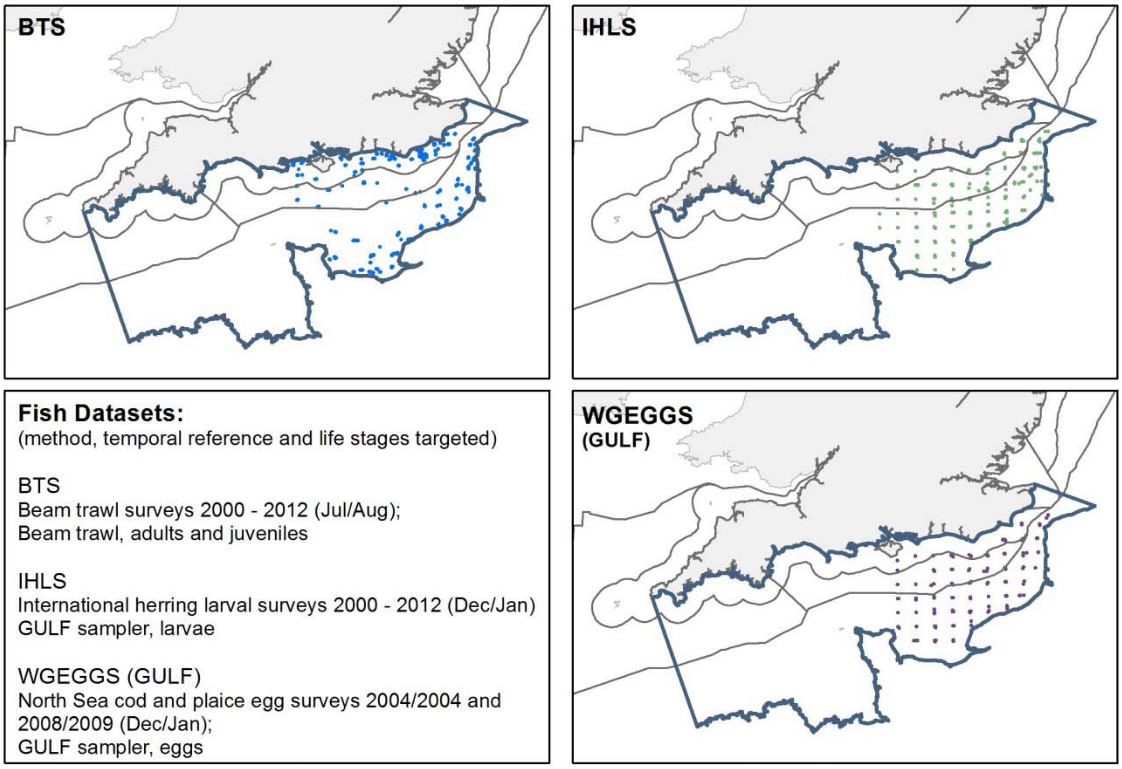


Table 3: Selected fish species for EFH modelling. Life stage, size criterion[4] used for its identification and the relevant dataset are also indicated (fish dataset name is coded according to Table 2).

no.	Species	life stage	EFH	size range (mm) /stage criterion	Source Dataset (dataset size, N)	Occurrences (%freq)
1	**Plaice**	Juveniles	nursery habitat	40-180 (0-group)	BTS 2000-12 (N=854)	138 (16%)
		Adults	adult habitat	190-640	BTS 2000-12 (N=854)	620 (73%)
		Eggs	spawning habitat	1.75-2.28 (early stage, EG1)	WGEGGS 2003/4 and 2008/9 (N=172)	50 (29%)
2	**Sole**	Juveniles	nursery habitat	40-200 (likely including also >1year old)	BTS 2000-12 (N=854)	225 (26%)
		Adults	adult habitat	210-470	BTS 2000-12 (N=854)	663 (78%)
3	**Lemon Sole**	Juveniles	nursery habitat	50-200 (likely including also >1year old)	BTS 2000-12 (N=854)	116 (14%)
		Adults	adult habitat	210-400	BTS 2000-12 (N=854)	198 (23%)

[4] Size criterion for juvenile identification was derived from available information in Stephens *et al*., 2010 (CHARM Project), Ellis *et al*., 2010, 2012, Lauria *et al*., 2011, Froese and Pauly 2013 (FishBase), and from size frequency histograms in the analysed fish dataset.

no.	Species	life stage	EFH	size range (mm) /stage criterion	Source Dataset (dataset size, N)	Occurrences (%freq)
4	**Dab**	Juveniles	nursery habitat	20-80 (0-group)	BTS 2000-12 (N=854)	99 (12%)
		Adults	adult habitat	90-380	BTS 2000-12 (N=854)	459 (54%)
5	**Red gurnard**	Juveniles	nursery habitat	50-180 (0-group)	BTS 2000-12 (N=854)	117 (14%)
		Adults	adult habitat	190-420	BTS 2000-12 (N=854)	395 (47%)
6	**Dragonet**	Juveniles	nursery habitat	10-95 (likely including also >1year old)	BTS 2000-12 (N=854)	265 (31%)
		Adults	adult habitat	100-290	BTS 2000-12 (N=854)	802 (94%)
7	**Solenette**	Juveniles	nursery habitat	10-70 (immature)	BTS 2000-12 (N=854)	141 (17%)
		Adults	adult habitat	80-290	BTS 2000-12 (N=854)	437 (51%)
8	**Thickback sole**	Juveniles	nursery habitat	30-200 (likely including also >1year old)	BTS 2000-12 (N=854)	271 (32%)
9	**Thornback ray**	Juveniles	nursery habitat	100-280 (likely including also >1year old)	BTS 2000-12 (N=854)	158 (19%)
		Adults	adult habitat	290-800	BTS 2000-12 (N=854)	244 (29%)
10	**Herring**	Larvae	spawning habitat	<11mm (early stage)	IHLS 2000-11 (N=1503)	1062 (71%)

Table 4: Confidence assessment for fish habitats based on fish data availability and data quality in the analysed datasets. The suitability of life stages (as identified in Table 3) to assess EFH is also taken into consideration.

Species	Source Dataset	Fish habitat	Confidence	Rationale
Plaice	UK Eastern English Channel Beam Trawl Survey (BTS)	general/nursery	High	Beam trawl surveys (BTS) are appropriate for abundance of flatfish and are designed to target plaice and sole nursery grounds. The use of early juvenile stage (0-group) increases probability of identification of primary nursery habitats. Limited BTS data offshore and in the western part of the study area (west of Isle of Wight) limit characterisation of species habitats possibly occurring in these areas. Also limited BTS data in shallower inshore habitats limits characterisation of nursery grounds likely occurring in shallow inshore habitats. Size threshold used to identify juveniles likely allows identification of primary nursery grounds.

Species	Source Dataset	Fish habitat	Confidence	Rationale
	ICES North Sea Cod and Plaice Egg Surveys in the North Sea (WGEGGS)	spawning	Moderate-High	WGEGGS survey is devised to target plaice eggs. Limited data coverage inshore and in the western part of the study area (west of Isle of Wight) limit characterisation of spawning habitats possibly occurring in these areas. There is an error associated with using pelagic egg stage as in indicator of spawning areas (due to transport of pelagic eggs away from spawning grounds), but use of early egg stage reduces this error thus increasing probability of identification of spawning habitats.
Sole	UK Eastern English Channel Beam Trawl Survey (BTS)	general/nursery	Moderate-High	Beam trawl surveys (BTS) are appropriate for abundance of flatfish and are designed to target plaice and sole nursery grounds. Limited BTS data offshore and in the western part of the study area (west of Isle of Wight) limit characterisation of species habitats possibly occurring in these areas. Also limited BTS data in shallower inshore habitats limits characterisation of nursery grounds likely occurring in shallow inshore habitats. Size threshold used to identify juveniles allows identification of general nursery grounds.
Lemon sole	UK Eastern English Channel Beam Trawl Survey (BTS)	general/nursery	Moderate-High	Beam trawl surveys (BTS) are appropriate for abundance of flatfish. Limited BTS data offshore and in the western part of the study area (west of Isle of Wight) limit characterisation of species habitats possibly occurring in these areas. Also limited BTS data in shallower inshore habitats limits characterisation of nursery grounds possibly occurring in shallow inshore habitats. Size threshold used to identify juveniles allows identification of general nursery grounds.
Dab	UK Eastern English Channel Beam Trawl Survey (BTS)	general/nursery	High	Beam trawl surveys (BTS) are appropriate for abundance of flatfish. Limited BTS data offshore and in the western part of the study area (west of Isle of Wight) limit characterisation of species habitats possibly occurring in these areas. Also limited BTS data in shallower inshore habitats limits characterisation of nursery grounds possibly occurring in shallow inshore habitats. Size threshold used to identify juveniles likely allows identification of primary nursery grounds.
Red gurnard	UK Eastern English Channel Beam Trawl Survey (BTS)	general/nursery	High	Beam trawl surveys (BTS) are appropriate for abundance of small-medium sized demersal fish. Limited BTS data offshore and in the western part of the study area (west of Isle of Wight) limit characterisation of species habitats possibly occurring in these areas. Also limited BTS data in shallower inshore habitats limits characterisation of nursery grounds possibly occurring in shallow inshore habitats. Size threshold used to identify juveniles likely allows identification of primary nursery grounds.
Dragonet	UK Eastern English Channel Beam Trawl Survey (BTS)	general/nursery	Moderate-High	Beam trawl surveys (BTS) are appropriate for abundance of small-medium sized demersal fish. Limited BTS data offshore and in the western part of the study area (west of Isle of Wight) limit characterisation of species habitats possibly occurring in these areas. Also limited BTS data in shallower inshore habitats limits characterisation of nursery grounds possibly occurring in shallow inshore habitats. Size

Species	Source Dataset	Fish habitat	Confidence	Rationale
				threshold used to identify juveniles allows identification of general nursery grounds.
Solenette	UK Eastern English Channel Beam Trawl Survey (BTS)	general/nursery	Moderate-High	Beam trawl surveys (BTS) are appropriate for abundance of flatfish. Limited BTS data offshore and in the western part of the study area (west of Isle of Wight) limit characterisation of species habitats possibly occurring in these areas. Also limited BTS data in shallower inshore habitats limits characterisation of nursery grounds possibly occurring in shallow inshore habitats. Size threshold used to identify juveniles likely allows identification of primary nursery grounds. Size threshold used to identify juveniles allows identification of general nursery grounds.
Thickback sole	UK Eastern English Channel Beam Trawl Survey (BTS)	general/nursery	Moderate	Beam trawl surveys (BTS) are appropriate for abundance of flatfish. Limited BTS data offshore and in the western part of the study area (west of Isle of Wight) limit characterisation of species habitats possibly occurring in these areas. Also limited BTS data in shallower inshore habitats limits characterisation of nursery grounds possibly occurring in shallow inshore habitats. Juvenile size threshold identified by similarity with other flatfish, as no information has been found in the literature.
Thornback ray	UK Eastern English Channel Beam Trawl Survey (BTS)	general/nursery	Moderate	Juveniles are captured in beam trawl surveys (BTS), but some of the available data may have resulted from incorrect species identification. Limited BTS data offshore and in the western part of the study area (west of Isle of Wight) limit characterisation of species habitats possibly occurring in these areas. Also limited BTS data in shallower inshore habitats limits characterisation of nursery grounds possibly occurring in shallow inshore habitats. Size threshold used to identify juveniles allows identification of general nursery grounds.
Herring	ICES International Herring Larval Survey (IHLS)	spawning	Moderate-High	The International Herring Larval Survey (IHLS) is designed to target herring larvae using appropriate methods and design. Limited data coverage inshore and in the western part of the study area (west of Isle of Wight) limit characterisation of spawning habitats possibly occurring in these areas. There is an error associated with using larval stage as in indicator of spawning areas (due to transport of pelagic larvae away from spawning grounds), but use of early larval stage (small larvae) likely reduces this error thus increasing probability of identification of spawning habitats.

2.2.2 Environmental data

Environmental data to be associated with the fish catch data are necessary to calibrate the EFH model, and the associated data layers are needed to implement the model and predict EFH distribution in the study area.

Information on the ecology of the fish species initially selected for the project was obtained from available literature, including published scientific literature (e.g., Ellis *et al*., 2000; Hinz *et al*., 2006; Lauria *et al*., 2011) and previous projects and reports (e.g., CHARM Project; Ellis *et al*., 2012)[5] (see also data on spawning seasonality, presented in Table 1b).

Factors such as depth, water temperature and sediment type were identified as relevant environmental factors, particularly for the distribution of demersal fish species/life stages. Salinity (particularly in coastal inshore and estuarine areas) and hydrodynamic conditions (e.g., wave and tidal currents) can be important factors, for both pelagic and demersal species/life stages. Also the presence of frontal zones between freshwater-influenced water masses (Regions Of Freshwater Influence, ROFI) and shelf water has been reported as an important factor affecting larval distribution of several species (Munk *et al*., 2002). This information was used to address the selection of relevant environmental data layers for the analysis (as possible predictors of fish distribution).

Ideally, environmental data for model calibration (as potential predictors of the fish habitat distribution) are collected during fish surveys to characterise the environment at the time and location of the fishing event, so that all catch data can be directly related to a set of environmental variables. Environmental data associated with the fishing events are available for some of the collated datasets (e.g., depth, surface temperature, salinity). However, in most cases, these records are sparse and the information is missing for many fishing events, hence limiting the use of these data in the analysis. Only water depth was consistently recorded in almost all fishing events included in the BTS and IHLS datasets, hence this was the only environmental data obtained from fish dataset that was used for model calibration[6]. For other environmental variables, environmental data layers were identified to allow extraction of values to associate to fishing events as well as application of the model to predict the distribution of EFH within the study area.

The criteria for these data collation included the following aspects:

- data availability for the main environmental variables relevant to fish species (as described above)
- full spatial coverage of the study area, and, if possible, of the wider area in the English Channel where fish survey stations are located
- data layers at a spatial resolution equal or higher than the spatial resolution associated with fish data
- for variables showing a marked seasonal and inter-annual variability (e.g., oceanographic data, like water temperature), data layers available for different

[5] These data sources included both studies carried out within the English Channel (e.g., Lauria *et al*., 2011; CHARM project) and literature reporting on general characteristics of a species ecology (e.g., Ellis *et al*., 2000, 2012; Hinz *et al*., 2006).

[6] Note that for model application (habitat prediction), depth maps are needed nevertheless (at least for those models where this variable is an important predictor of species habitat distribution), and that a good correlation (r>0.85) between the measured (fish surveys) and mapped data (EMODnet Bathymetry map) was observed, hence reducing any error in prediction that might be associated to discrepancies between measured and mapped depth.

seasons and years, covering the temporal extent/resolution of the specific fish survey dataset.

Several data layers were explored, but not all of them proved to be compliant with the above standards (e.g., due to limited spatial coverage of the area or overlapping with the fish survey data, or to resolution issues). The final selected data layers that have been used to obtain potential environmental predictors of the EFH distribution are summarised in Table 5. When available, data on the confidence of the collated data layers were obtained to calculate the confidence of the final model predictions.

The data layers were geo-processed and the relevant environmental variables extracted for each of the sampling stations within the fish survey datasets for the habitat model calibration. Data layers were also subject to geo-processing to obtain maps of the selected variables at the selected spatial resolution (5km grid cell) to be used for the model implementation (EFH habitat prediction over the whole study area). Details of the geo-processing methods are given in the Technical Annex.

Table 5: Environmental data layers used to obtain predictor variables in the analysis.

Data theme	Data layer (Source)	Description
Elevation and bathymetry	Bathymetry (EMODnet)	Bathymetric survey data and aggregated bathymetry data sets have been collated from public and private organizations. These have been processed and quality controlled and used to produce a regional Digital Terrain Model (DTM) with a grid size of .25 minute * .25 minute. The DTM values have been determined from the combination of bathymetric survey data (high resolution data sets from single and multibeam surveys), composite data sets produced and delivered by a number of external data providers such as Hydrographic Offices derived from their internal bathymetric database and based upon historic surveys, and GEBCO 30" gridded data, used to complete area coverage in case there are no survey data or composite data sets available to the partners.
Habitats and biotopes – substratum	Seabed substratum type (EMODnet)	The current map is collated from more than 200 separate sea-bed substrate maps provided by different partners (based on sediment sampling, multibeam echosounder, Side Scan Sonar, bathymetric and seismic surveys). Each partner harmonised their available sea-bed substrate data according to a common classification scheme (modified Folk triangle). Data are provided at a 1:1 million scale (the smallest cartographic unit (polygon) on the map being about 4 km^2).
Habitats and biotopes – substratum	JNCC EuSeaMap North and Celtic Seas Energy data layers (EUSeaMap)	Under a specific contract for the EUSeaMap project, energy layers were produced for the North and Celtic seas. Energy layers are built using data from National Oceanographic Centre (NOC) wave (ProWAM at a resolution of 12.5km) and current models (the CS20, CS3 and NEA models at resolutions of 1.8km, 10km and 35km respectively). These were all processed to populate a 1km resolution grid, with a high (~300m) bespoke resolution DHI Spectral Wave model used to augment the coastal areas where the ProWAM model resolution was inadequate. Data cover the EU Continental Shelf with variable resolution (0.1 to

Data theme	Data layer (Source)	Description
		35 kilometres). Wave and current data were combined to produce the input energy layer for the EUSeaMap model after classification into energy categories. No confidence estimates are available for the original data layers, but uncertainty in the class boundaries was assessed.
Habitats and biotopes - substratum	Habitats Directive Annex 1 Reefs (JNCC)	This is a collation of all data identifying surveyed Annex I reefs in UK waters out to the edge of the UK continental shelf. Data sources include Natural England, Countryside Council for Wales, Scottish Natural Heritage, Joint Nature Conservation Committee, British Geological Survey and National Oceangraphy Centre This dataset shows both potential and known Annex I reefs. Potential reefs include areas where seismic surveys show that there is bedrock up to 0.5m below the seabed (and there is therefore a possibility of exposed bedrock). It should be noted that areas which are dominated by a sand veneer are also classed as 'potential reefs', therefore the mapped occurrence of potential reefs is likely to overestimate actual reef habitats.
Habitats and Biotopes - water column	Marine Water Column Features (JNCC)	This dataset describes aspects of the watercolumn over the UKCS. 4 shapefiles, one for each season (Autumn, Winter, Spring, Summer), are given. It describes stratification and mixing of water types. Source data for these data layers were obtained from a number of hydrographic data sets were obtained from the Proudman Oceanographic Laboratory (POL) and these datasets were used within the UKSeaMap project (2006).
Habitats and Biotopes - water column	Global Ocean OSTIA Sea Surface Temperature and Sea Ice analysis REPROCESSED (1985-2007) (EU project MyOcean)	The Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) global Sea Surface Temperature Reanalysis product provides daily gap-free maps of sea surface temperature (referred to as an L4 product) at 0.05deg.x 0.05deg. horizontal resolution, using in-situ and satellite data from infra-red radiometers. The OSTIA system is run by the UK Met Office. The OSTIA reanalysis uses satellite data provided by the Pathfinder AVHRR project and reprocessed (A)ATSR data together with in-situ observations from the ICOADS data-set, to determine the sea surface temperature. It also uses reprocessed sea-ice concentration data from the EUMETSAT OSI-SAF. The reanalysis data is available from 1985-2007, providing full time series processed consistently with up-to-date knowledge on satellite sensor calibration, characterization and attitude, complete (as far as possible) ancillary data sets, latest versions of models and algorithms. The analysis product has been validated through calculation of mean and RMS statistics of observation-minus-background and observation-minus-analysis. Inter-comparisons with other historical data-sets, e.g. Reynolds OI, HadISST, have been carried out.

