Marine Management Organisation

Follow on to the Development of Spatial Models of Essential Fish Habitat for the South Inshore and Offshore Marine Plan Areas

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Follow on to the Development of Spatial Models of Essential Fish Habitat for the South Inshore and Offshore Marine Plan Areas

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Executive Summary

The ability to spatially locate resources in the marine environment with confidence and at high resolution is central to marine planning and required to manage anthropogenic activities for a sustainable integrated use of the seas. Essential fish habitats are important resources due to their high ecological value in supporting critical fish life stages and their social and economic value as highlighted by ecosystem service models. As such, essential fish habitat maps may represent important supporting tools for the development of marine plan policies in England.

The lack of high resolution data on essential fish habitats constitutes a major limitation for the reliable identification of high value habitats and their practical consideration in the marine planning process. To address this problem, a project (MMO (2013)) was undertaken in 2013 to improve the spatial resolution of data on essential fish habitat for fish species of commercial and / or ecological relevance in the South Inshore and South Offshore Marine Plan Areas (hereafter referred to as the South marine plan areas).

MMO (2013) used empirical geospatial modelling (classification tree models) of fish survey and environmental data to generate spatial predictions of the presence of fish life stages for ten fish species in the South marine plan areas. MMO (2013) also developed a methodology to assess the confidence associated with model outputs, by combining confidence assessments on the input data and the statistical model predictive ability. The project spatial outputs therefore included maps of the predicted distribution of essential fish habitats (nursery, spawning and adult foraging grounds) for individual species with associated confidence value and confidence maps. MMO (2013) also developed an integrative approach to combine these maps into multi-species hot spot maps (with associated confidence) identifying areas of higher ecological value based on the frequency of occurrence of the essential habitats for different species.

The outputs of MMO (2013) were heavily influenced by the availability and quality of source data and scientific evidence to support the modelling logic as well as the time available to collate and prepare the data. Stakeholder consultation and model validation were recommended to improve the confidence assessment of the MMO (2013) spatial outputs. The present project follows up on this recommendation with the aim of understanding whether the MMO (2013) spatial outputs can be used to support the development of marine plan policies in England.

The present project used a stakeholder consultation and validation activity to fulfil the following objectives: 1) validating the essential fish habitat maps developed in MMO (2013) against new data and expert judgement; 2) identifying additional data to improve the confidence in the MMO (2013) essential fish habitat predictions and for the application of the approach in other marine plan areas; 3) obtaining the consultees' view on the acceptability of the MMO (2013) approach as a tool to support marine planning in England; and 4) providing recommendations to make the model as robust as possible, run the model for all marine plan areas and ensure it can be used in development of marine plans for England.

The consultation engaged the Department for Environment, Food & Rural Affairs (Defra), the Centre for Environment, Fisheries and Aquaculture Science (Cefas), the Joint Nature Conservation Committee (JNCC) and Natural England, as well as other organisations within the UK such as Marine Scotland Science, Natural Resources Wales, Department of the Environment Northern Ireland, Agri-Food and Biosciences Institute Northern Ireland and the Inshore Fisheries and Conservation Authorities (IFCAs) within or adjacent to the South marine plan areas. A questionnaire and discussion via web conferencing were employed.

Consultees were asked to provide their view on the validity of the MMO (2013) approach and to identify areas of mismatch between the MMO (2013) spatial predictions of essential fish habitats and their expert knowledge. This information was used to identify areas of reduced confidence in the MMO (2013) maps. The confidence assessment of the MMO (2013) spatial outputs was also improved by statistically validating the model predictions against independent fish survey data. This allowed the re-evaluation of the model predictive ability hence the amendment of the overall confidence associated with the MMO (2013) spatial outputs.

Additional data from fish surveys or environmental data layers were also identified based on the consultees' suggestions and on further input from the Institute of Estuarine and Coastal Studies (IECS). The associated metadata were explored in order to assess the suitability of these data to improve the MMO (2013) models and/or to allow the application of the approach to other marine plan areas.

Due to the limited time available, Defra's acceptance of the MMO (2013) approach relied on MMO and Cefas judgement and the fishery research scientist consulted in Cefas could not provide an organisation level acceptance of the suitability of the method for marine planning. Although a formal agreement has not yet been obtained, discussion with Cefas, Defra and other organisations allowed identification of strengths and weaknesses associated with the MMO (2013) approach. It was therefore possible to formulate a series of recommendations to improve the approach.

The validation activity confirmed that confidence issues were mostly associated with input data layers used to obtain spatial predictions rather than model predictive ability. There was a good agreement of the accuracy of the maps with the expert knowledge and additional empirical evidence, and the statistical validation often led to an increase in the overall confidence in the spatial outputs. The importance of using expert knowledge in addition to statistical validation to refine the model outputs was highlighted during consultation and therefore it was recommended that this is included as a procedure within the MMO (2013) approach.

The confidence improvement was evident in particular for maps of nursery habitats based on the prediction of occurrence of fish juvenile stages. In most cases these maps reached a moderate confidence after validation. Such an improvement suggests that these maps may have increased utility as spatial areas for marine planning to use in policy formulation. Further improvements of these outputs could be obtained by replacing or integrating the environmental variables used in the models with additional environmental data layers with higher confidence which were not available in this study, as suggested during consultation. This represents a further step towards the improvement of the robustness of the models and the use of the resulting spatial outputs in marine planning.

A higher uncertainty was associated with the spatial prediction of spawning and adult feeding grounds relative to nursery areas and amendments to the models were identified as ways of making the models more robust and improving the confidence in their predictions. For example, the inclusion of abundance data of pelagic eggs and larvae in combination with the presence / absence data used in the current models was recommended.

The exploration of additional data allowed identification of environmental data layers that should be used as new, additional parameters in the MMO (2013) models. These include variables obtained from detailed energy data layers, Terrain Ruggedness Index obtained from bathymetric data layers and chlorophyll concentration. The use of these additional environmental data has the potential to improve the prediction and confidence in the model outputs in the South marine plan areas and also in other marine plan areas, hence increasing their suitability as supporting tools for marine planning.

During consultation, the limited coverage of species included in MMO (2013) was identified as an important limitation of the approach, particularly when an integrative assessment of the ecological value is undertaken by combining the information obtained from maps of essential fish habitats of individual species (as with hot spot maps). Additional fish survey data from datasets used in MMO (2013) and from additional datasets were identified as useful to increase the species coverage in the South marine plan areas (e.g. with inclusion of turbot, brill, whiting and cod) and expand the approach application to other marine plan areas.

Notwithstanding the availability of additional fish survey data, not all data are suitable for modelling according to data requirements specified in MMO (2013) (e.g. wide spatial coverage of a fish survey dataset in the marine plan area). A reduced spatial coverage of suitable fish survey data in inshore areas was also identified in MMO (2013) and confirmed in this project, hence limiting the applicability of the models in these areas. The integration of the MMO (2013) spatial outputs with information from other sources better covering these areas (e.g. EA assessments of fish distribution inshore) was therefore recommended. Considering that the above limitations could possibly lead to an underestimation of the overall ecological value of an area, the use of expert knowledge to validate hot spot maps was recommended.

Although a formal agreement could not be obtained within the timeline of this project, discussions are still ongoing within Cefas to provide the organisation's view on the MMO (2013) method. The confidence improvement that would likely result from addressing the recommendations above is considered an important factor that would further increase the suitability of the spatial outputs as supporting tools for the development of marine plan policies in England.

1. Introduction

Marine planning is one of the main responsibilities of the Marine Management Organisation (MMO). Marine planning provides an approach to the management of activities, resources and assets in England's waters to ensure sustainable development in the marine environment. The ability to spatially locate resources in the marine environment with confidence and at high resolution is important to the marine planning process and to manage anthropogenic activities for a sustainable integrated use of the sea.

Essential fish habitats are aquatic habitats which are necessary to fish for spawning, feeding or growth to maturity (e.g. nursery grounds, migration corridors). They have disproportionate ecological value in supporting critical fish life stages, hence ensuring viability of fish populations and provision of the associated ecosystem services. As such, essential fish habitats are areas of interest when considering the potential impacts of marine activities (e.g. Marine Policy Statement, paragraphs 3.3.30, 3.5.4).

At present data on essential fish habitat is at low resolution[1]. The lack of high resolution data on essential fish habitats constitutes a major limitation for the reliable identification of high value habitats and their practical consideration in the marine planning process. To address this problem, a project (MMO (2013)) was undertaken in 2013 to improve the spatial resolution of data on essential fish habitat for fish species of commercial and / or ecological relevance in the South Inshore and South Offshore Marine Plan Areas (hereafter referred to together as the South marine plan areas, or the study area).

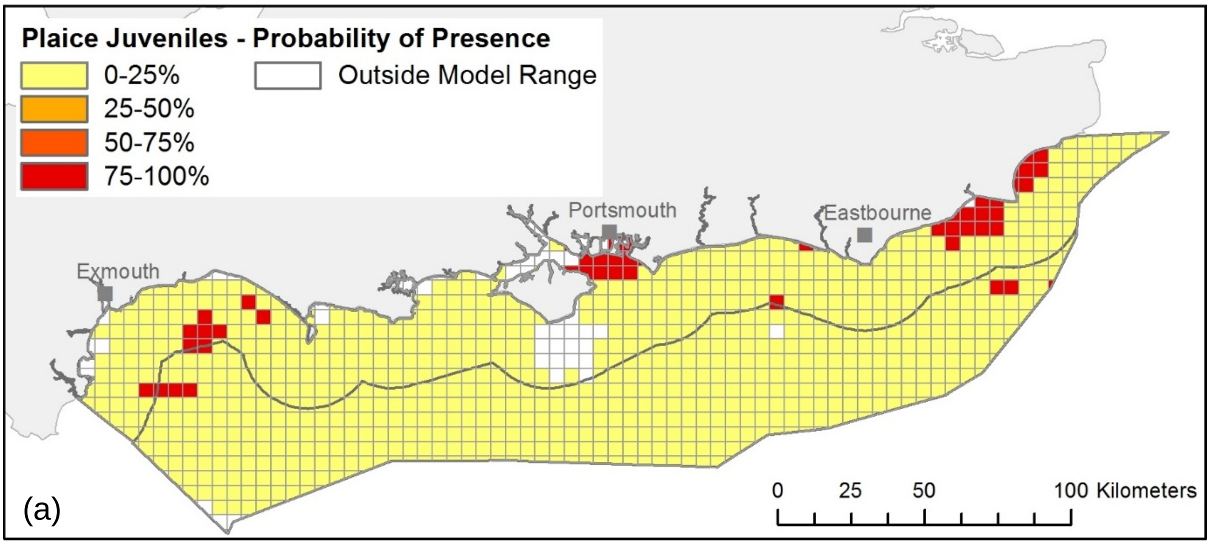
MMO (2013) used empirical geospatial modelling (classification tree models) to identify the physical, chemical and biological characteristics of the habitats where critical fish life stages occur in the South marine plan areas. These characteristics were used to predict the spatial distribution of potential essential fish habitats (in particular adult foraging, nursery or spawning habitats) for ten fish species (plaice, sole, lemon sole, dab, red gurnard, common dragonet, solenette, thickback sole, thornback ray and herring) in relation to the probability of occurrence of their life stages in the study area (for other marine plan areas, species may vary). As these spatial predictions were based on trends in environmental parameters that are usually available at a higher spatial resolution than currently available evidence on essential fish habitat, higher resolution (5km × 5km grid) spatial outputs were obtained (MMO, 2013a).