Data theme	Data layer (Source)	Description
Habitats and Biotopes - water column	Pan European Seas, Ocean Optics Products (monthly average) Reprocessed (1997-2010). (EU project MyOcean)	Ocean Colour "Optics" products are derived from remote sensing (MODIS-Aqua and SeaWIFS sensors). The spectral variations in the light leaving the water surface are related to inherent optical properties (IOPs), including the phytoplankton absorption coefficient (APH) . These IOPs can be interpreted in terms of concentrations of optically-significant constituents in the water. Corrections to remove the atmospheric contribution are applied and validation with in situ data has been carried out. The reprocessed data layer covers the period 1997-2010, providing full time series processed consistently with up-to-date knowledge on satellite sensor calibration, characterization and attitude, complete (as far as possible) ancillary data sets, latest versions of models and algorithms. Indication of a possible update is given, but there is no commitment that this will actually happen. Data are provided at a high resolution (2km).

The environmental variables derived from the data layers as potential predictors of EFH distribution are listed in Table 6. When extracting data for the BTS dataset (demersal fish), priority was given to variables characterising the bottom habitat, including depth, substratum type, energy associated with tidal currents and wave (at the bottom), although sea surface temperature[7] (summer average values over the different years) was also taken into account. In addition to these data, a proxy for phytoplankton abundance was also extracted for fish survey data related to pelagic egg and larval stages (WGEGGS and IHLS), as this provides information on the distribution of possible food resources for planktotrophic larvae developing from these stages. No consistent salinity data layers could be obtained for the study area (sparse data were available in fish survey datasets, and no consistent salinity maps for the study area could be found). Therefore, the categorisation of water quality characteristics in terms of mixing of water masses of continental and marine origin was used as a proxy. This also indicates the presence of thermo-haline fronts between freshwater-influenced water masses and shelf water, a factor that might be relevant in affecting the distribution of fish pelagic early stages. Seasonal and inter-annual variability was also taken into account during variable selection (in particular for water column variables, but depending also on data availability) in order to match the temporal variability of fish data. For example, summer (mean July/August) and winter (mean December/January) temperature maps for each year were used to obtain data matching with BTS and IHLS/WGEGGS fish data, respectively. Details on the methods adopted for data processing have been provided as excel files using the MMO geoprocessing templates and associated flowcharts.

[7] Water temperature at the bottom would have been more relevant to the distribution of demersal species, particularly in deeper offshore areas, but such data are not available (sparse records were available from the fish survey datasets).

Table 6: List of environmental variables obtained as potential predictors of EFH distribution.

Variable	Theme	Type	Description	Source	Predictor for fish data
WDepth	bathymetry	continuous	**Water depth** (m below surface) Mean depth calculated by averaging mean bathymetry within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation	EMODnet (derived)	WGEGGS
			Water depth recorded during fish sampling (for model calibration only). Depth ranges 8-81 m in stations from BTS surveys, 14-71 m in WGEGGS dataset and 17-75 m in IHLS dataset.	Fish survey data	BTS, IHLS
DomMix	water column, mixing type	categorical	**Type of mixing of the water column** Dominant type of mixing calculated based on the maximum polygon area within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation; Following types are included: 1 (a) = well-mixed ROFI (Region of Freshwater Influence); 2 (b) = well-mixed shelf water; 3 (c) = weakly stratified ROFI; 4 (d) = weakly stratified shelf water. Seasonal value matching seasonality of fish data (Summer - BTS; Winter - IHLS and WGEGGS) This variable can be considered a proxy for salinity (no salinity data layers could be obtained), with also information on the mixing of water masses of marine and continental origin.	JNCC, Marine water column features (Seasonal)	BTS, IHLS, WGEGGS
SST	water column, SST	continuous	**Sea surface temperature** (Celsius degrees) Mean temperature (seasonal) calculated by averaging mean temperature for the periods July-August (summer) and December-January (winter) each year within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation. Summer temperature (associated to BTS data) ranges 13.6-17.5 ºC; winter temperature ranges 11.9-13.7 ºC in the WGEGGS dataset, and 10.6-14.6 ºC in the IHLS dataset.	EU project MyOcean (derived)	BTS, IHLS, WGEGGS
APH	water column, APH	continuous	**Phytoplankton absorption coefficient** (m^{-1}) Monthly mean absorption coefficient due to phytoplankton at 443 nm Maximum value of monthly mean APH (in January each year) was calculated within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation. Winter APH ranges 0.015-0.110 m^{-1} in the WGEGGS dataset and 0.015-0.203 m^{-1} in the IHLS dataset.	EU project MyOcean (derived)	IHLS, WGEGGS

Variable	Theme	Type	Description	Source	Predictor for fish data
TidE	substratum, energy	continuous	**Tidal energy** (N m^{-2}) _ Mean tidal energy calculated by averaging mean tidal energy values within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation. Tidal energy ranges 31.31-1498.47 N m^{-2} in the BTS dataset, 248.51-1952.72 N m^{-2} in the WGEGGS dataset and 208.12-1768.51 N m^{-2} in the IHLS dataset.	EUSeaMap (derived)	BTS, IHLS, WGEGGS
WavE	substratum, energy	continuous	**Wave energy** (N m^{-2}) Mean wave energy calculated by averaging mean wave energy values within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation. Wave energy ranges 60.35-5361.51 N m^{-2} in the BTS dataset, 57.94-1112.05 N m^{-2} in the WGEGGS dataset and 58.01-1824.10 N m^{-2} in the IHLS dataset.	EUSeaMap (derived)	BTS, IHLS, WGEGGS
M-sM	substratum, type	continuous	**Mud to sandy mud relative coverage** Relative area covered by this substratum type within 2.5km from the station (mean location), for model calibration, or within 5km grid cell for model implementation. The relative area covered by the polygons for this substratum type was calculated as a proportion of the total area covered by all the polygons (for all substratum types) included in the buffer or grid cell. Being a proportion, the relative area varies theoretically between 0 (the substratum type is not present in the buffer/grid cell) and 1 (full coverage of the buffer/grid cell). For the BTS dataset, the actual range of variability was between 0 and 0.77.	EMODnet (derived)	BTS, IHLS, WGEGGS
S-mS	substratum, type	continuous	**Sand to muddy sand relative coverage** Relative area covered by this substratum type within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation. The relative area was calculated as described for M-sM. For the WGEGGS dataset, the actual range of variability was between 0 and 0.42, whereas the coverage of S-mS for the other datasets covered the full theoretical range of variability (0-1).	EMODnet (derived)	BTS, IHLS, WGEGGS
Cs	substratum, type	continuous	**Coarse sediment relative coverage** Relative area covered by this substratum type within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation. The relative area was calculated as described for M-sM. The coverage of Cs ranged 0-1 in all datasets.	EMODnet (derived)	BTS, IHLS, WGEGGS
Mx	substratum, type	continuous	**Mixed sediment relative coverage** Relative area covered by this substratum type within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation. The relative area was calculated as described for M-sM.	EMODnet (derived)	BTS, IHLS, WGEGGS

Variable	Theme	Type	Description	Source	Predictor for fish data
			The coverage of Mx ranged 0-1 in all datasets.		
R	substratum, type	continuous	**Rock or other hard substrata relative coverage** Relative area covered by this substratum type within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation. The relative area was calculated as described for M-sM. The coverage of R ranged 0-1 in all datasets.	EMODnet (derived)	BTS, IHLS, WGEGGS
Dom Subst	substratum, type	categorical	**Dominant substratum type** Dominant type of substratum calculated based on the maximum polygon area within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation. Codes for the dominant type are as follows: 1=M-sM, 2=S-mS, 3=Cs, 4=Mx, 5=R (substratum type codes as per variables above)	EMODnet (derived)	BTS, IHLS, WGEGGS
Reef	substratum, type	categorical	**Presence-absence of reef** Reef presence category calculated based on the occurrence of polygons for different reef categories within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation. Reef presence category takes into account also **level of confidence** in the reef map: 0 (a) =no reef 1 (b) =reef potentially present (lower confidence) 2 (d)=reef present	JNCC, Habitats Directive Annex 1 Reefs	BTS, IHLS, WGEGGS

2.2.3 Confidence assessment of input data

The quality of data obtained for use in this project underpins the validity of the evidence and so to ensure data are fit for purpose and to assist in the confidence assessment, metadata have been sought for any data used. To comply with international (ISO 19115) and national metadata standards, information about the identification, extent, quality, spatial and temporal schema, spatial reference, and distribution of the data have been recorded.

Based on this information, confidence in geo-spatial data have been measured by reference to methodology, timeliness, spatial confidence, completeness, and production quality standards using the criteria set by the MMO guidelines where possible (MMO, 2011). This information has been combined to give an overall confidence assessment rating (see attached files).

Further details on the method are provided in the Technical Annex.

2.3 Statistical and geo-spatial modelling

Fish catch (CPUE or density) and environmental data were explored to identify data characteristics (e.g., collinearity of environmental variables, data distribution). The fish catch data used in the present study contained a large proportion of zeros dependent on the selection of a particular life stage. Most of species/life stages (in particular juveniles) showed a low frequency of occurrence in the datasets (with often <25% occurrences) and highly variable abundance values. These are common characteristics of marine fish abundance survey data (Stefansson 1996) that make it difficult to apply standard statistical tools (Zuur *et al*., 2007). Consequently, a choice was made to reduce fish data to presence and absence data and classification tree models were identified as the most appropriate technique for their analysis.

Classification trees organise explanatory variables in a hierarchical way (based on their effect on the response variable). They allow the user to identify unique combinations of variables associated with specific levels of the response variable, and highlight and describe the major influencing variables as a series of branches. This type of model has several advantages (De'ath and Fabricius 2000, Zuur *et al*., 2007). The hierarchical nature of the trees allows identifying the relative importance of different explanatory variables, hence giving their ranking. In addition these models accommodate the non-linearity and interaction between explanatory variables and with missing values (which were often present for environmental variables in the datasets). They are also easily interpreted and the resulting algorithm (i.e., the combination of environmental ranges that can be used to predict the occurrence of a certain life stage) can be easily applied for the prediction of the EFH.

For each species, two types of models (M1 and M2) were calibrated:

M1. Overall species habitats model
Data on the presence of juveniles and adults of a species (from BTS dataset) were combined to identify four habitat categories that were used as the response variable in the model:

- 0 = habitats where the species is not present
- 1 = habitats where juveniles only are present
- 2 = habitats where adults only are present
- 3 = habitats where juveniles and adults are present.

Categories 1 and 3 identify the potential nursery habitat of a species (based on juvenile frequency of occurrence). Categories 2 and 3 identify the foraging habitats of adults, and category 0 identifies habitats where the species is less likely to occur (e.g., due to biogeographic distribution of the species or to possible unsuitable habitat conditions).

A classification tree was applied to these data and the set of environmental rules that allow predicting the presence of one of these habitats was identified by the model. This type of output was used to obtain an overview of the likely distribution of species habitats.

M2. Nursery/Spawning habitats model

A more detailed model of the probability of presence of nursery habitats (juvenile presence-absence in BTS dataset) or of spawning habitats (eggs and larvae presence-absence in WGEGGS and IHLS datasets, respectively) was calibrated. This type of classification tree model focused on the presence-absence of a single life stage of the species (eggs/larvae, or juveniles) to predict in greater detail specific EFH (spawning habitats or nursery habitats, respectively). The use of presence-absence categories combined with the information on the misclassification error[8] associated with each prediction allowed the calculation of the probability of occurrence of the target life stage associated with each set of environmental predictive rules.

Using the algorithm indicated by the tree model, relevant environmental data layers were combined in GIS in order to predict the distribution of EFH for each species over the whole study area. The mean environmental conditions over the period 2000-2012 were used to predict the species habitat using a 5x5 km grid.

2.3.1 Confidence assessment of outputs

Confidence levels in the spatial output originating from the model implementation in GIS give a context to the interpretation of the project findings. This assessment depends not only on the quality/confidence of input data layers implementing the model but also on the modelling procedure (including confidence in the data used for calibrating the model as well as on the modelling process itself). Therefore, a quantitative method was devised to assess the total confidence associated with each spatial output.

Confidence ratings were assigned to:

- the model predictive ability, based on total misclassification error
- the fish survey data used to calibrate the model (see Table 4)
- the environmental data layers used by the model, based on MMO standard assessment criteria (see Technical Annex for the complete table including confidence information on the input environmental data).

Assigned confidence ratings were given on a scale similar to the one used in the MMO standard assessment, so that they could be combined in a total confidence value associated with each output. The model specification on the ranked importance of the environmental variables in determining the EFH prediction was also taken into account to weight the contribution of the different environmental data layers to the final output and hence to determining the confidence in it.

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[8] Misclassification error is a parameter provided with the model results measuring the number of observations in the calibration dataset that are incorrectly classified by the model (e.g., the model predicts the presence of juveniles of a species based on the environmental conditions in a survey station, but no juveniles were actually recorded in the fish catches in that station). A similar measure can be applied to validate the model using an independent dataset. Provided that all the variables as included in the model are recorded (or available) for a series of fishing events (including information on presence-absence of a species life stage and environmental conditions), the model prediction on the presence-absence of the species life stage can be worked out based on the environmental conditions and compared with the data on the actual presence-absence of the life stage in the samples. The degree of agreement between the model predictions and the real data can be used to further validate the model hence adjust the confidence level in its results.

Similarly, confidence ratings were assigned to the spatial predictions of the model, by using the associated misclassification error and, where available, the spatial confidence maps obtained for input data layers. In addition, prediction outputs were clipped to remove areas of the prediction that extrapolated beyond the range of environmental variability of the calibration dataset.

Details on classification trees and the criteria applied for model selection and confidence assessment are given in the Technical Annex.

3. Derived outputs

In general, potential nursery habitats for a species were identified by the models as those where juveniles occurred with a probability of presence >50% (all red cells in the maps).

A similar result was obtained for the identification of spawning habitats based on the eggs or larvae distribution. However, in this case there is a potential error associated with the use of these stages as indicators of spawning grounds, given that pelagic stages can be transported away from spawning grounds. For example, plaice eggs may travel for several kilometres in a few days, a dispersion of up to 45km in 3 days of drift from spawning areas has been reported in the Southern Bight by Simpson (1959). Although the use of early egg stage (EG1) can reduce this error, this cannot be eliminated, given that plaice eggs takes 2.5-6.5 days to reach the end of stage 1 (Ryland and Nichols, 1975). Similar considerations can be made for herring larvae. This uncertainty has been incorporated in the estimation of the confidence in the obtained output.

The total confidence level associated with each spatial output (calculated as per method described in section 3.2.1 and in the Technical Annex) is presented in Table 7 (see Technical Annex for the complete table including confidence information on the input data and on the model predictive ability). Although moderate to high confidence levels were associated with fish data (Table 4) and the model predictive ability was moderate on average (with variation between low and high confidence), low confidence resulted for several outputs. This is mainly due to the low rating associated with relevant input environmental data layers, in particular those for wave and tidal current energy and seabed substratum type. Although these data layers have been used within EUSeaMap as input data layers for the prediction of seabed habitat types, little information/metadata could be found for them (particularly those where the original input data layers were obtained before processing for the EUSeaMap project). Hence some difficulties were encountered in their confidence assessment with a resulting inability to assess some of the elements taken into account in the MMO Quality Assurance Data Template.

Directly related to this overall confidence is the spatial confidence associated to the EFH maps. This confidence is shown as a relative value that has been normalised over a range from 0 to 1 (see Technical Annex for details) and its main purpose is to identify areas of higher and lower confidence in the prediction rather than identify absolute confidence estimates. For this reason, confidence maps must always be considered in conjunction with the total confidence associated to the map that provides the overall confidence level for the output (Table 7).

It should be noted that the obtained outputs have a clear temporal reference, dependent on the data used to calibrate the EFH models and those used to implement these models in the spatial domain. Results obtained from the models on adult foraging and nursery habitat are referred to the summer season whereas results on the spawning habitats are valid for the winter season.

Table 7: Total confidence associated with each model output. Confidence ratings associated with the input data layers and to the model are detailed in the Technical Annex.

Species	Model output	Rating	Class
Plaice	M1_species habitat	2.1	Moderate
	M2_nursery habitat	1.4	Low
	M2_spawning habitat	1.5	Moderate-Low
Sole	M1_species habitat	1.3	Low
	M2_nursery habitat	1.4	Low
Lemon sole	M1_species habitat	2.3	Moderate
	M2_nursery habitat	0.7	Low
Dab	M1_species habitat	2.1	Moderate
	M2_nursery habitat	0.7	Low
Red gurnard	M1_species habitat	1.5	Moderate-Low
	M2_nursery habitat	1.5	Moderate-Low
Dragonet	M1_species habitat	1.4	Low
	M2_nursery habitat	0.7	Low
Solenette	M1_species habitat	1.2	Low
	M2_nursery habitat	1.2	Low
Thickback sole	M2_nursery habitat	1.3	Low
Thornback ray	M2_nursery habitat	0.6	Low
Herring	M2_spawning habitat	2.1	Moderate

The results obtained from the statistical and geo-modelling of EFH are described below for each species.

3.1 Plaice, *Pleuronectes platessa*

Three habitat models were applied to the data available for plaice: a general habitat model describing the distribution of the species habitats (M1, based on BTS dataset) and two models predicting the distribution of potential nursery habitats and of spawning habitats, based on presence-absence data for juveniles (0-group individuals, from BTS dataset) and eggs (early stage, from WGEEGS dataset) (Table 8).

Tidal current energy on the seabed (TidE), the proportional coverage of sandy sediment (S-mS) and the dominant stratification and mixing of water masses (DomMix) proved to be the most important variables affecting the species distribution at juvenile and adult stages. Other relevant factors affecting the species distribution were depth, the proportional coverage of coarse and mixed sediment on the seabed (Cs and Mx), sea surface temperature (SST) and wave energy (WavE). In turn, the distribution of plaice egg early stages (indicative of spawning grounds) was mostly related to phytoplankton abundance (as measured by APH) and sea surface temperature.

Table 8: **Environmental conditions for the occurrence of plaice EFH. Relevant important variables are indicated in columns from left to right in order of decreasing importance, as identified by the models. Shaded cells in the table identify the combination of environmental conditions leading to predictions of EFH with higher confidence.**

Adult foraging habitat

Model prediction (life stage occurrence)	Tidal energy (TidE, N m^{-2})	Type of mixing of the water column (DomMix)	Sand to muddy sand relative coverage (S-mS)	Coarse sediment relative coverage (Cs)	Depth (m)	Mixed sediment relative coverage (Mx)
Adults	≥618.90	well-mixed ROFI	-	-	-	-
	<618.90	-	< 0.001	<0.72	-	-
	<618.90	-	≥0.001 and <0.98	-	≥20.5	-
	<618.90	well-mixed shelf water	≥0.001 and <0.98	-	<20.5	-
	<618.90	well-mixed ROFI	≥0.001 and <0.98	-	<20.5	≥0.013
Adults and Juveniles	<618.90	-	≥0.98	-	-	-
	<618.90	well-mixed ROFI	≥0.001 and <0.98	-	<20.5	<0.013

Nursery habitat

Model prediction (juveniles probability of occurrence)	Sand to muddy sand relative coverage (S-mS)	Tidal energy (TidE, N m^{-2})	Type of mixing of the water column (DomMix)	Sea surface temperature (SST (summer), °C)	Mixed sediment relative coverage (Mx)	Wave energy (WavE, N m^{-2})
0.89	<0.97	<303.39	Shelf water (well mixed and weakly stratified)	≥15.84	<0.05	-
0.86	<0.97	<303.39	ROFI (well mixed and weakly stratified)	-	<0.30	-
0.82	≥0.97	-	-	-	-	-
0.70	< 0.97	<303.39	ROFI (well mixed and weakly stratified)	-	≥0.30	≥600.41

Spawning habitat

Model prediction (eggs probability of occurrence)	Phytoplankton absorption coefficient (APH (January), m^{-1})	Sea surface temperature (SST (winter), °C)
0.80	<0.023	-
0.67	≥0.023	≥13.16

Lauria *et al*. (2010) also investigated environmental influences on presence/absence of juveniles (0-group) and older (1-group) plaice in the Eastern English Channel, using BTS fish survey data. Although these authors used slightly different environmental predictors and a different statistical modelling technique (GLM), similar results were obtained, with substratum type being the most important predictor in explaining plaice distribution, particularly during early life stage, and also bed shear stress, bathymetry and temperature.