MMO (2013) also developed a methodology to assess the confidence associated with model outputs, by combining confidence assessments on the input data and the statistical model predictive ability MMO (2013). As a result, spatial outputs developed

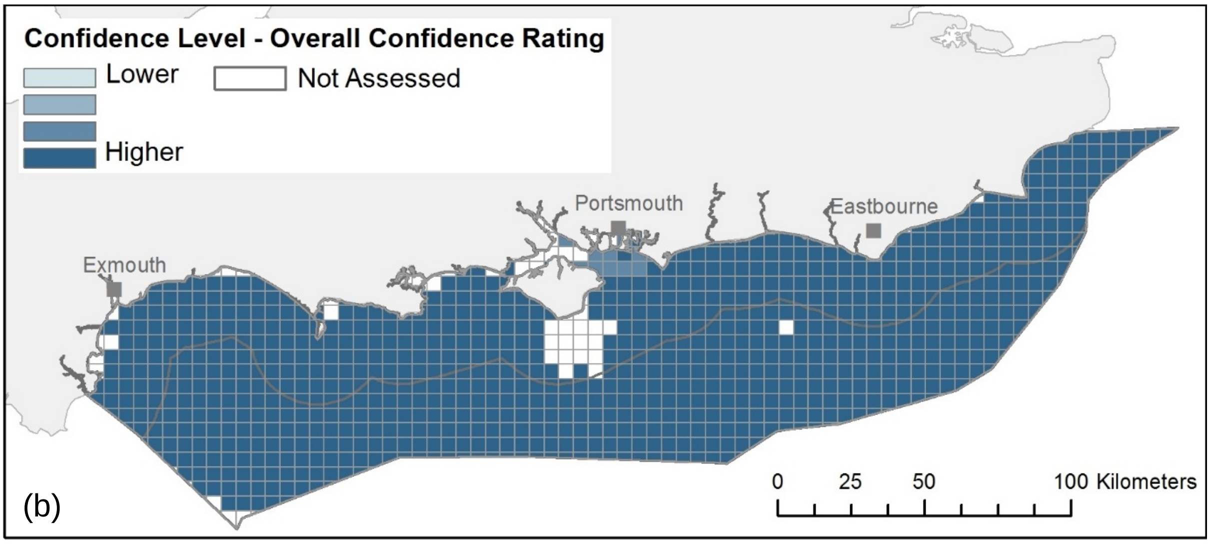
[1] Existing data available to the MMO on the distribution of essential fish habitats (in particular, nursery and spawning areas in Ellis *et al*., 2012) are resolved at the ICES rectangle scale, approximately 3000km^2.

in MMO (2013) included maps of essential habitats of single fish species with associated confidence value and confidence maps (an example is given in Figure 1).

Figure 1: a) Nursery habitats for European plaice (*Pleuronectes platessa*) predicted by classification tree modelling of the distribution of juveniles (40-180mm total length; 0-group; Lauria *et al.*, 2011) in the South marine plan areas. b) Relative confidence associated with the model spatial prediction.



Contains Ordnance Survey and UK Hydrographic Office data. Based on a model produced by the Institute of Estuarine and Coastal Studies using data products from ICES, EMODnet, JNCC and My Ocean. © Crown copyright and database right 2013. Marine Management Organisation. Projected to British National Grid.



Contains Ordnance Survey and UK Hydrographic Office data. Based on a model produced by the Institute of Estuarine and Coastal Studies using data products from ICES, EMODnet, JNCC and My Ocean. © Crown copyright and database right 2013. Marine Management Organisation. Projected to British National Grid.

These maps were then combined in MMO (2013) in a multi-species hot spot map where areas with higher ecological value were identified based on the frequency of occurrence of the essential habitats for different species. A confidence map was associated to the hot spot map, taking into account the confidence maps and the limitations of spatial predictions for the single species essential fish habitats included in the calculation of the hot spots (MMO, 2013a).

The outputs of MMO (2013) were heavily influenced by the availability and quality of source data and scientific evidence to support the modelling logic as well as the time available to collate and prepare the data. This work also highlighted data and knowledge gaps and data quality issues, and outlined limitations and caveats associated with the obtained outputs which are to be taken into account as an integral part of the spatial outputs produced in MMO (2013).

In order to understand whether the approach and spatial outputs obtained in MMO (2013) can be used in the development of marine plan policies, and if so how, a stakeholder consultation and model validation was recommended. This led to the stakeholder consultation and validation activity undertaken in the present project.

As a follow up work on MMO (2013), the present project built on the methodology and spatial outputs developed in the previous project. As such, this report assumes prior reading of the documents produced in MMO (2013) for a full understanding of the methods, outputs and limitations mentioned here. In particular the MMO (2013) Project Report describes the general approach, main results, caveats and data limitations, whereas the details on data sources and methodological approach to modelling and confidence assessment are given in the MMO (2013) Technical Annex.

1.1 Aim and objectives

The present project provides an expanded assessment of the confidence associated with the MMO (2013) outputs and understanding of whether and how the model outputs can be used to support the development of marine plan policies in England (i.e. as policy maps to develop prescriptive or spatially explicit marine plan policies, as opposed to indicative maps providing guidance for the development of high level policies).

In order to achieve this aim, a general agreement was sought with the Department for Environment, Food & Rural Affairs (Defra) and its statutory advisers for the marine environment (including the Centre for Environment, Fisheries and Aquaculture Science (Cefas), the Joint Nature Conservation Committee (JNCC) and Natural England) on the validity of the modelling method developed in MMO (2013), and its suitability as a tool to support marine planning in England.

The project used a stakeholder consultation and validation activity that engaged both MMO staff (including Marine Licensing Team and Coastal staff within the South marine plan areas) and the four main partner organisations identified above. Consultation also engaged other organisations within the UK such as Marine Scotland Science, Natural Resources Wales, Department of the Environment Northern Ireland, Agri-Food and Biosciences Institute Northern Ireland and the Inshore Fisheries and Conservation Authorities (IFCAs) within or adjacent to the South marine plan areas.

The following objectives were identified:

- Undertake **model validation** by assessing essential fish habitat maps developed in MMO (2013) for the species and plan area against new data and expert judgement.

- Identify **additional data** that may allow improvement of the confidence associated with essential fish habitat maps for the South marine plan areas and wider application of the approach to additional species and other marine plan areas.

- Obtain the view of the main partner organisations and other consultees on the **acceptability** of the approach as a tool to support marine planning in England.

- Provide detailed **recommendations** on the next steps to: i) make the model as robust as possible, ii) run the model for all marine plan areas and iii) ensure it can be used in development of marine plans for England.

2. Project Approach and Methodology

2.1 Stakeholder consultation

A stakeholder consultation was organised with MMO (including staff from Marine Licensing and Coastal Teams), Defra, Cefas, JNCC and Natural England (hereafter referred to together as the main partner organisations), as well as other organisations such as, Devon & Severn IFCA, Southern IFCA, Marine Scotland Science, Natural Resources Wales, Department of the Environment Northern Ireland and Agri-Food and Biosciences Institute Northern Ireland.

The consultation was undertaken via email by circulating a questionnaire (Annex 1) to all the identified consultees. The document was built upon an existing online questionnaire developed for MMO (2013).

The questionnaire's objectives were to:

a. Obtain expert judgement of the validity of the model outputs of MMO (2013) by comparing model predictions with the consultee knowledge (where possible supported by evidence, e.g. empirical data on fish species presence in the study area, comparison with fish sensitivity maps developed in other studies[2]).

b. Identify possible additional data sources that could be used to improve the existing model for the South marine plan areas and/or to extend its application to all marine plan areas. These included in particular:

    - Additional fish survey data covering other relevant fish species or life stages not modelled in MMO (2013), with also consideration of possible inclusion of shellfish in the models.
    - Additional environmental data layers not available or not considered at the time MMO (2013) was undertaken, that might replace or integrate with data layers for variables already included in the existing models (e.g. data layers with higher confidence than those used) or which might be relevant to the modelling of additional species.

c. Obtain the consultee's general opinion on the validity and usefulness of the approach developed in MMO (2013) as a tool to support the development of marine plan policies in England, while taking into consideration the possible areas of improvement of the model.

The spatial outputs of MMO (2013) (essential fish habitat of individual fish species and associated confidence maps) were provided to the consultees for evaluation. In order to aid the consultees' understanding of the spatial outputs and the approach that led to their development, a general background to the work undertaken in MMO

[2] Such as for example previous mapping of spawning and nursery grounds for selected fish species in UK waters (Ellis et al., 2012; albeit at a coarser resolution than the MMO (2013) outputs) or Fisheries Sensitivity Maps in British Waters developed by Marine Scotland (2014).

(2013) was also given as part of the questionnaire documentation. This included information on the input data used along with its caveats and limitations, the modelling technique applied, method and model outputs and the reports main findings (Annex 1).

The stakeholder answers to the questionnaire were collated and where required, further clarification/discussion of the comments was sought with the consultees. A transcript of all stakeholder comments obtained during this phase of the consultation was collated in a single document which was circulated back to stakeholders for any amendment and agreement.

Further discussion with the main partner organisations (Defra, Cefas, JNCC and Natural England) was undertaken based on the outcome of the questionnaire. The aim was to obtain the organisations' view on whether (or how) the MMO (2013) model approach could be used to generate policy rather than indicative maps for plan led management of the marine environment in England.