3.1.1 Adult foraging habitat

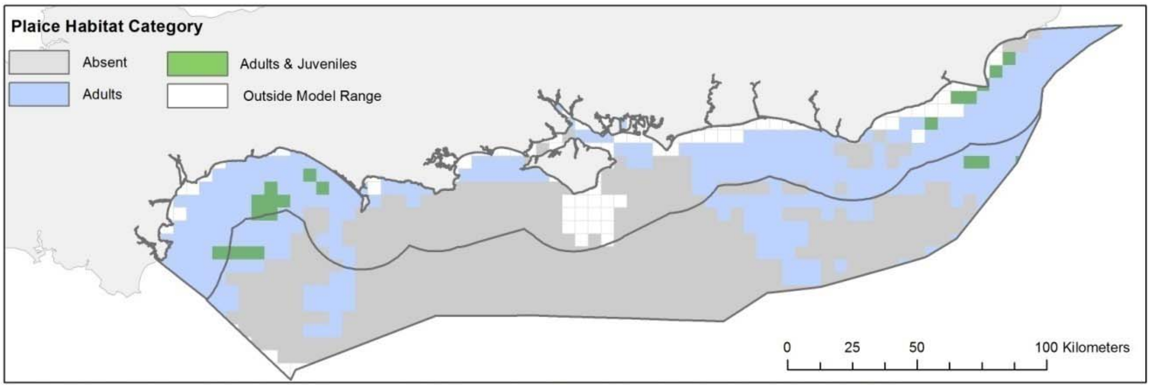
This habitat is identified by the occurrence of adults (alone or together with juveniles), as predicted by the species model (M1; Table 8, Figure 3).

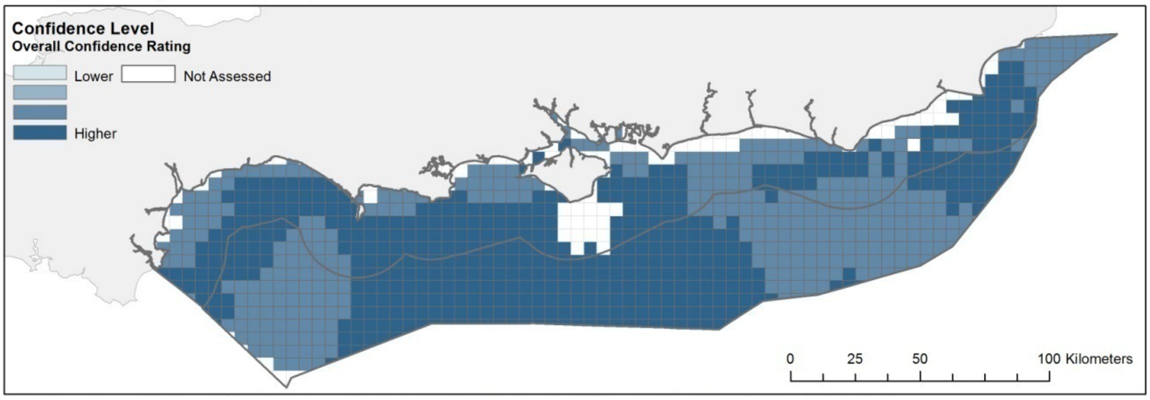
Adult foraging habitats are predicted with higher confidence in areas deeper than 20.5m, where the energy associated with tidal currents on the seabed is low-moderate[9] (TidE <619 N/m^2) and the relative spatial coverage of sand is variable (between 0.001% and 98%) (Table 8). Within areas where low-moderate energy (at the seabed) is associated to tidal currents (TidE <619 N/m^2), these habitats occur also where the seabed is dominated by sandy sediments (coverage ≥98%), irrespectively of the depth (Table 8).

Within the study area, the above conditions occur mostly in the western zones (Devon to west Dorset, West of Portland), around the boundary between inshore and offshore areas, as well as in inshore areas along the coast from East Sussex to Kent (Figure 3).

It is of note that the species was predicted to be absent in habitats where coarser sediments dominate the seabed (Cs≥72% and S-mS<1%) in low-moderate tidal energy conditions, as well as in marine areas (well mixed shelf waters) of higher tidal energy.

Figure 3: Plaice, M1 - predicted habitats distribution and associated relative spatial confidence.





Contains Ordnance Survey and UK Hydrographic Office data. Based on data processing carried out by the Institute of Estuarine and Coastal Studies using data products from MyOcean © Crown copyright and database right 2013. Marine Management Organisation.

[9] Identification of low, moderate and high levels of energy associated to tidal currents and waves is based on criteria defined within the EUSeaMap (EMODnet). For tidal current energy these are: Low 0-130 N/m^2, Moderate 130-1160 N/m^2, High >1160 N/m^2. For wave energy these are: Low 0-210 N/m^2, Moderate 210-1200 N/m^2, High >1200 N/m^2.

Figure 4: Plaice, M2 - predicted nursery habitat distribution and associated relative spatial confidence.

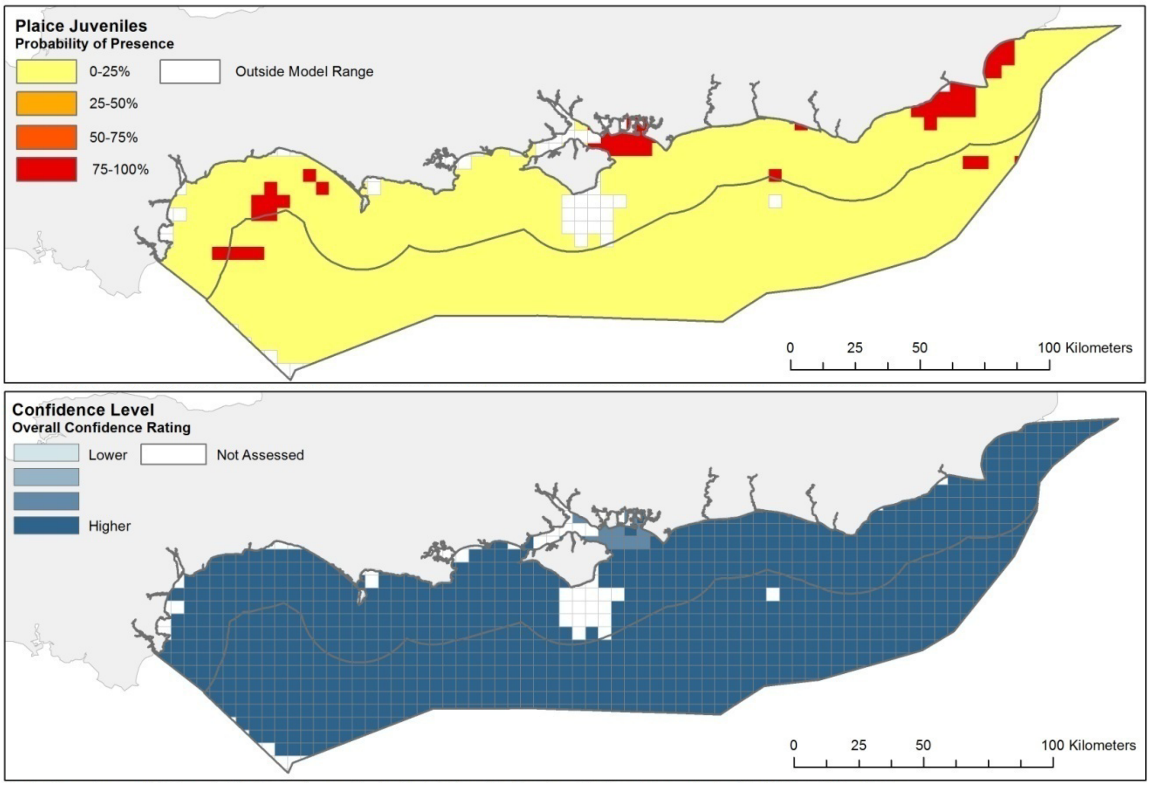
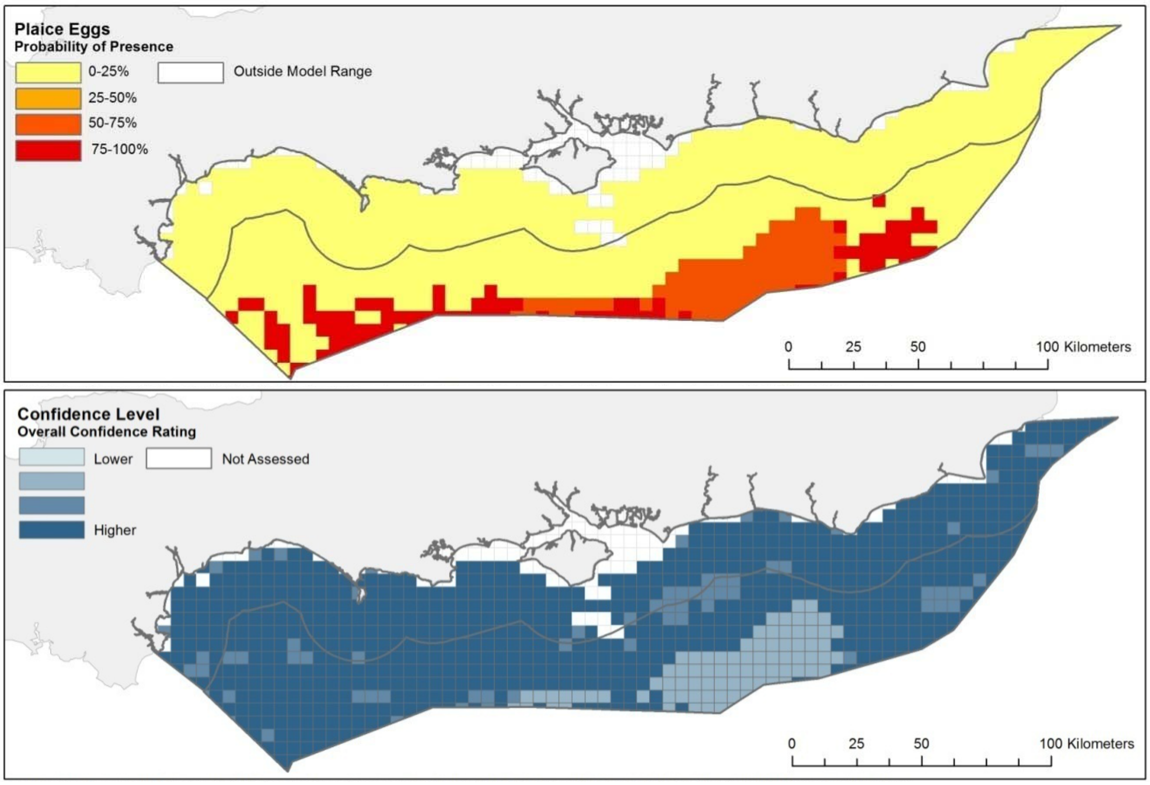


Figure 5: Plaice, M2 - predicted spawning habitat distribution and associated relative spatial confidence.



3.1.2 Nursery habitat

This habitat is identified in detail by the nursery habitat model (M2) as those areas with higher (>70%) probability of occurrence of plaice at juvenile stage, Table 8, Figure 4).

Plaice nursery habitats are predicted with higher confidence in areas of lower tidal energy (TidE <303 N/m^2). These conditions are associated with variable relative spatial sand coverage (<97%) and relatively low spatial coverage of mixed sediment (<30%), possibly indicating the preference for finer substrata compared to adults (as observed also by Lauria *et al*., 2010). These habitats occur in coastal areas where there is a freshwater influence (ROFI areas). Habitats where there is a relatively high probability of occurrence of young plaice also include areas dominated by sandy substrata (coverage ≥97%).

The spatial predictions based on these results show that young plaice are likely to have a more restricted distribution compared to adults, with the conditions characterising potential nursery being found mostly inshore. Sparse suitable nursery grounds are located mostly on the eastern part of the study area (East Sussex and Kent coast) and on its western side (Devon and west Dorset coast) (Figure 5), confirming the limited extent of low intensity plaice nursery grounds along the South coast as identified previously by Coull *et al*. (1998) and Ellis *et al*. (2012). Suitable conditions for the presence of nursery grounds for plaice are identified with high confidence also in the most inshore areas near Portsmouth (Figure 4).

3.1.3 Spawning habitat

This habitat is identified by the predictions of the model calibrated on plaice egg distribution (M2) as those areas with higher (>65%) probability of occurrence of plaice eggs (Table 8, Figure 5).

According to the model results, plaice spawning habitats are more likely to occur in areas where the phytoplankton abundance proxy indicates a possible lower concentration of phytoplankton during the summer season (APH<0.023 m^{-1}), or in areas where mean summer temperature at the sea surface is ≥13.6 °C and APH values are higher (although a lower confidence is associated with this latter habitat).

Spawning habitats for the species are located with higher confidence at the offshore margin of the study area. This broadly agrees with the spawning areas identified by Coull *et al*. (1998) and confirmed by Ellis *et al*. (2012, for the eastern Channel), although the higher spatial resolution of the data in this study more precisely indicates the differences in the probability of occurrence of these habitats at a finer scale.

3.2 Sole, *Solea solea*

Two habitat models were applied to the data available for sole: a general habitat model describing the distribution of the species habitats (M1, based on BTS dataset) and a model predicting the distribution of potential nursery habitats based on presence-absence data on juveniles (from BTS dataset) (Table 9).

Tidal current energy on the seabed (TidE), sediment type (in particular the proportional coverage of sandy and mixed sediments on the seabed, S-mS and Mx, respectively) and the dominant stratification and mixing of water masses (DomMix) proved to be the most important variables affecting the species distribution of young and adult sole. Other relevant factors affecting the species distribution were the proportional coverage of muddy sediment on the seabed (M-sM), depth and wave energy (WavE).

Table 9: **Environmental conditions for the occurrence of sole EFH. Relevant important variables are indicated in columns from left to right in order of decreasing importance, as identified by the models. Shaded cells in the table identify the combination of environmental conditions leading to predictions of EFH with higher confidence.**

Adult foraging habitat

Model prediction (life stage occurrence)	Tidal energy (TidE, N m^{-2})	Mixed sediment relative coverage (Mx)	Sand to muddy sand relative coverage (S-mS)	Type of mixing of the water column (DomMix)	Mud to sandy mud relative coverage (M-sM)	Wave energy (WavE, N m^{-2})
Adults	<607.99	-	<0.07	-	-	-
	≥251.81 and <607.99	-	≥0.07	Shelf water (well mixed and weakly stratified)	-	-
	≥607.99	≥0.60	-	-	-	-
	<251.81	-	≥0.07	Shelf water (well mixed and weakly stratified)	<0.43	<1577.30
	≥314.36 and <607.99	-	≥0.07	ROFI (well mixed and weakly stratified)	-	<850.15
Adults and Juveniles	<314.36	-	≥0.07	ROFI (well mixed and weakly stratified)	-	-
	<251.81	-	≥0.07	Shelf water (well mixed and weakly stratified)	<0.43	≥1577.30
	<251.81	-	≥0.07	Shelf water (well mixed and weakly stratified)	≥0.43	-
	≥314.36 and <607.99	-	≥0.07	ROFI (well mixed and weakly stratified)	-	≥850.15

Nursery habitat

Model prediction (juveniles probability of occurrence)	Sand to muddy sand relative coverage (S-mS)	Type of mixing of the water column (DomMix)	Tidal energy (TidE, N m^{-2})	Depth (m)	Mud to sandy mud relative coverage (M-sM)	Wave energy (WavE, N m^{-2})
0.86	≥0.07	Shelf water (well mixed and weakly stratified)	<251.81	-	≥0.43	-
0.80	≥0.07	Shelf water (well mixed and weakly stratified)	<251.81	-	<0.43	≥1577.30
0.75	≥0.07 and <0.24	ROFI (well mixed and weakly stratified)	-	≥25.5	-	-
0.72	≥0.07	ROFI (well mixed and weakly stratified)	-	<25.5	-	-
0.67	≥0.07 and <0.15	Shelf water (well mixed and weakly stratified)	<251.81	-	<0.43	<1577.30

3.2.1 Adult foraging habitat

This habitat is identified by the occurrence of adults (alone or together with juveniles), as predicted by the species model (M1; Table 9, Figure 6).

Adult foraging habitats are predicted with higher confidence on substrata with low-moderate tidal energy (TidE <608 N/m^2) and limited sand coverage (<7%), or, where sand coverage is higher, with moderate tidal energy conditions (TidE still <608 N/m^2 but ≥251 N/m^2) in fully marine (shelf) water. Sole adults, however, are likely to occur also together with juveniles on less dynamic substrata (TidE <314 N/m^2) with sand coverage ≥7%, in areas of freshwater influence or in fully marine (shelf) water where there is high wave energy at the seabed (WavE ≥1577 N/m^2) and the coverage of mixed sediments on the seabed is <43%.

Within the study area, the above conditions occur both inshore and offshore in the most eastern and western parts of the study area (in front of Devon to Dorset and West Sussex to Kent coasts), although some suitable foraging habitats for adult sole have been identified also inshore, between Portland and the area around Portsmouth (Figure 6).

It is of note that the distribution of the species is limited in particular by stronger tidal energy conditions (TidE ≥608 N/m^2) associated with lower coverage of mixed sediment (<60%) on the seabed. In these conditions, occurring mostly in the central part of the study area, there is a lower probability of finding the species.

Figure 6: Sole, M1 - predicted habitats distribution and associated relative spatial confidence.

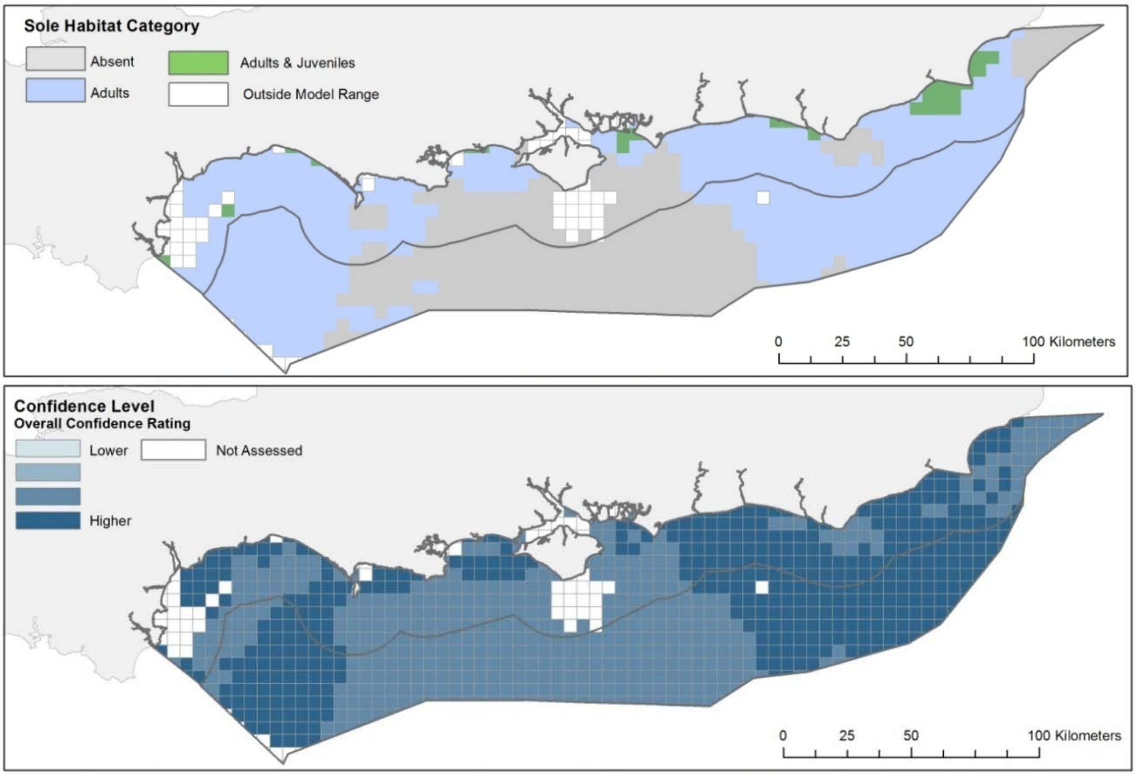
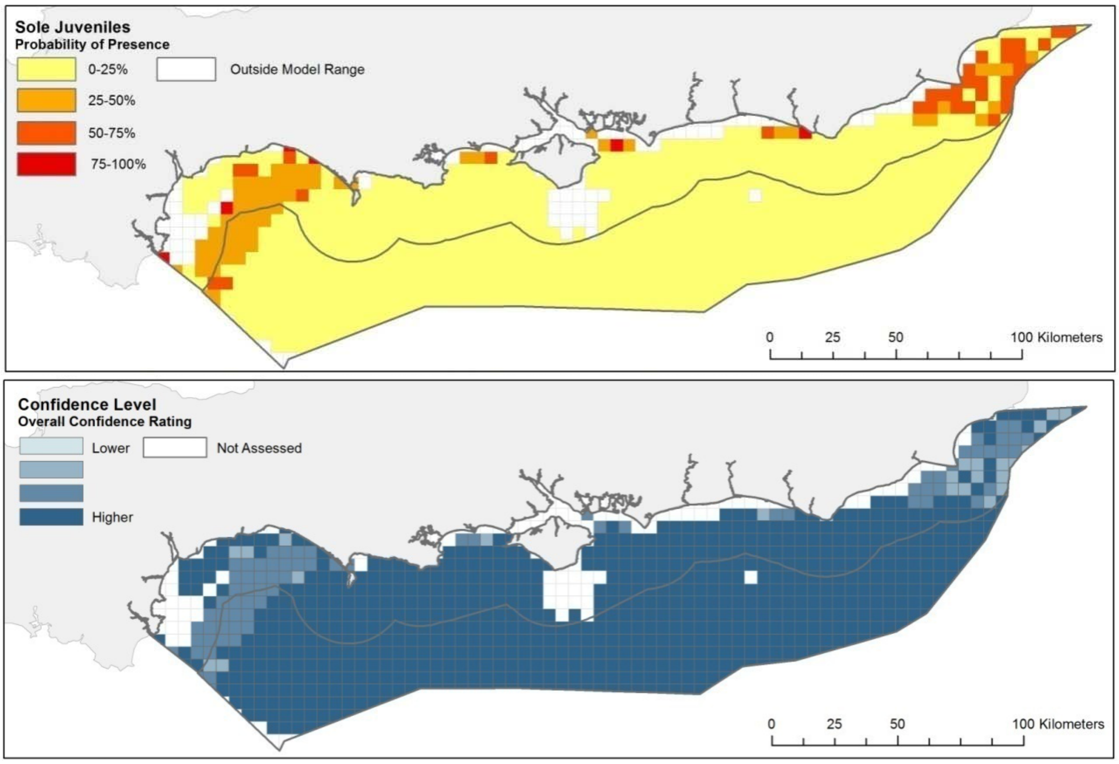


Figure 7: Sole, M2 - predicted nursery habitat distribution and associated relative spatial confidence.