Web conference facilities were used to undertake this discussion. Based on the consultees' availability within the time line of the project, it was not possible to involve all four main partner organisations in a single web meeting. As a result, two web meetings were held, the first on the 13th March involving IECS, MMO, JNCC and Natural England, and the second held on the 20th March involving IECS, MMO and Cefas. In addition, during the early stage of the consultation process Defra stated they did not require direct involvement and would rely on the expert view of MMO and Cefas as organisations that fulfil advisory functions for Defra in this subject area.

The participants were provided with information on the comments obtained from the questionnaire (summarised in Section 3) and on the changes/amendments applied to the MMO (2013) maps following the validation activity (see Section 2.2) in advance of the meeting. This information was used as the baseline to initiate the discussion, with further points of discussion being developed during the meetings.

2.2 Validation activity

Validation of the MMO (2013) outputs for individual fish species used both expert judgement obtained during stakeholder consultation and independent fish survey data.

2.2.1 Validation using expert judgement

The information obtained from the consultation was used to validate MMO (2013) spatial outputs. The use of expert judgement to support decision making has always played a large role in science and particularly as an approach within marine biodiversity status assessments (Barnard and Boyes, 2013).

In the questionnaire, the consultees were asked to identify discrepancies between the MMO (2013) predicted distributions of essential fish habitats and their personal experience or knowledge. A labelled grid was included in the MMO (2013) maps to aid consultees in the location of specific areas where discrepancies were present (Annex 1).

Based on the consultees' comments, these areas were manually outlined as polygons on the essential fish habitat maps. These primarily related to defined areas where the presence of a species life stage was either underestimated or overestimated. Where possible, consultee comments were verified against evidence indicated by the consultee themselves before amending the maps.

Where the model prediction within the areas identified by the consultees was not in agreement with their expert knowledge, these were regarded as areas with a lower confidence than originally estimated in the confidence maps produced in MMO (2013). These maps represented the relative spatial variability of confidence around the total confidence value associated with the output as a whole and a colour pattern was used to represent the relative degree of confidence associated to each cell in the map grid, using a four level scale ranging from higher (darker colour) to lower confidence (paler colour) (MMO, 2013).

In order to include the expert judgment obtained during the consultation undertaken in the present study, the polygons identifying the areas indicated by the consultees were outlined also on the confidence maps, and the confidence level associated with these cells in the map grid was lowered by one level.

Where the consultees did not highlight any issues, the confidence level was not changed and the validity of the original prediction and the associated confidence were therefore confirmed. As only negative feedbacks were required from the consultees (i.e. identification of areas of prediction not matching their knowledge), the absence of any issue could not be considered a sign of higher confidence in the model prediction. In fact, it might have been determined by other factors such as for example a poorer knowledge of the consultee regarding the distribution of a particular species in certain areas. This should be taken into account when using the report.

2.2.2 Model statistical validation

A statistical approach was also applied to validate the MMO (2013) outputs allowing the confirmation or amendment of the total confidence associated with an MMO (2013) output as a whole, as described below.

The model statistical validation assessed the ability of the models developed within MMO (2013) to predict the presence of fish life stages based on the environmental conditions. Accuracy was assessed by comparing the model predictions with independent data and by computing measurements of the prediction (or misclassification) error (Fielding and Bell, 1997).

Different survey datasets were used to test the model, depending on the fish species and life stage considered. The fish data characteristics, source and how they were selected for the model validation are described in detail in Annex 2, along with the methodology for the statistical model validation.

The match/mismatch (error) between the model prediction of occurrence of a species life stage in a site and the observed presence/absence as obtained from the additional fish survey data were assessed based on an error matrix (Table 1). This cross-tabulates the observed and predicted presence/absence patterns, by reporting the number of cases when the model successfully predicted the presence (true positives, TP) or absence (true negatives, TN) of a species life stage and the number of cases when the prediction did not match survey data (false positives, FP, and false negatives, FN).

False positives and false negatives are indicative of the error made by the model and, based on these parameters, the model misclassification error was calculated (Annex 2). This parameter was used to re-evaluate the confidence in the model predictive ability by using the criterion applied in MMO (2013) to transform the misclassification error into a confidence rate. The re-evaluated confidence in the model predictive ability was therefore combined with the confidence in the input data originating the model prediction by applying the methodology devised in MMO (2013) in order to obtain the amended overall confidence rating (ranging between low and high) associated with the validated map.

Table 1: An error matrix.

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Actual
(from fish surveys)</td></tr>
<tr><td>Presence</td><td>Absence</td></tr>
<tr><td rowspan="2">Predicted
(from
model)</td><td>Presence</td><td>True Positives
(TP)</td><td>False Positives
(FP)</td></tr>
<tr><td>Absence</td><td>False Negatives
(FN)</td><td>True Negatives
(TN)</td></tr>
</table>

This information was integrated in the confidence maps by using different colours to represent the different overall confidence associated with the spatial outputs (e.g. red if low confidence, purple if low-moderate confidence, blue if moderate confidence). The different shades of the colour in the map (from paler to darker shade) therefore represented the relative confidence in each grid cell of the map in relation to the overall confidence level associated with the map as a whole.

2.3 Additional data

The information provided by the consultees on the additional data layers to improve the models was also used as a starting point to seek further information. In particular, available information and metadata on the content, spatial and temporal extent, source and availability of the data were sought in order to assess the potential suitability of these data to improve the existing maps or extend the application of the modelling approach to other species and marine areas.

3. Results

The main results of the stakeholder consultation have been summarised below, integrating questionnaire results and further discussions with the main partner organisations.