3.2.2 Nursery habitat

This habitat is identified in detail by the nursery habitat model (M2) as those areas with higher (>65%) probability of occurrence of sole at juvenile stage (Table 9, Figure 7).

Sole nursery habitats are predicted with higher probability and confidence in coastal inshore areas, in full marine conditions (shelf water), on substrata where sand coverage is ≥7% and tidal energy is relatively low (<251 N/m^2), and with variable coverage of muddy sediment (associated with high wave energy conditions on shallower coastal areas where muddy sediment covers less than 43% of the area). The presence of these habitats inshore, in shallower areas with a muddy component on the substratum has been reported in previous studies (Claridge and Potter, 1987; Le Pape *et al*., 2003; Ellis *et al*., 2012).

Based on the above conditions, sparse sole nursery grounds can be identified with higher confidence particularly inshore, in front of the coast from Devon to west Dorset (West of Portland), in front of Portsmouth and in the area in front of Brighton (Figure 7). More extensive nursery grounds are likely to occur inshore, in the eastern and western side of the study area, although there is lower confidence in these predictions. This is possibly due to a high interannual variability in the juvenile occurrence in the beam trawl catches, suggesting that other factors (not considered in this study) might influence this variability. The distribution of these predicted habitats broadly agrees with the limited extent of low intensity sole nursery grounds identified along the South coast by Coull *et al*. (1998) and Ellis *et al*. (2012) based on fish survey data.

The observed distribution of the sole EFH towards the opposite sides of the English Channel seems to agree with the presence of two distinct stocks in the English Channel area, one to the east and one to the west. However, these are not fully separated with some exchange of juveniles occurring during the recruitment period (MMO, 2012a).

3.3 Lemon sole, *Microstomus kitt*

Two habitat models were applied to the data available for lemon sole: a general habitat model describing the distribution of the species habitats (M1, based on BTS dataset) and a model predicting the distribution of potential nursery habitats based on presence-absence data on juveniles (from BTS dataset) (Table 10).

Tidal currents energy on the seabed (TidE) and the dominant stratification and mixing of water masses (DomMix) proved to be the important variables affecting also this species distribution at juvenile and adult stages. Other relevant factors were depth and the proportional coverage of coarse sediment on the seabed (Cs), particularly for describing the lemon sole general distribution, whereas the sand coverage (S-mS) and wave energy measured on the seabed (WavE, although this variable may be related to depth) were relevant predictors particularly of the distribution of young lemon sole.

Table 10: Environmental conditions for the occurrence of lemon sole EFH. Relevant important variables are indicated in columns from left to right in order of decreasing importance, as identified by the models. Shaded cells in the table identify the combination of environmental conditions leading to predictions of EFH with higher confidence.

Adult foraging habitat

Model prediction (life stage occurrence)	Depth (m)	Type of mixing of the water column (DomMix)	Coarse sediment relative coverage (Cs)	Tidal energy (TidE, N m^{-2})
Adults	≥25.5	ROFI (well mixed and weakly stratified) and weakly stratified shelf water	≥0.006	<574.12
Adults and Juveniles	≥25.5	ROFI (well mixed and weakly stratified) and weakly stratified shelf water	≥0.006	≥574.12

Nursery habitat

Model prediction (juveniles probability of occurrence)	Tidal energy (TidE, N m^{-2})	Type of mixing of the water column (DomMix)	Sand to muddy sand relative coverage (S-mS)	Wave energy (WavE, N m^{-2})
0.92	≥853.82	well-mixed ROFI	-	-
0.76	≥414.61 and < 853.82	well-mixed ROFI	≥0.009 and <0.77	<379.88
0.64	≥538.26 and < 853.82	well-mixed ROFI	≥0.009 and <0.77	≥379.88

3.3.1 Adult foraging habitat

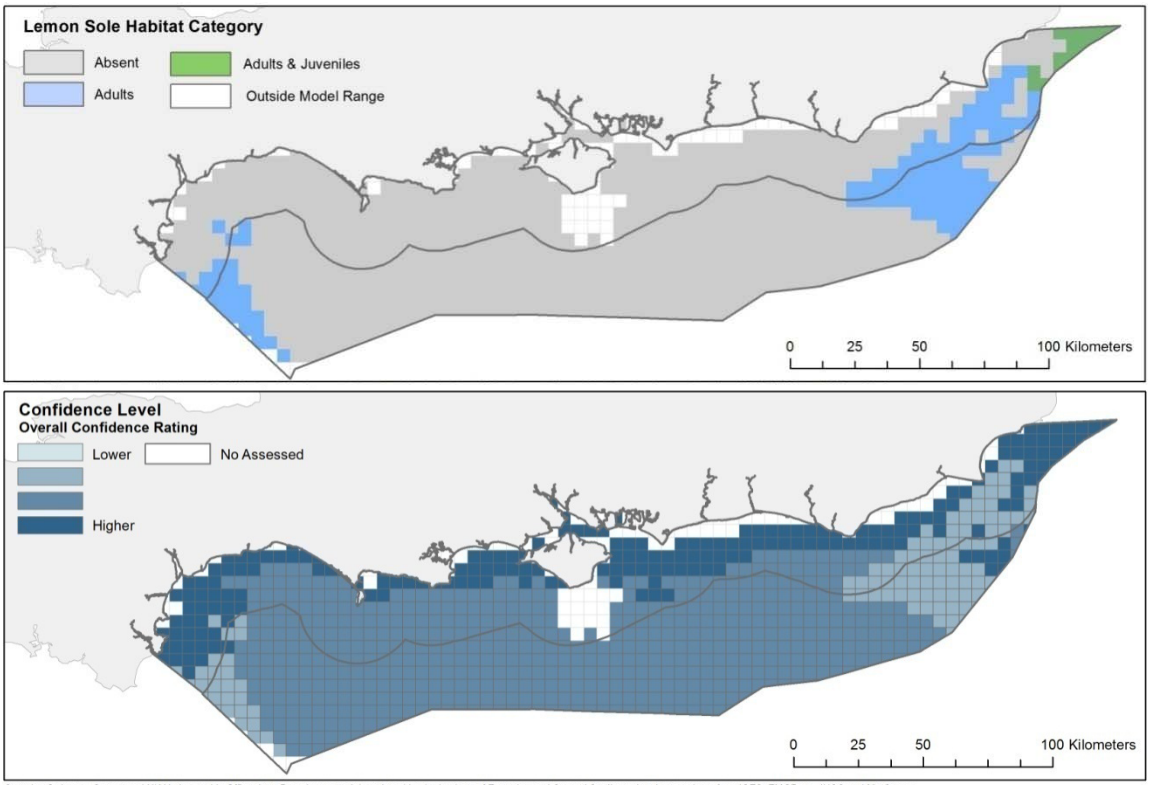
This habitat is identified by the occurrence of adults (alone or together with juveniles), as predicted by the species model (M1; Table 10, Figure 8).

Adult foraging habitats are predicted with higher confidence in deeper areas (≥25m), with variable mixing/stratification conditions (with the exception of well mixed shelf waters), the presence of coarse sediments in variable coverage (Cs>0.6%) and in both moderate-low and moderate-high energy conditions associated with tidal currents on the seabed (TidE <574 N/m^2 and≥574 N/m^2, respectively). This result seems to partly agree with Hinz *et al*. (2006), reporting sites of consistently high abundance of lemon sole in the Channel in deeper areas where a coarse component is present in the sediment (sandy and gravelly sand substrata).

The conditions suitable for the presence of lemon sole adult foraging habitat occur both offshore, in front of the coast of Devon, and inshore, in the North-East corner of the study area (east Sussex to Kent coast) (Figure 8).

There is a lower probability of finding the species in shallower areas (<25m deep) or, in deeper areas, where coarser sediments are scarce (Cs<0.6%) and in variable conditions of mixing/stratification of water masses. As a result, most of the marine area (inshore and offshore) in front of the coast from Dorset to West Sussex is considered less suitable for this species.

Figure 8: Lemon sole, M1 - predicted habitats distribution and associated relative spatial confidence.



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3.3.2 Nursery habitat

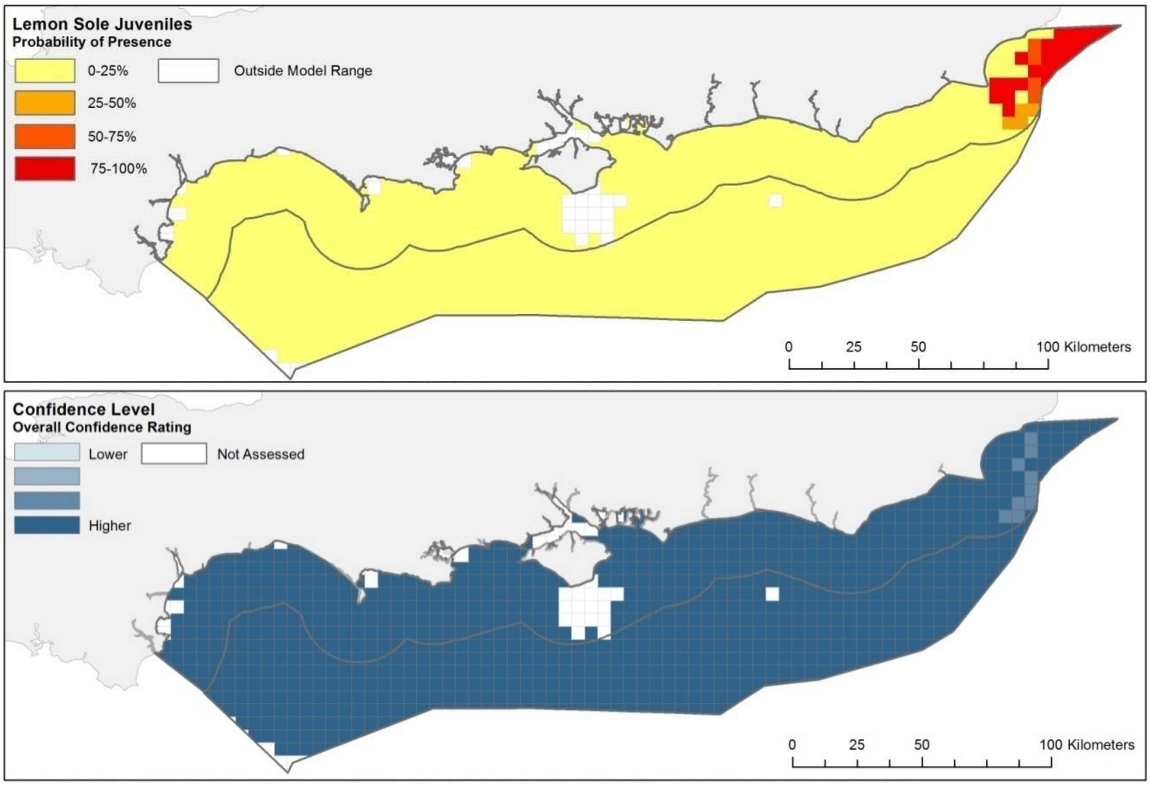
This habitat is identified in detail by the nursery habitat model (M2) as those areas with higher (>60%) probability of occurrence of lemon sole at juvenile stage (Table 10, Figure 9).

Nursery habitats for the species are generally located in coastal areas where there is an influence of freshwater (well mixed ROFI). Within these areas, a higher probability of presence of lemon sole juveniles is associated relatively dynamic conditions at the seabed (TidE ≥854 N/m^2), although a lower confidence is attached to these predictions. In turn, nursery habitats that are predicted with higher confidence are characterised by moderate tidal energy at the seabed (with TidE values always <854 N/m^2), with variable coverage of sandy sediment (S-mS between 0.9 and 77%) and variable energy associated to waves (WavE either above or below 380 N/m^2).

These conditions occur in particular inshore, in the North-East corner of the study area, along the Kent coast (Figure 9).

It is of note that juveniles of this species are rarely caught in the groundfish surveys, indicating that lemon sole juveniles do not use the common nursery areas for Dover sole and plaice juveniles (Pawson, 1995) and probably inhabit deep rocky areas (50–100 m; Jennings *et al*., 1993).

Figure 9: Lemon sole, M2 - predicted nursery habitat distribution and associated relative spatial confidence.



3.4 Dab, *Limanda limanda*

Two habitat models were applied to the data available for dab: a general habitat model describing the distribution of the species habitats (M1, based on BTS dataset) and a model predicting the distribution of potential nursery habitats based on presence-absence data on juveniles (from BTS dataset) (Table 11).

Tidal currents energy on the seabed (TidE) and the dominant stratification and mixing of water masses (DomMix) proved to be important variables affecting the species distribution at both juvenile and adult stages. In particular, these were the only two environmental predictors selected by the model specifically addressing nursery habitat. In turn, the general distribution of the species was influenced also by other relevant factors characterising the seabed, such as sand coverage (S-mS), depth, coarse sediment coverage (Cs) and wave energy (WavE).

Table 11: Environmental conditions for the occurrence of dab EFH. Relevant important variables are indicated in columns from left to right in order of decreasing importance, as identified by the models. Shaded cells in the table identify the combination of environmental conditions leading to predictions of EFH with higher confidence.

Adult foraging habitat

Model prediction (life stage occurrence)	Sand to muddy sand relative coverage (S-mS)	Tidal energy (TidE, N m^{-2})	Depth (m)	Coarse sediment relative coverage (Cs)	Type of mixing of the water column (DomMix)	Wave energy (WavE, N m^{-2})
Adults	<0.001	<618.90	≥25.5	≥0.19 and <0.68	-	-
	≥0.001	≥184.19 and <224.12	-	-	ROFI (well mixed and weakly stratified) and weakly stratified shelf water	-
	<0.001	<350.99	≥25.5	<0.19	-	-
	≥0.001	≥262.19	-	-	-	-
	≥0.001	<262.19	-	<0.012	well-mixed shelf water	-
	≥0.001	≥224.12 and <262.19	-	-	ROFI (well mixed and weakly stratified) and weakly stratified shelf water	≥1879.89
	≥0.001	≥224.12 and <262.19	≥25.5	-	ROFI (well mixed and weakly stratified) and weakly stratified shelf water	<1879.89
	<0.001	≥534.34 and <618.90	≥25.5	<0.19	-	-
Adults and Juveniles	≥0.001	≥224.12 and <262.19	<25.5	-	ROFI (well mixed and weakly stratified) and weakly stratified shelf water	<1879.89
	≥0.001	<184.19	-	-	ROFI (well mixed and weakly stratified) and weakly stratified shelf water	-

Nursery habitat

Model prediction (juveniles probability of occurrence)	Tidal energy (TidE, N m^{-2})	Type of mixing of the water column (DomMix)
0.92	<184.19	ROFI (well mixed and weakly stratified)

3.4.1 Adult foraging habitat

This habitat is identified by the occurrence of adults (alone or together with juveniles), as predicted by the species model (M1; Table 11, Figure 10).

Adult foraging habitats are predicted with higher confidence on substrata characterised by coarser sediments (Cs between 19 and 68%) and almost absent sand coverage (<0.01%) in areas deeper than 25.5m and subject to moderate-low tidal energy (TidE <619 N/m^2). Adult foraging habitat is not restricted to these conditions, as it can also be found in areas where variable sand coverage (≥0.01%) and mixing/stratification conditions (with the exception of well mixed shelf waters) are associated with moderate-low or moderate tidal energy, with TidE values <184 N/m^2, or between 184 and 224 N/m^2 or 224 and 262 N/m^2, respectively. These latter conditions are usually associated with seabed shallower than 25.2m and where variable wave energy is present (WavE <1880 N/m^2).

The conditions suitable for the presence of dab adult foraging habitat occur mostly at the two sides of the study area, in front of the Devon coast, both inshore and offshore, and in inshore areas along the coast of west Kent (Figure 10).

There is a lower probability of finding the species in areas with almost absent sand coverage (<0.01%) where stronger tidal currents affect the seabed (TidE ≥619 N/m^2), or in deeper areas (≥25.5m), where tidal energy is lower (but still moderate), and coarse sediment coverage is variable (<19% or ≥68%). As a result, most of the marine area (inshore and particularly offshore) comprised between east Dorset and Hampshire is considered less suitable for the occurrence of dab.

Figure 10: Dab, M1 - predicted habitats distribution and associated relative spatial confidence.

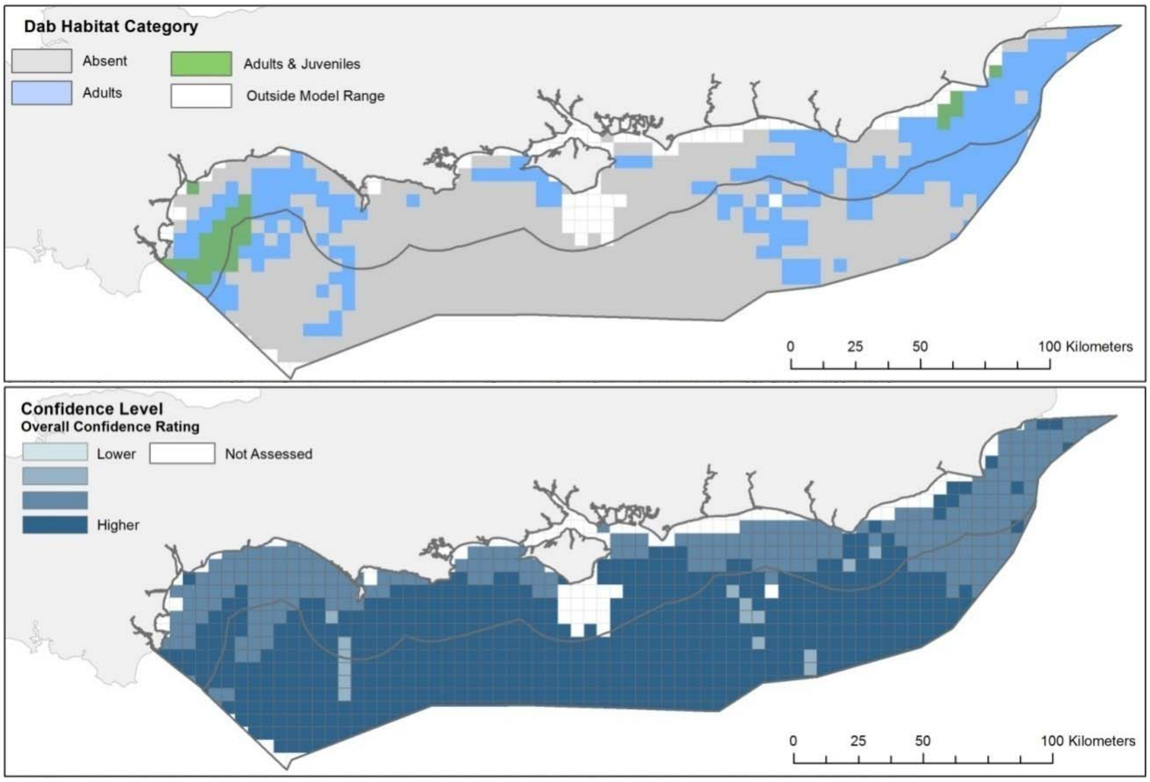


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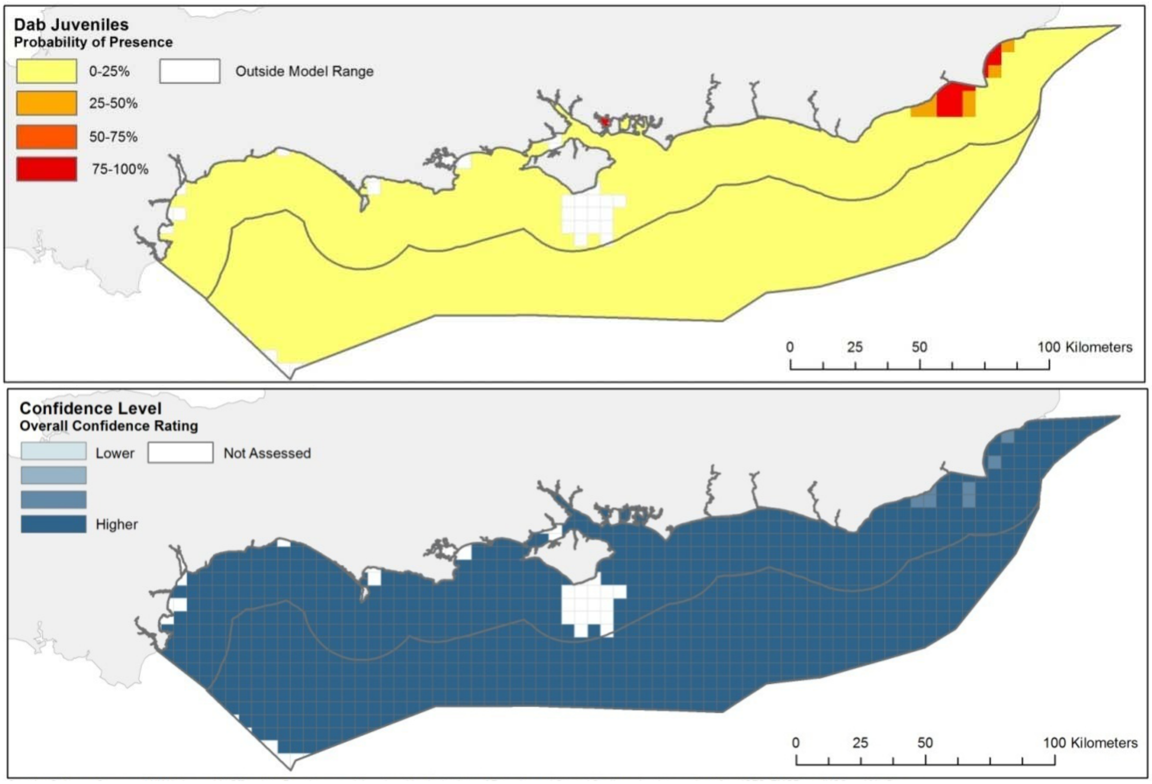
Figure 11: Dab, M2 - predicted nursery habitat distribution and associated relative spatial confidence.



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3.4.2 Nursery habitat

This habitat is identified in detail by the nursery habitat model (M2) as those areas with higher (>90%) probability of occurrence of dab at juvenile stage (Table 11, Figure 11).

Dab potential nursery habitats are more likely to occur in coastal areas where there is an influence of freshwaters (ROFI areas with variable stratification) and the tidal energy affecting the seabed is low (TidE <184 N/m^2). As a result, habitats potentially suitable as nursery for the species show a more restricted distribution in the study area, being located inshore, along the coast of west Kent and in the Portsmouth area (Fareham lake) (Figure 11).

3.5 Red gurnard, *Chelidonichthys cuculus*

Two habitat models were applied to the data available for red gurnard: a general habitat model describing the distribution of the species habitats (M1, based on BTS dataset) and a model predicting the distribution of potential nursery habitats based on presence-absence data on juveniles (from BTS dataset) (Table 12).

Depth and tidal current energy on the seabed (TidE) proved to be important variables affecting the species distribution at both juvenile and adult stages. Also the coverage of mixed sediment on the seabed (Mx) was a relevant predictor for the general distribution of the species, and, for juvenile stages in particular, additional factors were sand coverage (S-mS) and wave energy on the bottom (WavE).

Table 12: **Environmental conditions for the occurrence of red gurnard EFH. Relevant important variables are indicated in columns from left to right in order of decreasing importance, as identified by the models. Shaded cells in the table identify the combination of environmental conditions leading to predictions of EFH with higher confidence.**

Adult foraging habitat

Model prediction (life stage occurrence)	Depth (m)	Tidal energy (TidE, $N\ m^{-2}$)	Mixed sediment relative coverage (Mx)
Adults	≥24.5	≥1089.85	-
Adults and Juveniles	≥32.5	<606.30	≥0.92
	≥24.5	≥606.30 and <1089.85	-
	≥42.5	<606.30	<0.92

Nursery habitat

Model prediction (juveniles probability of occurrence)	Depth (m)	Tidal energy (TidE, $N\ m^{-2}$)	Wave energy (WavE, $N\ m^{-2}$)	Sand to muddy sand relative coverage (S-mS)
0.75	≥32.5	<1092.91	-	<0.79
0.67	≥25.5 and <32.5	≥365.11	<508.78	-

3.5.1 Adult foraging habitat

This habitat is identified by the occurrence of adults (alone or together with juveniles), as predicted by the species model (M1; Table 12, Figure 12).

Adult foraging habitats are predicted with higher confidence in relatively deep areas (always ≥24.5m), with a moderate-low tidal energy (<606 N/m^2) on mixed substrata (Mx ≥92%), or in areas with higher tidal energy (TidE between 606 and 1090 N/m^2).

The conditions suitable for the presence of red gurnard adult foraging habitat occur mostly in the offshore areas between Portland and the Isle of Wight and in front of the West Sussex coast, as well as in the North-East corner of the study area (Figure 12).

Figure 12: Red gurnard, M1 - predicted habitats distribution and associated relative spatial confidence.

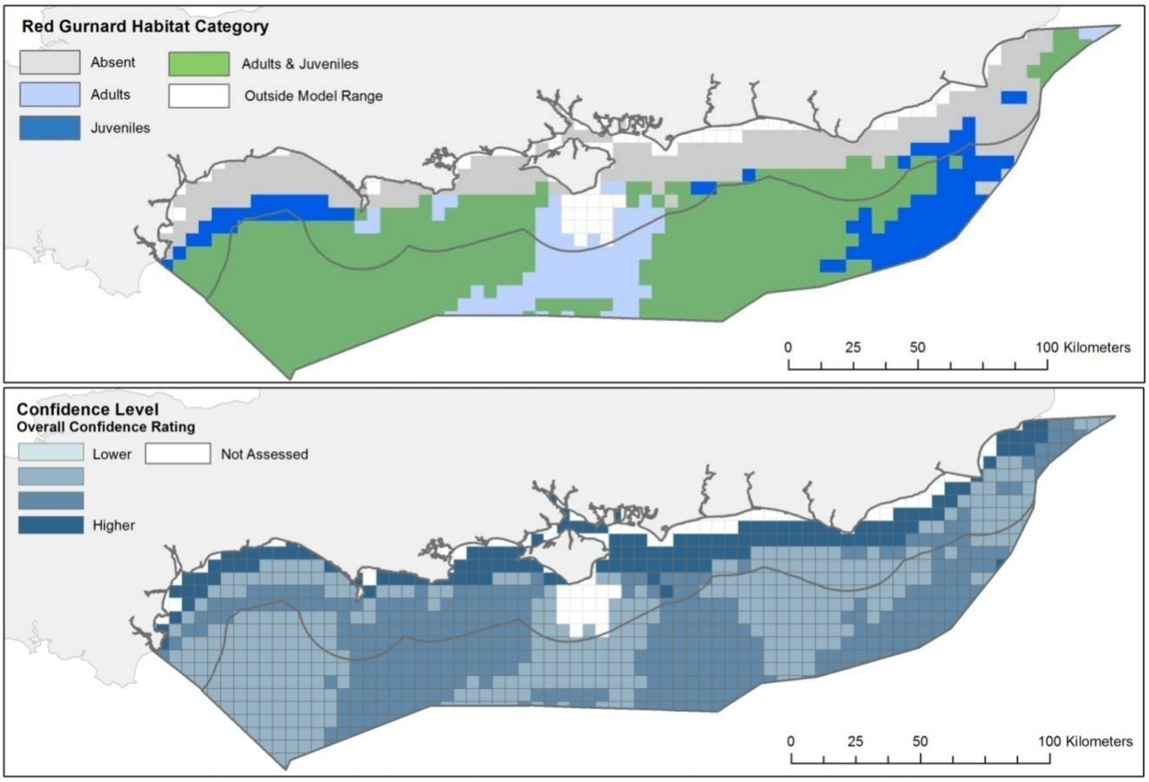
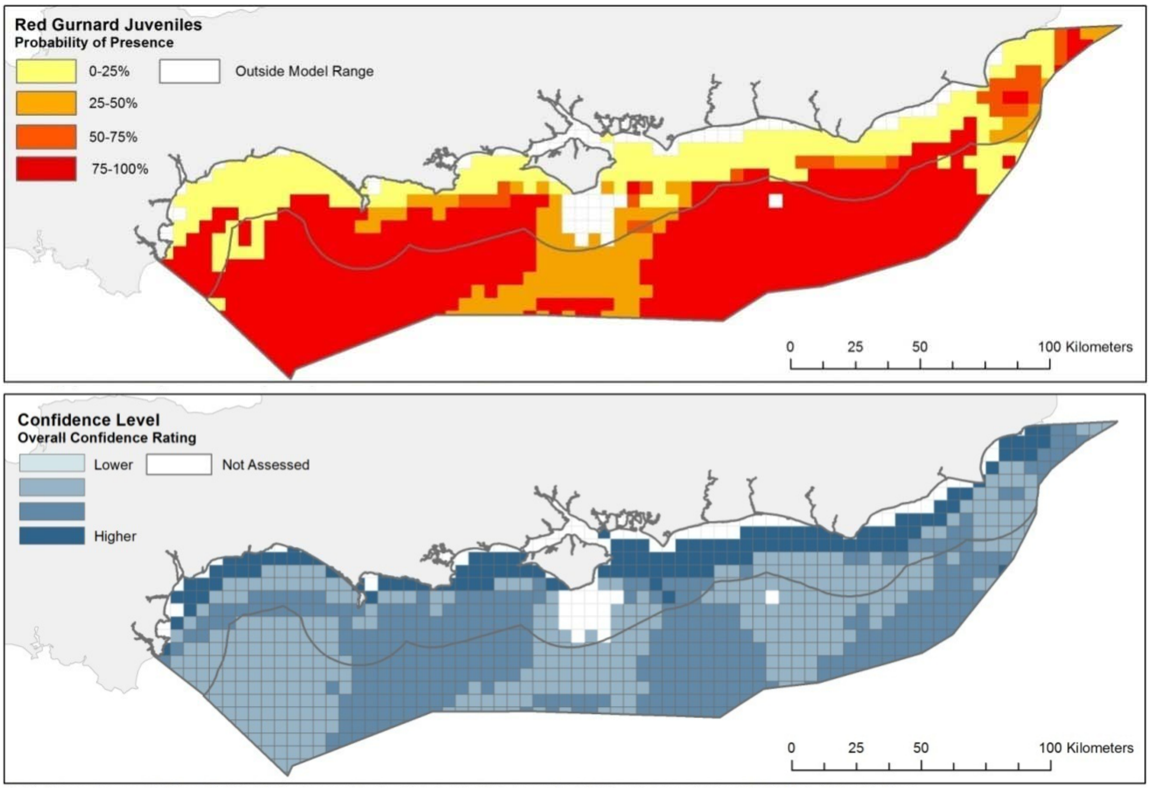


Figure 13: Red gurnard, M2 - predicted nursery habitat distribution and associated relative spatial confidence.



The model indicated a lower probability of finding the species in shallower conditions (at depth <24.5m), these identifying most of the inshore areas along the study area.

3.5.2 Nursery habitat

This habitat is identified in detail by the nursery habitat model (M2) as those areas with higher (>65%) probability of occurrence of red gurnard at juvenile stage (Table 12, Figure 13).

Like for adult habitat, also red gurnard potential nursery habitats are more likely to occur in relatively deeper areas (always ≥25.5m), with substrata being characterised by variable tidal energy (but never higher than 1093 N/m^2) and sand coverage <79% where depth is ≥32.5m, or by moderate-low wave energy (<509 N/m^2) and tidal energy higher than 365 N/m^2 at shallower depth (between 25.5 and 32.5m).

This habitat mostly located offshore, East and West of the Isle of Wight, although some are predicted to occur in inshore areas (but not too shallow waters), particularly in front of the Dorset coast (Figure 13).

3.6 Common dragonet, *Callionymus lyra*

Two habitat models were applied to the data available for common dragonet: a general habitat model describing the distribution of the species habitats (M1, based on BTS dataset) and a model predicting the distribution of potential nursery habitats based on presence-absence data on juveniles (from BTS dataset) (Table 13).

The coverage of mixed sediment on the seabed (Mx) and depth were the only environmental variables selected as predictors of the distribution of the habitats for dragonet in the study area. The same model applied to both the adult foraging habitats and juvenile distribution.

Table 13: **Environmental conditions for the occurrence of common dragonet EFH. Relevant important variables are indicated in columns from left to right in order of decreasing importance, as identified by the models. Shaded cells in the table identify the combination of environmental conditions leading to predictions of EFH with higher confidence.**

Adult foraging habitat

Model prediction (life stage occurrence)	Mixed sediment relative coverage (Mx)	Depth (m)
Adults	<0.26	-
	≥0.26	≥27.5
Adults and Juveniles	≥0.26	<27.5

Nursery habitat

Model prediction (juveniles probability of occurrence)	Mixed sediment relative coverage (Mx)	Depth (m)
0.73	≥0.26	<27.5

3.6.1 Adult foraging habitat

This habitat is identified by the occurrence of adults (alone or together with juveniles), as predicted by the species model (M1;Table 13, Figure 14).

Adult foraging habitats for the species are predicted with higher confidence on substrata with low coverage of mixed sediments (Mx <26%) at any depth, or, where mixed sediments are more abundant, at depth <27.5m.

The above conditions are found in most of the study area (with some exceptions associated to limitations in the calibration dataset; see section on issues and gaps) (Figure 14). This is probably due to the high frequency of occurrence of the species (considering the different life stages altogether) in the catch data used to calibrate the model (with only 6% of the data not having common dragonet in the catch), leading to a likely wider distribution of the predicted habitat.

Figure 14: Common dragonet, M1 - predicted habitats distribution and associated relative spatial confidence.

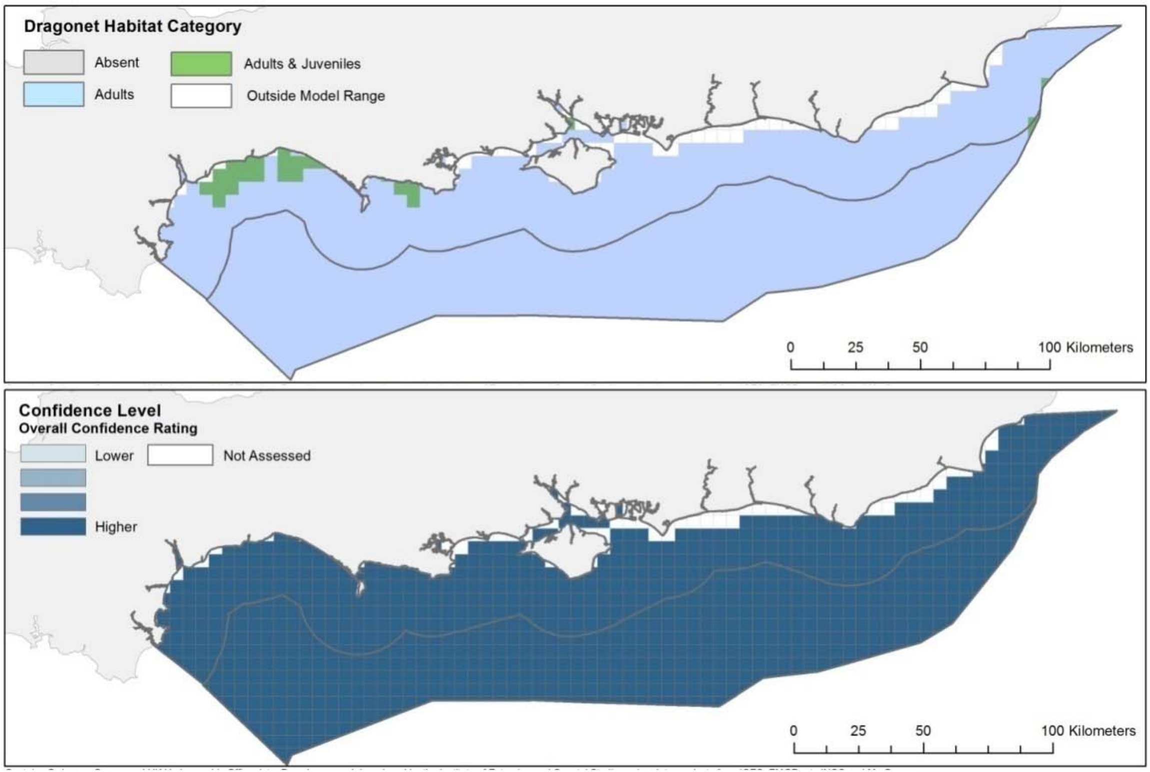


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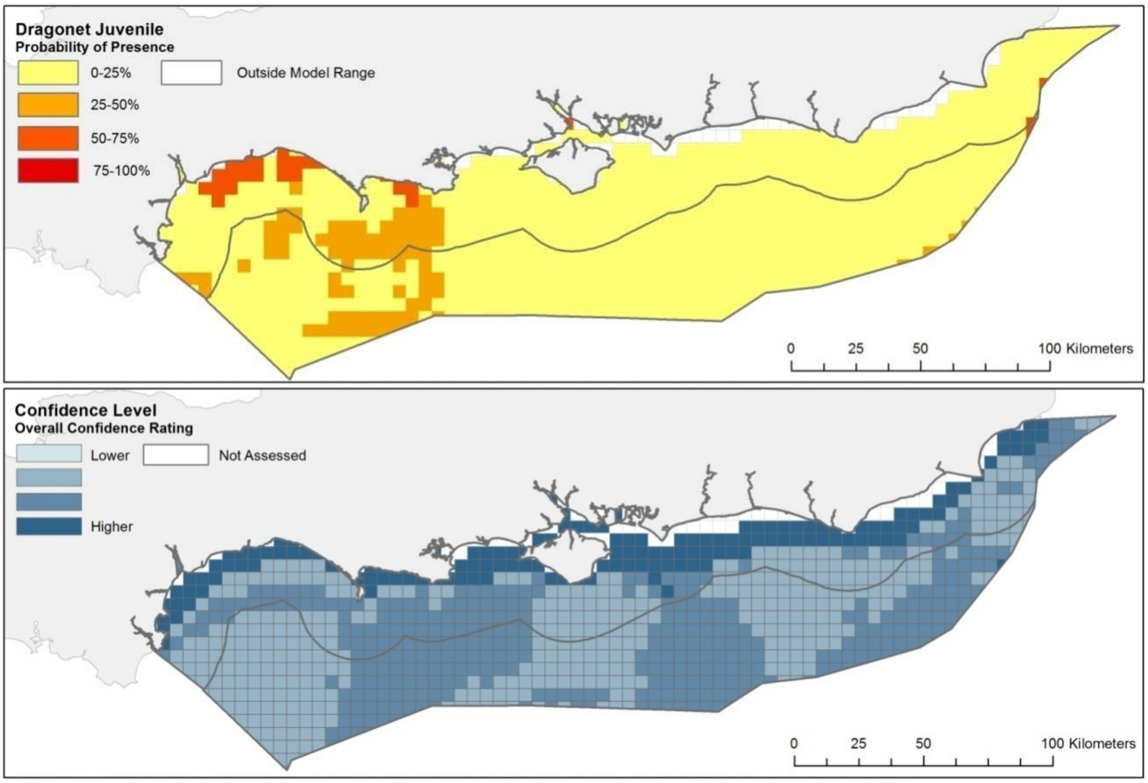
Figure 15: Common dragonet, M2 - predicted nursery habitat distribution and associated relative spatial confidence.