Stakeholder availability was limited due to the timing of the project (as this coincided with the end of the financial year), but consultees with relevant expertise (e.g. marine planning, local knowledge on the fish distribution in the English channel, understanding of the data and issues associated with the statistical modelling) were involved. All consultees were made aware that they would be providing expert opinion on behalf of their organisation. However, Cefas made it clear that the responses and comments obtained from their fishery research scientist involved in the consultation represented a personal viewpoint only, and that discussion with other divisions within Cefas would be required in order to obtain the organisation's view. This was outside of the ;project timeline and so was not sought.

3.1 General assessment

The maps and approach developed in MMO (2013) was generally well received by the consultees. The Department of the Environment Northern Ireland and JNCC considered the MMO (2013) maps and approach a valuable input to support the development of marine plan policies in England. JNCC also highlighted that the use of confidence maps associated with the essential fish habitat predictions is an improvement compared to previous projects mapping essential fish habitats (Coull *et al.*, 1998; Ellis *et al.*, 2012). Agri-Food and Biosciences Institute Northern Ireland regarded the approach as particularly useful when used in association with ecological hot-spot maps.

The approach was considered robust and made the best use of available datasets (Agri-Food and Biosciences Institute Northern Ireland). Agri-Food and Biosciences Institute Northern Ireland and JNCC agreed with the conclusions of MMO (2013), i.e. that the quality and resolution of the environmental data layers which provided the model predictors are likely factors reducing the confidence in the outputs. Therefore the use of additional physical datasets, as suggested by the consultees and identified in this project (see Section 3.4) was identified as a significant area of improvement for the current and future applications of the suggested approach.

Cefas highlighted the importance of ecological processes (e.g. multi-species interactions within communities, population size and dynamics) in determining the spatial distribution of a fish species, in addition to the environmental habitat characteristics. The fact that deterministic models like those applied in MMO (2013) do not take these factors into account was considered as a source of error and inaccuracies in the modelled distributions. However, it was acknowledged that there are still gaps in knowledge regarding ecological processes and spatially mapping these data is more difficult compared to mapping physical habitat data due to the complexity of factors affecting these processes (e.g. competition between species depends on the resource availability they are competing for; strength of recruitment may change in space and time with environmental conditions). Therefore, it is unlikely that these data are currently available and suitable for inclusion in the modelling of the distribution of fish life stages for the study area.

3.2 Validation of maps

Overall, the consultation process highlighted a fair agreement between the maps with existing expert knowledge. This was corroborated by consultee reference to previous broad scale maps (Coull *et al*., 1998; Ellis *et al*., 2012) and recent fish sensitivity maps for British waters (Aires *et al*., 2014).

Following the consultees' assessment of the MMO (2013) project outcomes, specific issues regarding the accuracy of map predictions in certain locations were identified. As required, the consultees provided information or links to supporting evidence. Most frequently, this evidence consisted of existing maps developed within studies investigating the distribution of fish spawning and nursery grounds in UK waters (Coull *et al*., 1998; Ellis *et al*., 2012), updating fishery sensitivity areas in British waters (Aires *et al*., 2014), or reviewing and updating the understanding on herring spawning potential with particular interest towards aggregate extraction licences in the East Channel Region (ECA and RPS Energy, 2010) and around the UK (MarineSpace *et al*., 2013).

It is noted that there is a significant overlap in the fish survey data used to generate the above mentioned maps with those used for the mapping of South marine plan areas in MMO (2013) (e.g. International Herring Larvae Surveys (IHLS) data; Cefas 4m beam trawl surveys for nursery grounds), albeit with variable temporal reference, depending on the study. Cefas confirmed that these are the appropriate fish survey datasets for the study area.

The statistical validation of the MMO (2013) essential fish habitat maps often resulted in an increase in the overall confidence associated with these spatial outputs, from low confidence (before validation) to moderate confidence (after validation). This was evident in particular for those maps predicting the distribution of juvenile life stages. In most of these cases, the results of the statistical validation suggested that the maps provided a conservative representation of the distribution of nursery habitats (i.e. where comparison with survey data was possible, the model tended to underestimate the presence of juveniles).

In turn, when considering the maps used to assess the combined distribution of adults and juveniles, the model statistical validation led to no change or to a decrease of the overall confidence associated with these outputs. The resulting confidence was generally low or moderate-low (after validation). However, it was noted that in several cases, when the prediction of the presence of adults was considered, irrespective of whether juveniles were also present, a higher confidence was associated with it.

The detailed results of the validation process are reported below for each of the essential fish habitat maps produced in MMO (2013). In the following sections, the relevant comments given by the consultees during the validation activity are summarised and the validated essential fish habitat maps are given showing the areas where there was a mismatch between the consultees' knowledge and the model prediction (explanation of this mismatch is given in the text).

The confidence maps before and after validation are also presented. The latter incorporates both the amendments to the overall confidence associated with the essential fish habitat map (as per statistical validation) and the specific areas where a lowered confidence in the model prediction was identified following the issues indicated by the consultees (as per expert knowledge-based validation).

3.2.1 European plaice (*Pleuronectes platessa*)

The life stages modelled for this species included juveniles (40-180mm total length; 0-group), adults (190-640mm total length) and eggs (1.75-2.28mm diameter; early stage, EG1).