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3.6.2 Nursery habitat

This habitat is identified in detail by the nursery habitat model (M2) as those areas with higher (>70%) probability of occurrence of common dragonet at juvenile stage (Table 13, Figure 15).

Common dragonet potential nursery habitats show a more restricted distribution in the study area, compared to adult habitat, being more likely to occur in shallower substrata (< 27.5m deep) with mixed sediment coverage (≥26%).

These conditions mostly occur in sparse shallower inshore areas located along the Devon and Dorset coast (between Exmouth and Weymouth and East of Portland) and in front of Southampton. Small areas potentially suitable as nursery habitats are located also along the margin of the inshore area in front of the Kent coast (Figure 15).

3.7 Solenette, *Buglossidium luteum*

Two habitat models were applied to the data available for solenette: a general habitat model describing the distribution of the species habitats (M1, based on BTS dataset) and a model predicting the distribution of potential nursery habitats based on presence-absence data on juveniles (from BTS dataset) (Table 14).

Tidal currents energy (TidE) and wave energy (WavE) on the seabed were identified as the most important variables affecting the species distribution at both juvenile and adult stages, with also coarse sediment coverage (Cs) being relevant to the distribution of young solenette.

Table 14: **Environmental conditions for the occurrence of solenette EFH. Relevant important variables are indicated in columns from left to right in order of decreasing importance, as identified by the models. Shaded cells in the table identify the combination of environmental conditions leading to predictions of EFH with higher confidence.**

Adult foraging habitat

Model prediction (life stage occurrence)	Tidal energy (TidE, N m^{-2})	Wave energy (WavE, N m^{-2})
Adults	≥191.17 and <407.30	≥177.74
Adults and Juveniles	<191.17	-

Nursery habitat

Model prediction (juveniles probability of occurrence)	Tidal energy (TidE, N m^{-2})	Wave energy (WavE, N m^{-2})	Coarse sediment relative coverage (Cs)
1.00	≥122.90 and <270.70	≥2211.79	-
0.90	<122.90	≥419.31	-
0.83	≥122.90 and <270.70	≥419.31 and <1021.26	<0.45

3.7.1 Adult foraging habitat

This habitat is identified by the occurrence of adults (alone or together with juveniles), as predicted by the species model (M1; Table 14, Figure 16).

Adult foraging habitats for the species are predicted with higher confidence where tidal current energy is moderate-low (<191 N/m^2) or moderate (between 191 and 407 N/m^2), with also moderate to high wave energy levels (>178 N/m^2) associated with this latter condition. These conditions are mostly found in shallower inshore areas along the South Coast, although they might extend also to offshore areas in front of the Devon and East Sussex coasts (Figure 16).

There is a lower probability of finding the species in areas with stronger tidal currents at the seabed (TidE ≥407 N/m^2), these conditions occurring in most of the offshore areas but also inshore, between Dorset and West Sussex and along the Kent coast.

Figure 16: Solenette M1 - predicted habitats distribution and associated relative spatial confidence.

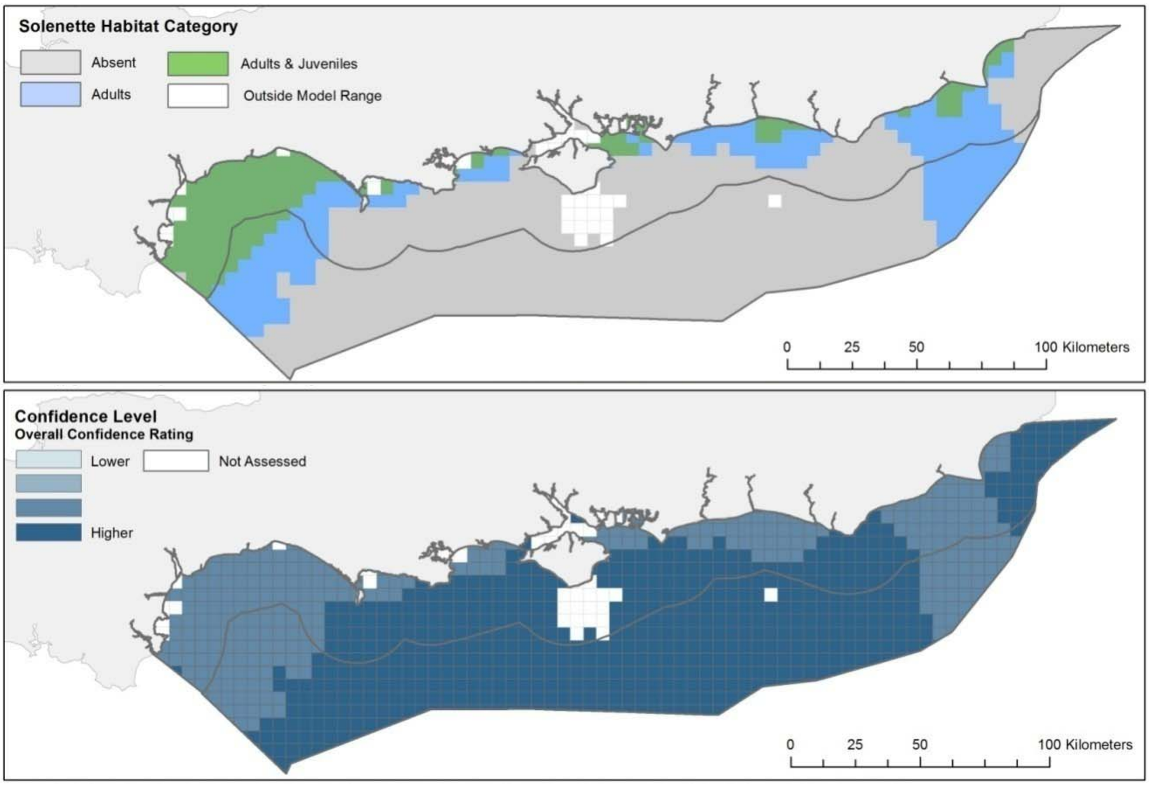
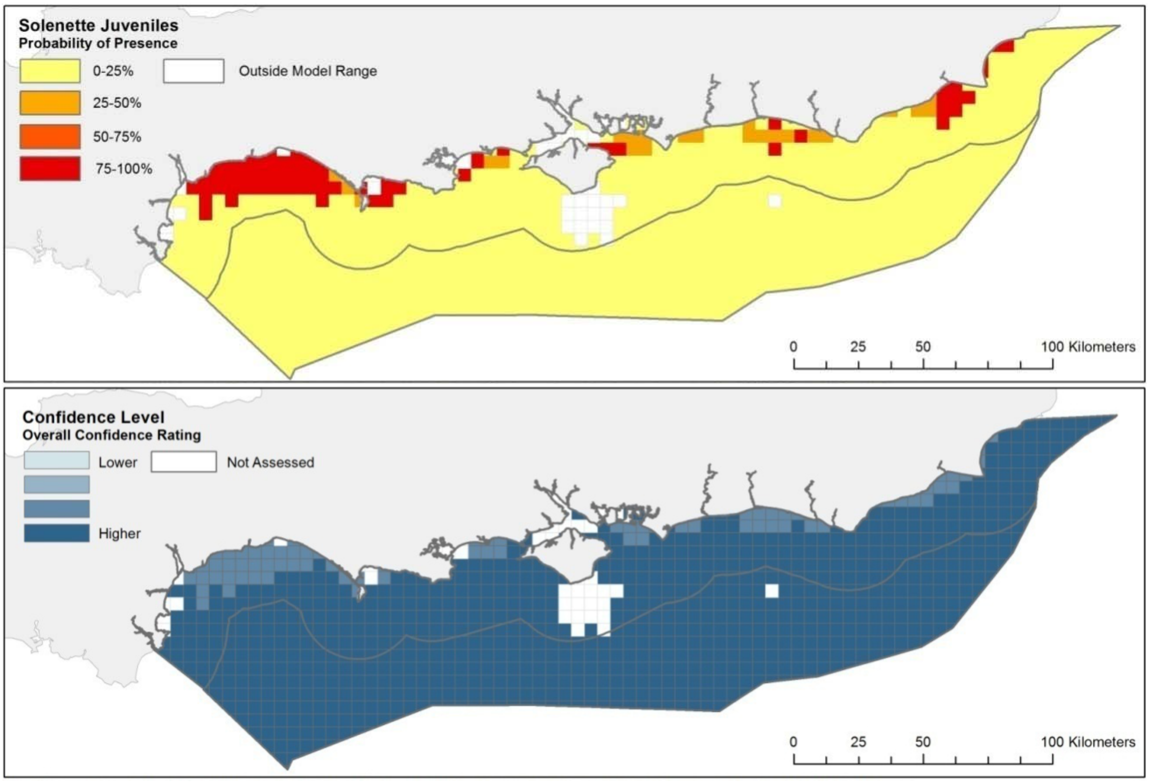


Figure 17: Solenette, M2 - predicted nursery habitat distribution and associated relative spatial confidence.



3.7.2 Nursery habitat

This habitat is identified in detail by the nursery habitat model (M2) as those areas with higher (>80%) probability of occurrence of solenette at juvenile stage (Table 14, Figure 17).

Although the highest probability of finding juveniles solenette is associated with moderate tidal energy (between 123 and 271 N/m^2) and high wave energy (≥2212 N/m^2) at the seabed, a lower confidence is attached to this habitat prediction. In turn, solenette potential nursery habitats are identified with higher confidence in areas where tidal currents are of low (<123 N/m^2) or moderate (123 to 271 N/m^2) energy, but with wave energy always ≥419 N/m^2 (moderate and high), and, where this energy remains within moderate levels (<1021 N/m^2), with coarse sediment coverage on the substratum being lower than 45%.

Based on the conditions described above, nursery habitats for solenette are located mostly in shallower inshore areas, particularly along the Dorset coast (around Portland), in the area between the Isle of Wight and Portsmouth, along the coast in front of Brighton and of the west coast of Kent (Figure 17).

3.8 Thickback sole, *Microchirus variegatus*

All individuals present in the catches from the analysed dataset (BTS dataset) had a body length between 3 and 20cm, which characterises them as juveniles (but see considerations on confidence in Table 4). Therefore, the specific model predicting the distribution of potential nursery habitats based on presence-absence data on juveniles could only be applied to these data (Table 15).

The coverage of mixed sediment on the seabed (Mx) was the most important environmental predictor of the distribution of the nursery habitat of this species in the study area, followed by tidal currents energy (TidE) and wave energy (WavE) on the seabed, depth and coarse sediment coverage (Cs).

Table 15: **Environmental conditions for the occurrence of thickback sole EFH. Relevant important variables are indicated in columns from left to right in order of decreasing importance, as identified by the model. Shaded cells in the table identify the combination of environmental conditions leading to predictions of EFH with higher confidence.**

Nursery habitat

Model prediction (juveniles probability of occurrence)	Mixed sediment relative coverage (Mx)	Type of mixing of the water column (DomMix)	Depth (m)	Wave energy (WavE, N m^{-2})	Tidal energy (TidE, N m^{-2})	Coarse sediment relative coverage (Cs)
0.91	<0.22	weakly stratified ROFI and shelf water	-	<358.75	-	-
0.89	≥0.92	-	-	-	-	-
0.89	≥0.22 and <0.92	-	≥31.5	≥453.46	<493.97	-
0.84	≥0.22 and <0.92	-	-	<453.46	<575.03	-
0.79	<0.22	well-mixed ROFI and shelf water	≥21.5	-	<620.96	≥0.75
0.68	≥0.22 and <0.92	-	-	≥453.46	≥493.97 and <575.03	-
0.67	<0.22	well-mixed ROFI and shelf water	≥51.5	-	<724.50	<0.75

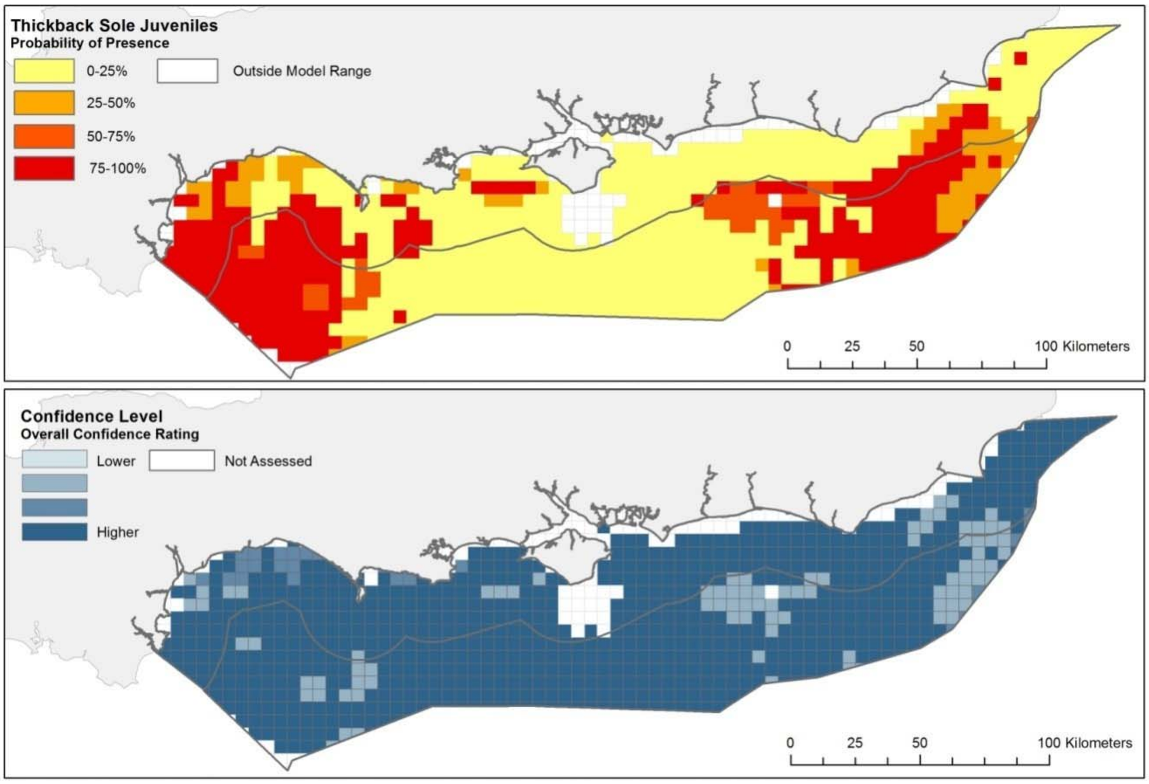
3.8.1 Nursery habitat

This habitat is identified in detail by the nursery habitat model (M2) as those areas with higher (>65%) probability of occurrence of thickback sole at juvenile stage (Table 15, Figure 18).

Potential nursery grounds for the species are predicted with higher confidence on substrata where coverage of mixed sediment is lower than 22%, either in areas where there is weak stratification of the water column (both in ROFI and shelf water conditions) and low-moderate wave energy on the bottom (<359 N/m^2), or in areas of well mixing conditions, at depth ≥21.5m, with dominant coarse sediments (Cs≥75%) and moderate-low tidal current energy at the seabed (<621 N/m^2). Environmental conditions characterising potential nursery habitats of thickback sole are also associated with substrata where mixed sediments are dominant (Mx ≥ 92%) or with variable coverage (between 22 and 92%), and, in this latter case, affected by moderate-low energy, associated with both tidal currents (<453 N/m^2) and waves (<575 N/m^2).

Based on the combination of these environmental characteristics, nursery areas for young thickback sole are located mostly (but not exclusively) offshore, on the east and west side of the study area, along the coasts between west Sussex and Kent, and Devon to west Dorset, respectively (Figure 18).

Figure 18: Thickback sole, M2 - predicted nursery habitat distribution and associated relative spatial confidence.



3.9 Thornback ray, *Raja clavata*

The model on the overall habitat distribution for thornback ray could not be calibrated (no relevant environmental variables were selected). This is probably due to the combination of a general low frequency of occurrence of the species in the catches (321 out of 852 records, i.e. 38% of the cases, considering all life stages together) and the variability in the distribution of the species in the catches over the spatial-temporal scale of the dataset. Only the specific model predicting the distribution of potential nursery habitats could be applied based on presence-absence data on juveniles (Table 16).

The coverage of mixed sediment on the seabed (Mx) was the most important environmental predictor of the distribution of the nursery habitat of this species in the study area, followed by tidal currents energy (TidE) and wave energy (WavE) at the seabed, depth and coarse sediment coverage (Cs).

Table 16: **Environmental conditions for the occurrence of thornback ray EFH. Relevant important variables are indicated in columns from left to right in order of decreasing importance, as identified by the model. Shaded cells in the table identify the combination of environmental conditions leading to predictions of EFH with higher confidence.**

Nursery habitat

Model prediction (juveniles probability of occurrence)	Tidal energy (TidE, N m^{-2})	Depth (m)	Sand to muddy sand relative coverage (S-mS)	Sea surface temperature (SST (summer), °C)
0.58	<271.42	<23.5	≥0.04	<16.09

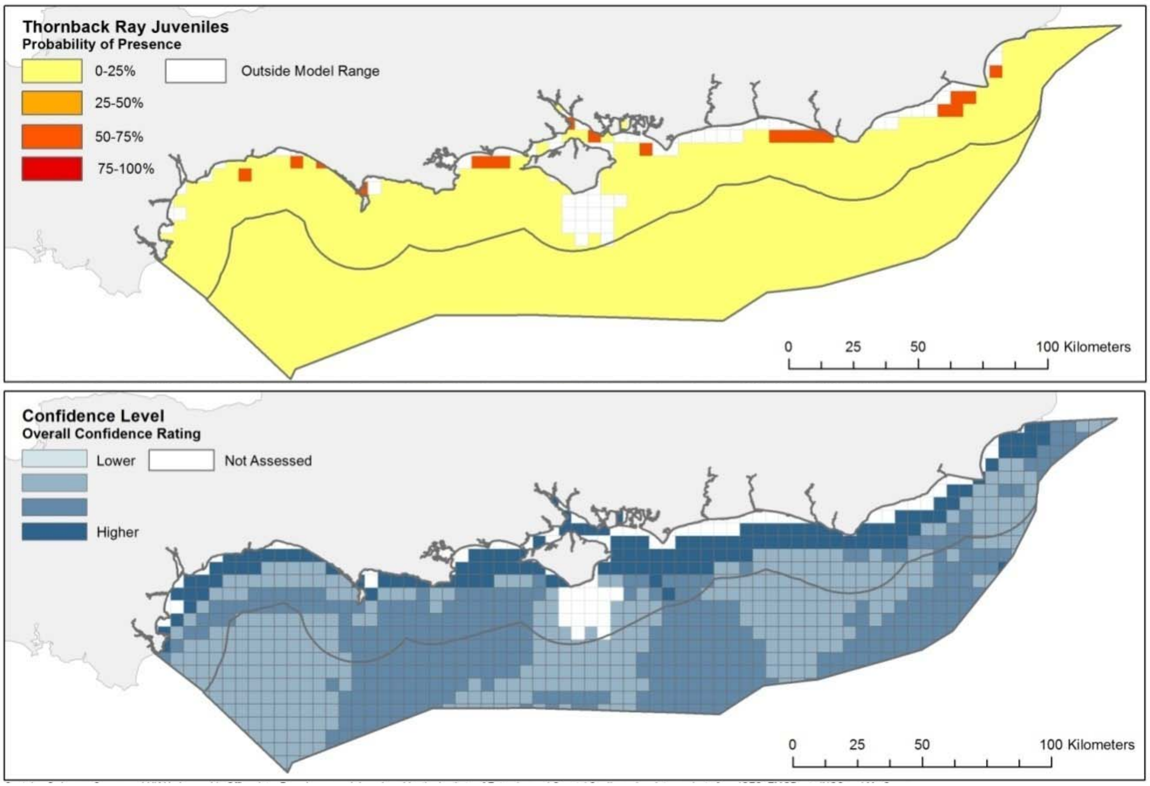
3.9.1 Nursery habitat

This habitat is identified in detail by the nursery habitat model (M2) as those areas with higher (>55%) probability of occurrence of thornback ray at juvenile stage (Table 16, Figure 19).

Potential nursery grounds for the species are more likely to occur in relatively shallow areas (<23.5m deep), with moderate-low tidal energy on the seabed (<271 N/m^2) and presence of some sand coverage (≥4%). Also the presence of mean summer water temperature (at the sea surface) with values lower than 16.1°C was a condition for the occurrence of young thornback ray, possibly indicating that this stage is unlikely to occur in too shallow areas, where warmer waters are found in summer.

Based on the above environmental conditions, the predicted nursery habitat of thornback ray occurs only sparsely in the study area, in relatively shallow inshore waters along the coast between Dorset and Hampshire and between east Sussex and west Kent. It is of note that the predicted extent of this habitat in very inshore areas is likely to be underestimated, due to limitations in the spatial distribution of the data obtained from beam trawl surveys and used to build the model.

Figure 19: Thornback ray, M2 - predicted nursery habitat distribution and associated relative spatial confidence.



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3.10 Herring, *Clupea harengus*

A model predicting the distribution of potential spawning habitats was applied to the data available for herring based on presence-absence of early larval stage from ichthyoplankton survey catches obtained during the winter season (IHLS dataset) (Table 17).

Wave energy (WavE) on the seabed and depth were selected as relevant predictors of the probability of occurrence of this life stage in the study area. It is of note that, besides the inclusion of variables characterising the water column and sediment characteristics in the initial (full) model, these were not identified as relevant in affecting the distribution of this pelagic life stage.

Table 17: **Environmental conditions for the occurrence of herring EFH. Relevant important variables are indicated in columns from left to right in order of decreasing importance, as identified by the model. Shaded cells in the table identify the combination of environmental conditions leading to predictions of EFH with higher confidence.**

Spawning habitat

Model prediction (larvae probability of occurrence)	Wave energy (WavE, N m^{-2})	Depth (m)
0.85	≥392.63	-
0.70	≥125.98 and <392.63	≥35.5

3.10.1 Spawning habitat

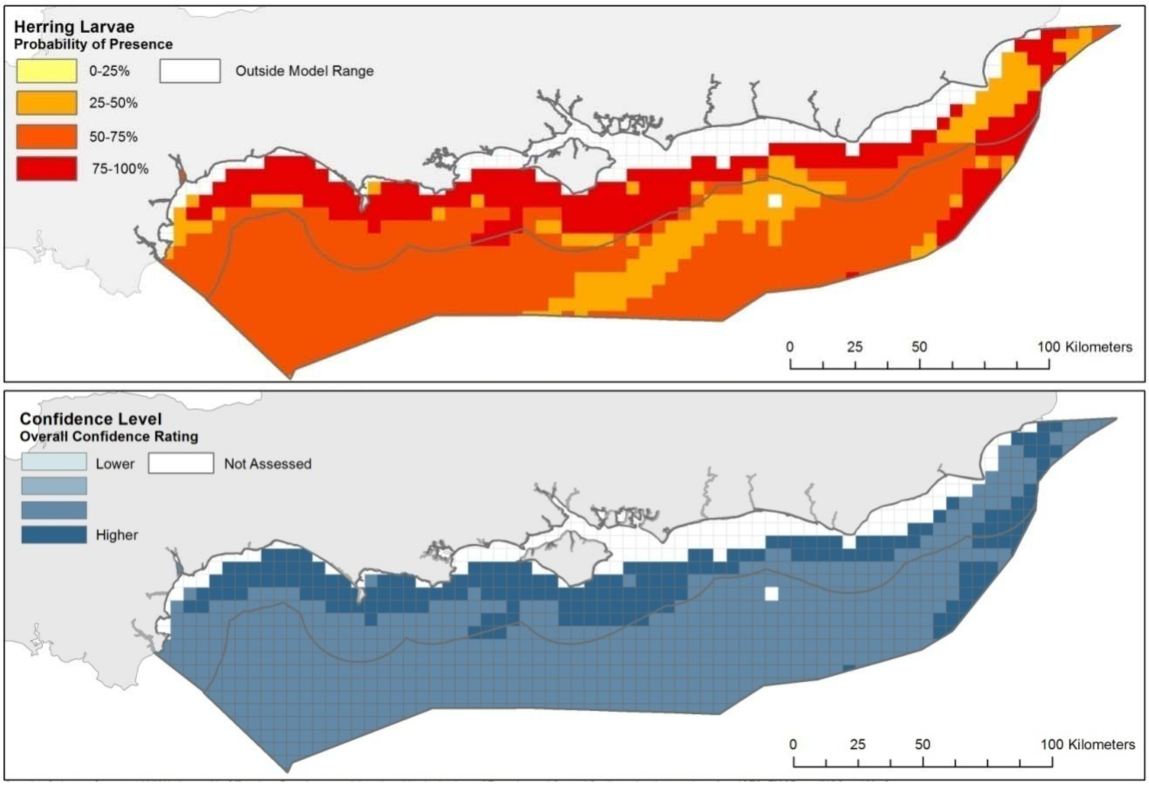
This habitat is identified in detail by the spawning habitat model (M2) as those areas with higher (>70%) probability of occurrence of herring at larval stage (Table 17, Figure 20). .

The occurrence of herring larvae (hence of potential spawning habitats) is predicted with higher probability of presence (0.85) and confidence in areas characterised solely by moderate wave energy on the seabed (≥393 N/m^2).

The resulting distribution of potential spawning grounds for the species covers most of the study area, with wider extent particularly in inshore areas along the whole South Coast, although suitable conditions for spawning habitats have been identified also in offshore areas in front of the coast of East Sussex and Kent (Figure 20). It is of note that the predicted extent of herring spawning habitat in inshore areas is likely to be underestimated, due to limitations in the spatial distribution of the data obtained from herring larval surveys (obtained mostly from offshore stations) and used to build the model.

Although the wide distribution of potential spawning grounds predicted by the model broadly agrees with the location of spawning areas reported for the species in previous studies (Coull *et al*., 1998; Dickey-Collas *et al*., 2010; Ellis *et al*., 2012), the higher probability of presence predicted in inshore areas is unexpected. In addition, surprisingly, sediment characteristics were not identified as relevant predictors of this habitat. The presence of coarse substrata (gravel or similar habitats), associated with a low proportion of fine sediment and well-oxygenated water, in fact, is considered an important characteristic of herring spawning grounds (Maravelias *et al*., 2000). These substrata occur mostly offshore, in deeper areas (where wave energy on the seabed is generally low) to the South of the study area, where also higher concentrations of herring larvae are found (Ellis *et al*., 2012). This might highlight a lower suitability of presence-absence data for herring larvae as an indicator of spawning habitats, suggesting the possible higher relevance of quantitative (abundance) data to be used for this purpose. It is of note that this limitation is likely to be particularly relevant to the planning and management of activities in the study area, as described in Section 4.

Figure 20: Herring, M2 - predicted spawning habitat distribution and associated relative spatial confidence.



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4. Value of Essential Fish Habitats

Allocating a relative value to areas in the marine environment is of particular relevance to marine planning. Identifying the location of most valuable marine areas allows management of the marine space to be prioritised, thus facilitating provision of a greater-than-usual degree of risk aversion in management of activities in such areas. This approach is also known as hotspot approach (e.g., Myers *et al*., 2000; Derous *et al*., 2007).

The ecological value of EFH is evident in that these habitats provide suitable conditions where critical life stages can survive (eggs and larvae in spawning habitats and juveniles in nursery habitats) or where adults can find available food for their growth (adult foraging grounds). In doing so, these aquatic habitats contribute to the growth and viability of fish populations hence providing support to the functioning of the ecosystem also via the links to other ecosystem components through the marine food webs. The socio-economic value of EFH, in turn, can be related to the benefits that are gained by the human society from the use of the resources (goods) that these habitats provide or from the services that they provide to the ecosystem for its functioning. These goods and services are associated not only to the fish component characterising EFH (for example, fishery and larval supply, respectively), but also to the other components (abiotic and biotic) of the habitat (for example, clean water/sediments and primary production, respectively).

Both the ecological and socio-economic values were taken into account to allocate a non monetary value to the EFH. Detailed methods and results (including gaps and limitations) are presented in a separate Annex ("Assessing the Value of EFH"), and the main results are summarised here to allow spatial identification of the most valuable EFH areas within the study area. Environmental economic methods were also identified that will allow assigning a monetary value to these areas and data requirements for their application to the EFH were outlined. These are reported in the Annex "Assessing the Value of EFH".

4.1 Ecological value

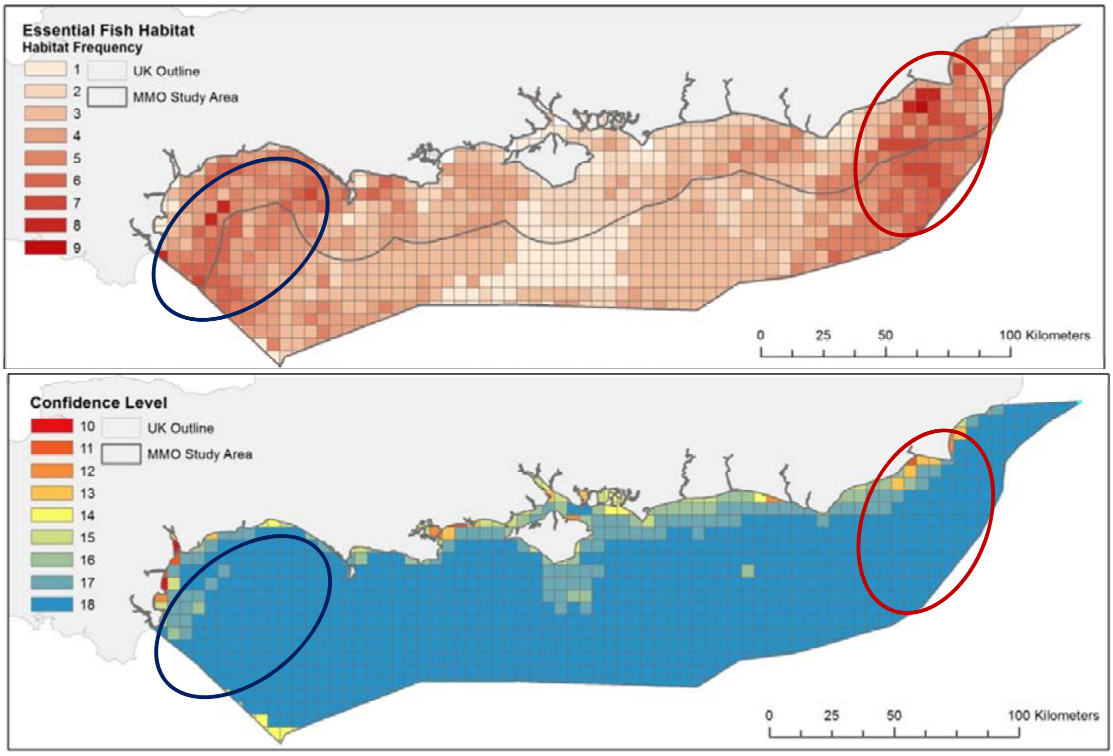
For highly mobile species, like fish, the localisation of critical areas for a species' foraging, nursing or spawning (i.e., EFH) is considered important for the purpose of ecological valuation. In addition, a holistic approach (considering different components of a system) is called for ecosystem management as opposed to the reductionist view of single-species management (Simberloff, 1998). The occurrence and importance of different EFH in a marine area can therefore be used as a criterion to quantify the ecological value of that area.

The 18 EFH spatial outputs (including associated confidence maps) obtained in the project were taken into account for this assessment. The most important marine areas acting as EFH for each species were identified as the EFH predicted with higher confidence level (EFH hotspots). These were combined to assess the overall relative ecological value of marine zones within the study area by estimating the frequency of presence of the EFH hotspots. This frequency was calculated considering the 18 EFH altogether to identify hotspots of overall ecological value, but also by distinguishing EFH by their function, in order to identify areas more valuable either as adult foraging grounds, nursery areas or spawning grounds.

A limitation in the estimates of ecological value was identified in that, in some areas, low 'values' could be determined by limitations in predictive models (i.e., absence of valid predictions) rather than by an actual absence of certain EFH. In order to account for these limitations, a measure of confidence was associated with the estimate of ecological value. For each EFH, the grid cells were identified where the problem described above occurred and marked as invalid. When combining the information across EFH, the frequency of valid cases was calculated as an estimate of the relative confidence associated with the estimate of ecological value in a grid cell.

The resulting hotspot map showing the overall relative ecological value of marine areas along the South Coast and the associated confidence level is shown in Figure 21 (maps of ecological value by EFH function are shown in the Assessing the Value of EFH Annex).

Figure 21: Overall ecological value of marine areas (Habitat frequency) and associated confidence (as frequency of occurrence of valid predictions obtained from the EFH models). Habitat frequency measures the occurrence of EFH hotspots in the study area when all the EFH modelled in the project are considered (adult foraging grounds (7 species), nursery habitats (9 species), spawning grounds (2 species)). Circles indicate the general location of the main hotspots of overall ecological value.



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Areas of higher ecological value (overall) are located in the eastern and western sides of the study area, in front of the coasts of Devon and of East Sussex and Kent, respectively. A higher confidence is associated particularly to the eastern hotspot areas, whereas part of the western hotspots, as well as some areas of lower ecological value (in front of the Isle of Wight and inshore areas), show a lower confidence in these estimates. This lower confidence is likely the result of gaps in the model predictions hence higher caution should be placed when considering the ecological value of these areas.

The hotspots of ecological value observed in front of the coasts of Devon are mostly ascribed to the higher frequency of adult foraging grounds (including most of the species except for red gurnard), and, in places, also to fish nursery hotspots (particularly for red gurnard, thickback sole, sole and plaice). Relatively valuable areas are identified also in the inshore waters around Portland, due to the frequency of adult foraging habitats (mostly for thickback sole and red gurnard) and to the presence of potential spawning grounds for herring.

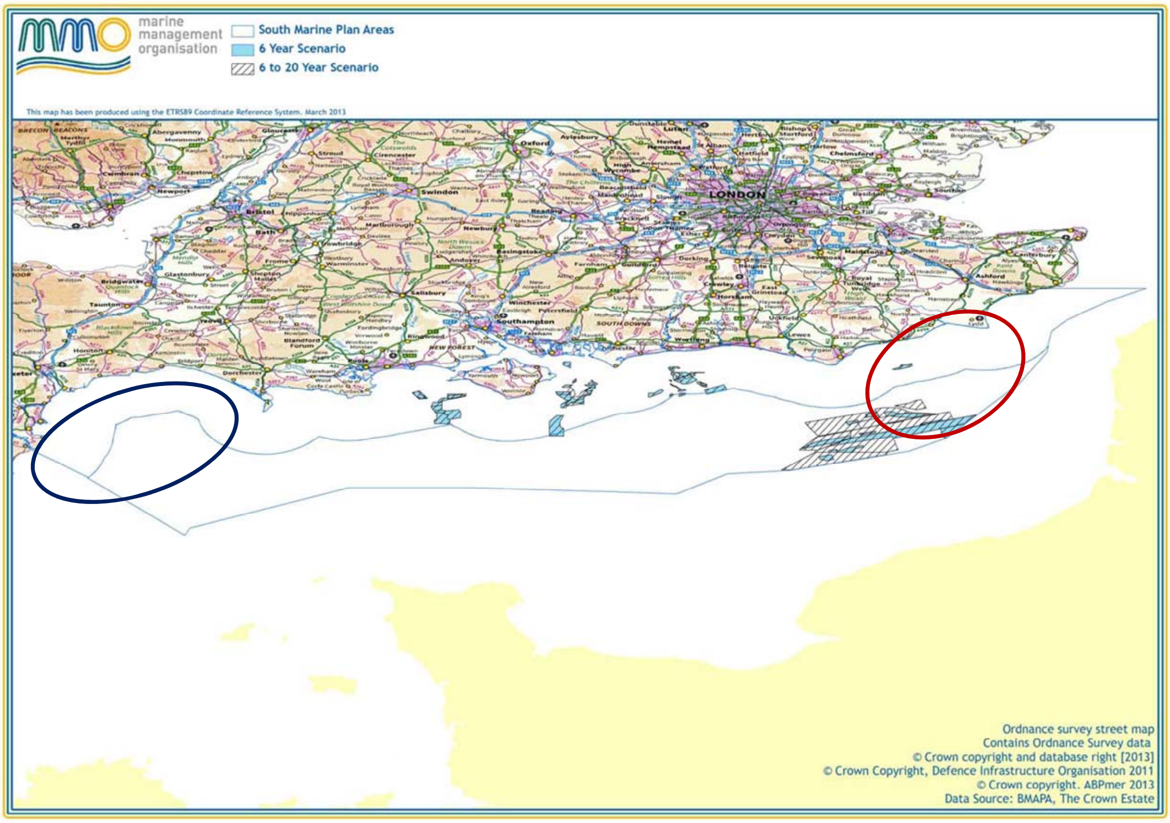
In the eastern side of the study area, hotspots of ecological value are observed inshore, although relatively valuable areas occur also offshore from Dungeness. The presence of adult foraging grounds for most of the species considered in the study (with the exception of red gurnard) highly contribute to the ecological value of both these areas, with also nursery grounds occurring frequently in places, particularly inshore (particularly for plaice, red gurnard, thickback sole and thornback ray). The presence of potential herring spawning grounds also contributes to the ecological value of the areas offshore.

These hotspot areas can be considered as warning systems for marine managers who are planning new activities at sea, and can help to indicate conflicts between human uses and an area's high 'value' during spatial planning. For example, the ecological hotspots located offshore from Dungeness are included in areas currently used for marine aggregate extraction or where these activities are likely to increase in the next future (MMO, 2013; Figure 22). In particular, the co-occurrence with herring spawning grounds constitutes an important management issue for the MMO, and it is often a condition on licences and an issue for integrating these activities with other industry sectors (e.g., fishery).

This specific issue is not restricted to the hotspot area above, but might occur also in the inshore areas around the Isle of Wight, where also a significant amount of future dredging activity (MMO, 2013) would co-exist with the presence of herring spawning grounds. The ability of identifying herring spawning habitats with high confidence is therefore important to inform marine planning in the South marine plan areas hence it is acknowledged the need of improving these EFH models by using larval abundance rather than presence-absence (see Section 3.10).