Adult plaice (foraging habitat)

Expert judgement:

- Cefas: Extensions of range into muddy areas in D&E3[3] and in C&D7 are not matched by survey data.

- Marine Science Scotland (MSS): The distribution of juveniles agrees broadly with that of the MSS Fish Sensitivity Maps (FSM) however the FSM only show the 0-group (fish in the first year of life) and there is a slightly higher probability of finding 0-group aggregations that agrees spatially with the MMO model outputs. The Coull *et al*. (1998) plaice nursery layers overlap with the MMO area of study also, especially towards the coast at Dover, this matches with the MMO "adults and juveniles" category.

Following these comments, specific areas were marked on the validated maps (Figure 2 and 3b):

> Areas where the model overestimates the presence of adult plaice and as a result a lower confidence is associated to the model output in these areas.

It is of note that these were areas where a lower confidence was already associated with the model prediction in the original maps.

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) resulted in a misclassification error of 49% when considering the predictions of all the combinations of presence/absence of juveniles and adults. This led to a moderate confidence in the model predictive

[3] Maps were provided to consultees with a broad scale numbered grid overlaid in order to facilitate the identification of specific locations or areas of concern. This grid has been left on the validated maps shown in this report for a better understanding of how the consultees' comments have been addressed in the validation activity.

ability (albeit close to the threshold of 50% misclassification error between moderate and low confidence). This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO 2013), led to a slight decrease in the overall confidence in the spatial output from moderate (before validation; Figure 3a) to **moderate-low** (after validation; Figure 3b).

Figure 2: Validated map of adult foraging habitat of European plaice (*Pleuronectes platessa*) predicted by classification tree modelling of the distribution of adults (190-640mm total length) in the South marine plan areas. The cells outlined in black (1) indicate areas where the model overestimates the presence of adult plaice.

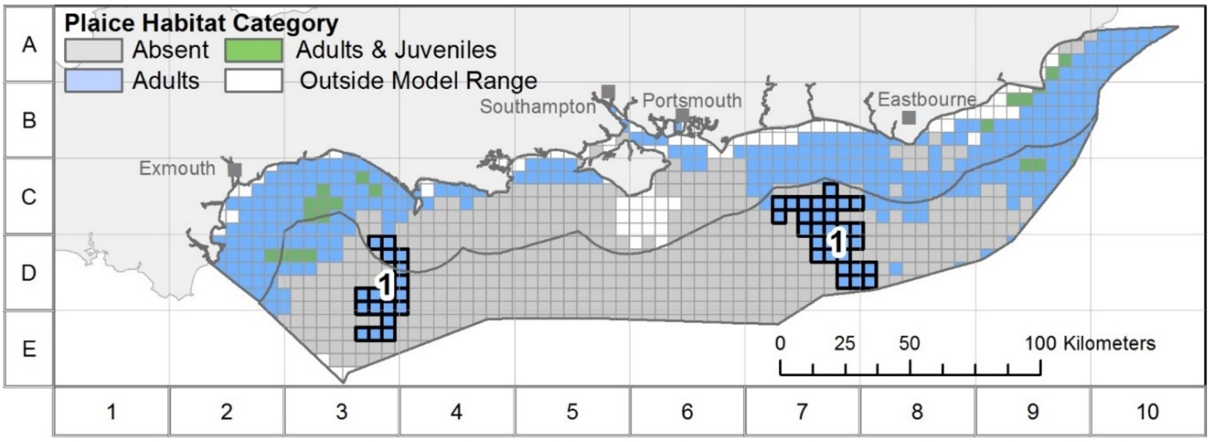


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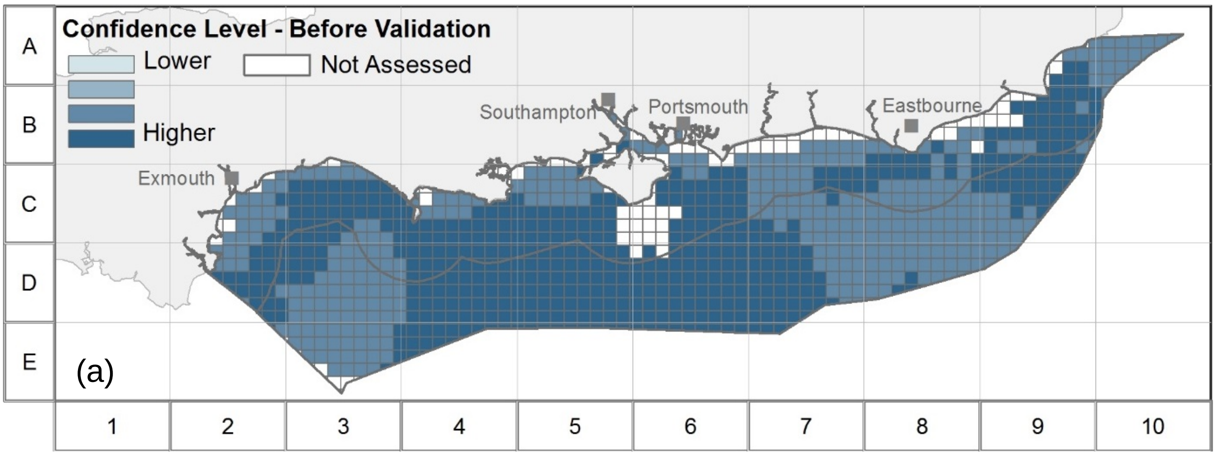
Figure 3: Confidence associated with the predicted adult foraging habitat of European plaice (*Pleuronectes platessa*) in the South marine plan areas: a) before validation (overall confidence: moderate); b) after validation (overall confidence: moderate-low).
The cells outlined in black (1) indicate areas where the model overestimates the presence of adult plaice.