It is of note that the relative ecological value calculated here takes into account only the selection of species, mostly demersal fish, modelled in this study. Therefore, it is likely that the extent and ecological value of marine areas as EFH in the study area is underestimated.

Figure 22: Future trends for marine aggregate extraction in the South marine plan areas (source: MMO project 1039, MMO, 2013). Circles indicate the approximate location of the main hotspots of overall ecological value as identified in Figure 2.



4.2 Ecosystem services provision

Ecosystem services are defined by the Millennium Ecosystem Assessment as the outputs of ecosystems from which society derives benefits (MEA, 2005). A framework that classifies ecosystem services and interprets how they interact in the marine environment is provided by the UK National Ecosystem Assessment. This framework identifies ecosystem services as either supporting, regulating, provisioning or cultural, and shows how marine ecosystems comprise of a range of fundamental components (e.g. habitats, species, substratum) and processes (e.g. production, food web dynamics) which lead to the provision and delivery of intermediate supporting services (e.g. primary production, nutrient cycling) and regulatory services (e.g. biological control, carbon sequestration).

The intermediate services are processes, and do not have a direct influence on human welfare, however, they provide the basis for final ecosystem services which are the end result of this process, providing direct use and benefits to society such as resources for consumption (e.g. fisheries, seaweed for fertilizer), important coastal processes which help sustain human populations (e.g. hazard protection, waste breakdown), and the production and development of natural areas providing socially and culturally valuable benefits (e.g. recreation, aestheticism).

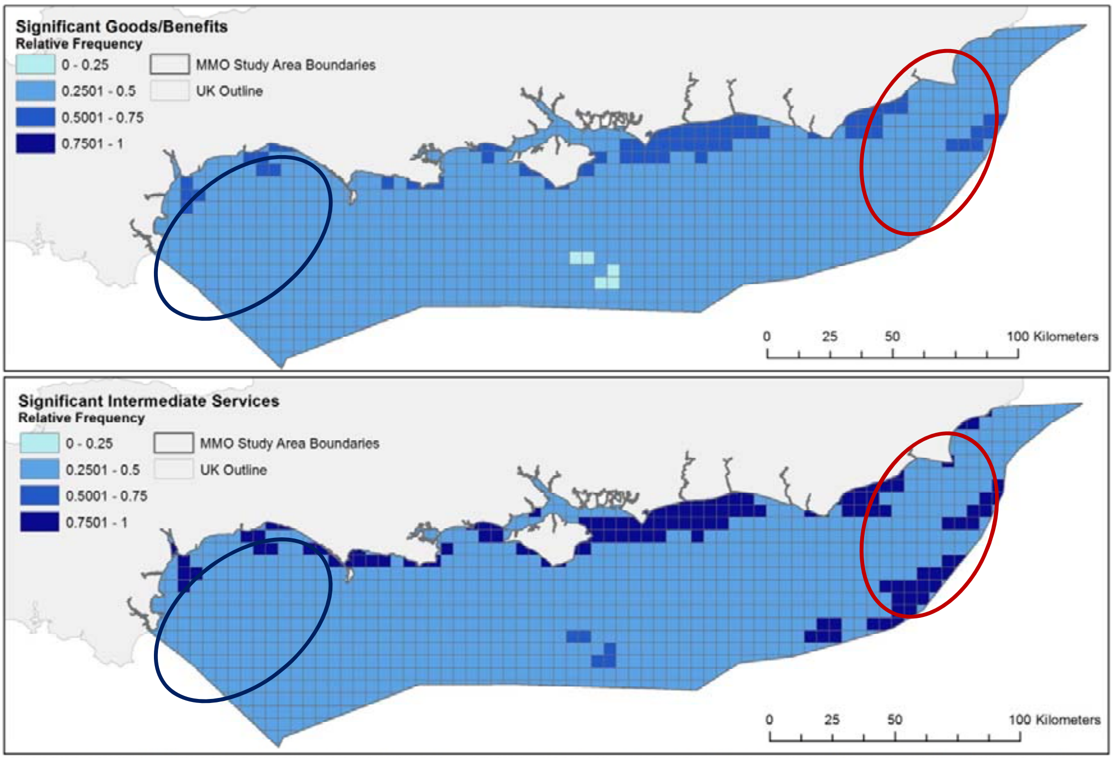
Through both intermediate and final services, as well as the input of complimentary capital (e.g. labour, fishing vessels, time, energy, machinery), society can obtain goods/benefits from marine ecosystems in the form of food, raw materials, sea defences, tourism, etc. and can be broadly defined as something of anthropocentric instrumental value, of both personal use (direct/indirect) or non-personal use (altruistic/existence value) (Potts *et al*., 2013).

A relative (non monetary) value was applied to EFH based on the ecosystem services they provide. The assessment proposed by Potts *et al*. (2013) was used for this purpose. These authors defined a relationship between the provision of ecosystem services and the EUNIS habitat features of marine areas by scoring the relative importance of these features in providing a set of intermediate ecosystem services and goods/benefits.

Using the EUNIS seabed habitat map obtained during the EUSeaMap project and provided by JNCC, the EUNIS habitats occurring in the study area were identified (by using the 5 x 5km grid as spatial reference). The habitat-ecosystem services association given by Potts *et al* (2013) was then applied, and their importance in terms of ecosystem services provision was identified (the full list of habitats and associated ecosystem services is given in the Annex “Assessing the Value of EFH”). This importance was given a s a score identifying provision of significant, moderate low or negligible importance of each ecosystem service associated to the habitat. An overall importance was then assigned to the grid cells in the study area by considering the relative frequency of services of significant and moderate importance associated to the habitat dominating in the grid cell. Considering the inter-dependence between intermediate services and goods/benefits, these two types of ecosystem services were considered separately to avoid double counting.

The importance of ecosystem services provision can be seen as an added value to the relevant ecological hotspots identified in the study area due to their functioning as EFH (Figure 23). The areas occurring in both hotspots supply important ecosystem services, mostly associated to dominant subtidal sedimentary habitats in the western area and in the eastern areas offshore, whereas rocky habitats were more frequent in the eastern area inshore. This added value is associated in particular to the supply of goods and benefits like food, fish feed, clean water and sediments and, secondarily, immobilisation of pollutants, and to the provision of intermediate services like the formation of species habitat, larval and gamete supply, and nutrient cycling. This additional value is particularly evident in the eastern hotspots, due to the larger overlapping with important areas for ecosystem services provision (Figure 23). This overlap is particularly significant offshore, on sedimentary habitats, where ecological hotspots are identified with the highest confidence (Figure 21). As discussed before, these areas are likely to provide important spawning areas for herring, hence the particular relevance of intermediate ecosystem services like larval/gamete supply and formation of species habitat.

Figure 23: Distribution of the overall importance of marine areas within the South marine plan areas in providing significant and moderate goods/benefits and intermediate services. Circles indicate the approximate location of the main hotspots of overall ecological value as identified in Figure 2.



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Most of the data supporting the assessment of ecosystem services provision in the selected hotspot areas were obtained from UK-related, peer-reviewed literature (hence with a higher level of confidence attached), particularly when considering sedimentary habitats (Potts *et al*., 2013). The only exception was the information on the provision of food that, for sedimentary habitats, was obtained mostly from grey or overseas literature. Therefore a lower confidence should be attached to the assessment of the importance due to good/benefits provision resulting in the eastern offshore hotspot and in the western areas (where sedimentary habitats dominate), compared to the eastern inshore hotspot (where rocky bottom is more frequent).

In order to attach a monetary value to the relevant ecosystem services provided by the EFH in the study area, possible valuation techniques were identified, with detailed description and requirements provided in particular for the valuation of those ecosystem services that are relevant to the ecological hotspots as identified above. An example of the application of these valuation techniques was also provided by applying Market Analysis to assess economic value of the good/benefit food provided by the ecological hotspots in the study area. The economic value of these areas to fishery was calculated based on landing data, by using associated fishing effort within the EFH as a proxy to the associated landed value. Details on methods and results are given in the Annex “Assessing the Value of EFH”. In this Annex, also the importance of the connectivity of EFH with fishing areas is highlighted in order to allow a more accurate assessment of the economic value of EFH while accounting for the transferability of their value to other areas.

5. Conclusions

EFH constitute an important component of the marine ecosystem that the MMO is designed to manage. Their ecological value is evident in that these habitats provide suitable conditions where critical life stages (eggs, larvae, juveniles) of fish species can survive or where adults can find available food for their growth, thus contributing to the growth and viability of fish populations hence to the functioning of the ecosystem. A socio-economic value is also associated with these habitats, in that the human society may benefit from some of the ecosystem services they provide. The provision of resources for fishery is one of the main goods that are gained from these habitats.

The ability to spatially locate, with a known confidence and high resolution, areas of particular ecological importance, like EFH, is therefore a key priority for MMO planners. By providing a spatially explicit evidence-based understanding of the distribution of ecologically important fish habitats in the South marine plan areas, this study gives a powerful tool that can be used for marine planning and potentially licensing, conservation and enforcement activities. This is of particular importance in areas like the South marine plan areas where a high biological diversity coexists with a high number of activities from several economic sectors that can potentially affect the marine ecosystem components. In addition, the environmental and spatial definition of EFH provided by this study could also be useful in supporting other management measures that aim at the conservation of the natural environment, and, specifically, of widely dispersed and mobile species and their habitats. These include not only MPA designations, but also sectoral management measures (e.g., temporary closure of fishing grounds) as enforced by authorities like for example IFCAs.

It is of note that, rather than providing definitive outcomes, the study aimed at developing a robust and reproducible methodology which can be continuously improved. Although the methodology was calibrated on the data and features relevant to the South marine plan areas, it is highlighted that the general approach provided can be exported also to other areas, although some adaptations might be needed to account for different species and data availability.

The project involved the collation and analysis of a high amount of data and information. A number of gaps and limitations in the data, leading to limitations in the obtained results, were identified that should be taken into account by the MMO to address future studies. Some gaps were also highlighted during the consultation exercise for the validation of the project outputs (presented in detail in the Stakeholder Validation Annex), as well as limitations were also highlighted during the project peer review. These gaps and limitations are reported below, followed by the main recommendations on how to address these limitations in future studies to allow improvement of the methodology and its application.

5.1 Gaps and limitations

- **Species range**

This project focused on a selection of species prioritised according to their relevance (for fisheries and conservation). Limitations to the species selection were posed by the use of beam trawl survey data, due to the sampling method selectivity and also to the spatial distribution of the sampling effort. As a result, EFH outputs could be obtained for small-medium sized demersal species (mostly represented by flatfish), whereas there is a gap for larger and pelagic species. In particular, species like cod, haddock, hake, monkfish, mackerel are caught extensively within these waters, and some may use the area as nursery or for spawning. This gap has been highlighted also during the peer review and the consultation process (where Devon and Severn IFCA was indicated as a possible source of additional information). Due to this limitation in the range of species considered, it is likely that the extent and ecological value of marine areas as EFH is underestimated. Due to the commercial importance of some of the species not included in the project, this might lead also to an underestimation of the economic value of these areas to fishery were economic valuation techniques applied.

Shellfish species were not considered as they were outside the scope of the project. However, these species can be of high relevance in the study area, e.g. due to their commercial importance (e.g., scallop, crab, lobster, cuttlefish; MMO 2012 and EFH Socio-economic Evaluation Annex). The importance of these species was also highlighted during the consultation process.

- **Spatial coverage of fish survey data**

Gaps in the fish data spatial coverage have led to limitations in the ability to characterise and hence predict EFH for the species. In most cases, limited coverage of the predicted EFH is obtained for shallower inshore areas due to limitations of the used fish data distribution in these zones (e.g., no BTS fish survey data were available for areas shallower than 8m). This constraint may be particularly important for those species that are known to use shallow coastal and estuarine areas as nursery grounds (e.g., plaice, sole; Le Pape, 2003).

Some gaps in the predictions have been identified also for the western areas. Although the fish data selected for the modelling are those with the widest coverage of the South marine plan areas, there is poor coverage of western areas. Similarly, a gap in the model predictions has been often observed in the area offshore of the Isle of Wight. This is due to the high tidal energy levels recorded in this area, showing values falling outside the range of the data used to calibrate the model (as areas with these specific conditions were not covered by fish survey stations).

A lower confidence in the ecological value assessment is attached to some areas, due to the limitations in the spatial coverage of the data originating the EFH models. As a result, the ecological importance of these areas might be underestimated.

- **Fish occurrence vs. abundance**

Issues were encountered during the statistical modelling due to the high proportion of zero values associated with the fish catch data thus limiting the analysis towards the choice of using presence-absence and classification tree models. Zero-inflation is a common characteristic of abundance index data that precludes the use of a classical statistical approach. Although it has been reported that often sites with a high probability of presence are also supporting high densities (Trimoreau *et al*., 2013), the use of abundance data rather than presence-absence data to estimate the spawning and nursery habitat of fish species are likely to allow a more accurate evaluation of the importance of these habitats. This would include not only their ecological importance but also the estimation of their socio-economic importance.

Obtaining predictions of EFH in terms, e.g., of numerical density of juveniles, would allow estimating the potential contribution of these habitats by taking into account the connectivity with other areas and the equivalent number of adults that would recruit into adult stocks. The improved assessment of the ecological value of EFH by using abundance data would be of particular importance for those habitats which may constitute an important management issue in an area (e.g., herring spawning grounds in the South marine plan areas).

- **Environmental data**

As EFH models are calibrated by linking fish data with environmental variables, environmental variables recorded during the surveys would be preferable to those extracted from maps (particularly for those variables showing a seasonal and inter-annual temporal variability). Although environmental variables (e.g. surface temperature, depth) are recorded during the current surveys, these data were missing in the datasets on several occasions, hence limiting the use of these variables as predictors for the species habitat distribution and leading to the use of data extracted from maps.

Salinity has been identified in the literature as a potential relevant predictor of EFH distribution of certain species (e.g. plaice nursery grounds, Lauria *et al*., 2011). Salinity maps could not be obtained during this project and so a proxy for this variable was identified by using types of mixing and stratification of water masses of marine and continental origin. The use of a continuous raster data layer for salinity would be preferable to be able to identify the influence of this variable on the EFH distribution at a finer scale, for example by using a continuous variable instead of a categorical one, although it is likely that this will be more relevant in areas of variable salinity (e.g. estuaries).

The EFH models were calibrated in this project according to an understanding of the fish-habitat relationships taking into account mostly environmental (abiotic) variables. In addition to the habitat influencing the fishes, their spawning and nursery areas may also be influenced by biological factors such as competition and predator-prey relationships. For example, food availability can be an important factor affecting species distribution. This factor was taken into account here only for pelagic planktotrophic life stages (using APH as a proxy for phytoplankton abundance), but data on the distribution of benthic fauna (e.g. total abundance) could be valuable to characterise food availability to demersal benthivorous species. It is recognised however that this type of data might be fragmentary hence presenting limitations in their availability and confidence.

- **Confidence issues**

The overall low confidence associated with several of the outputs is mainly due to the low rating associated with relevant input environmental data layers, in particular those of wave and tidal currents energy and of the seabed substratum type. These data layers have been sourced via EUSeaMap, where they were used as input data for the habitat model prediction. For the EUSeaMap project, it was deemed not feasible to try to produce confidence layers for any of the input models and a confidence assessment was carried out for the habitat output and for the class boundaries applied to the wave and tide energy data layers to identify energy categories. These confidence data layers are only applicable to the energy classes (identified using boundaries defined in EUSeaMap project), not to the original data layers. As regards the seabed substratum data layer (produced by EMODnet for the EUSeaMap), a map was derived from qualitative evaluation of the confidence on the presence of hard substrata, whereas no information could be found that allowed the confidence on the other substratum types to be estimated; some of these types being more relevant to the fish distribution than hard substrata. This limited our ability to assess the confidence of these input data layers, hence reducing the total confidence rating associated with them. Provided that further information on the confidence associated with these data layers is available, the confidence assessment of the obtained outputs could be improved.

- **Temporal reference**

The outputs obtained in this project represent a general distribution of the potential EFH in the study area, being based on average environmental conditions referred to the years between 2000 and 2012, and their validity is related to a specific season depending on the data used to calibrate the models (summer for the adult foraging and nursery habitats; winter for the spawning habitats). Therefore certain variability in the species habitat distribution is to be expected compared to the maps when considering other seasons or specific years.

5.2 Recommendations

- **Integrate analysis of additional fish datasets**

The analysis and modelling of bottom trawl survey data, or data obtained from pelagic surveys (see Technical Annex for a complete list) could be valuable for the characterisation of EFH for additional species (e.g., sandeels, herring (adults), cod, whiting, mackerel) and to improve the spatial coverage of the data. Also fish surveys in coastal inshore and estuarine areas (e.g., EA NFPD) could be valuable for characterising habitats of migratory species. Following the project peer review, also the potential usefulness of Cefas sea observed programme data and some fisheries dependent data (beyond logbooks, for example from self-sampling or skipper logs) has been highlighted. Given the diversity of methods and survey strategies applied, it might not be possible to collate all the data in a single analysis and separate spatial predictions could be obtained for the same EFH (e.g., with variable seasonal validity or covering different areas). However, the resulting EFH outputs could then be merged for assessing the relative value of marine areas as EFH. Obtaining results on EFH for a wider range of species would improve the assessment of the ecological value of EFH areas. As some of the additional species that would be included in the analysis are of high commercial relevance, this would allow also a more accurate estimation of the economic value of these areas to fishery were economic valuation techniques applied. By improving the spatial coverage of the data, it would also improving the spatial validity and confidence in the outputs (e.g., by accounting for environmental conditions that are not included in the current analysis, hence increasing confidence in the predictions associated to these areas).

- **Address shellfish component**

Future studies should focus also on the shellfish component, by using suitable data at an appropriate scale. This would allow not only to integrate the EFH outputs by accounting for an important ecological component, but, given its high commercial relevance, this would allow a more accurate estimation of the economic value of these areas to fishery were economic valuation techniques applied.

- **Include fish abundance in the EFH assessment**

The integration of the analysis with additional fish survey data might result also in the increase of occurrence of species life stages in the dataset. This would allow the modelling of fish abundance data rather than presence-absence, thus improving the information provided by the EFH identification. Were a high proportion of zero values still associated with the fish catch data, thus precluding the use of a classical statistical approach, alternative statistical methods addressing this problem could be explored. for example, the Delta-model approach (Stefanson 1996, Martin *et al*., 2005, Rochette *et al*., 2010, Vasconcelos *et al*., 2013). This is a conditional approach coupling two sub-models: 1) a first testing for the presence; 2) a second explaining the variation of the abundance data where presence was recorded. This is a possible means of improving the output results by providing information on the EFH distribution based not only on the occurrence of a species/life stage, but also on its abundance.

- Use continuous raster data layer for salinity in estuarine and inshore coastal areas

Were additional fish data integrated in the analysis, particularly from the estuarine and inshore coastal areas, there will be the need of better characterising the salinity spatial gradients in these areas (more relevant than in marine areas). The use of continuous raster data layer for salinity would be preferable to the use of categorical variables (like in this study).

- **Validate the outputs**

The outputs validation is a way to integrate the confidence assessment of the EFH outputs. Although the stakeholders consultation provided useful information on gaps and limitations, it did not provide data for the validation of the spatial output (although a possible source was identified in the Devon and Severn IFCA). To do so, there is the need of spatially referenced data obtained from independent fish surveys, which identify the presence or absence of a species life stage (for the current models; or a standardised abundance, when abundance models are applied). The environmental data associated with the additional observations (including variables deemed relevant by the model) would be combined by applying the model and the resulting predicted classification compared the actual data. A misclassification error could be calculated (similarly to the one estimated during the model creation) and compared with the original one, thus allowing to adjust the confidence level (by using the methods given in the Technical Annex). The more data will be used for this process, the more powerful would be the validation process. It should be noted that the variability in the occurrence of a species life stage might depend of the seasonality of the data, therefore the validation dataset should have similar temporal reference to the model that is being validated.

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