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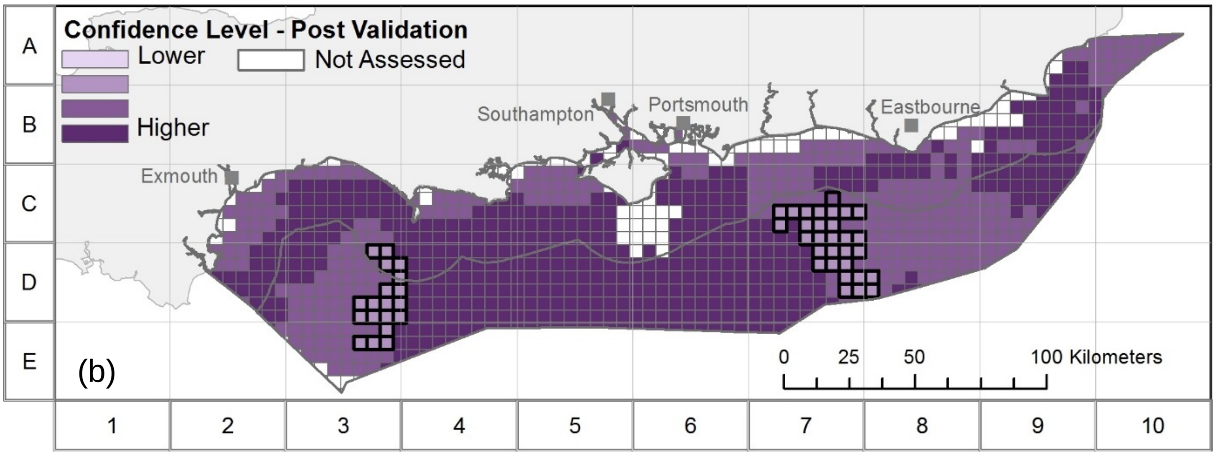

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Juvenile European plaice (nursery habitat)

Expert judgement:

- No major issues were identified during consultation.
- Marine Science Scotland: The distribution of juveniles agrees broadly with that of the MSS Fish Sensitivity Maps (FSM) but we must remember that the FSM only show the 0-group (fish in the first year of life.) However, there is a slightly higher probability of finding 0- group aggregations that agrees spatially with the MMO model outputs. The Coull (1998) plaice nursery layers overlap

with the MMO area of study also, especially towards the coast at Dover, this matches with the MMO “adults and juveniles” category.

Following these comments, the validity of the original spatial output for this species life stage was confirmed (Figure 4).

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data highlighted that the model tends to underestimate the presence of the species’ life stage, with 62% of the actual presence data (survey data) being predicted as absence by the model (false negative rate).

When considering the overall model accuracy (i.e. considering its prediction of both presence and absence of plaice juveniles), the total misclassification error measured during validation was 10%, hence leading to a high confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), led to an increase in the overall confidence in the spatial output from low (before validation; Figure 5a) to **moderate** (after validation; Figure 5b).

Figure 4: Validated map of nursery habitat of European plaice (*Pleuronectes platessa*) predicted by classification tree modelling of the distribution of juveniles (40-180mm total length) in the South marine plan areas. Nursery habitat is identified with probability of presence >50%.

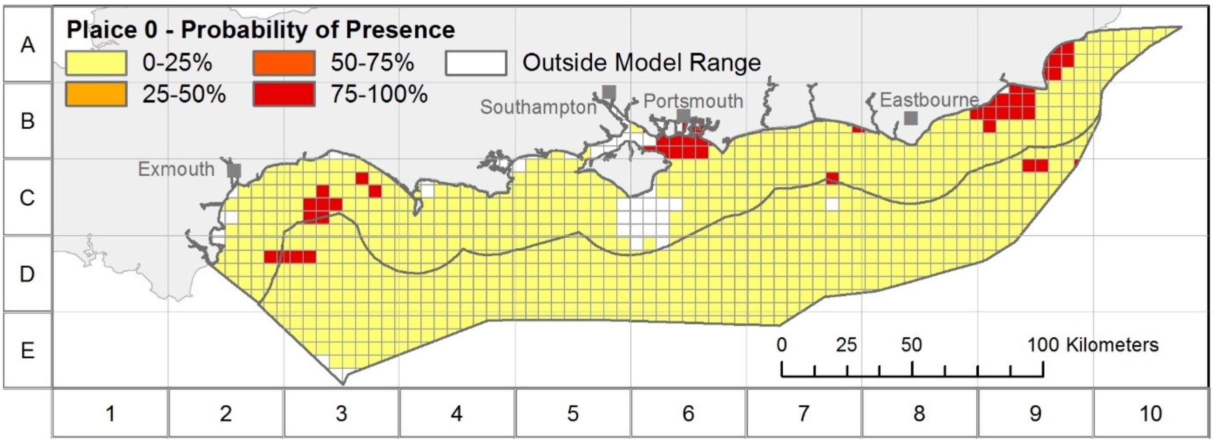

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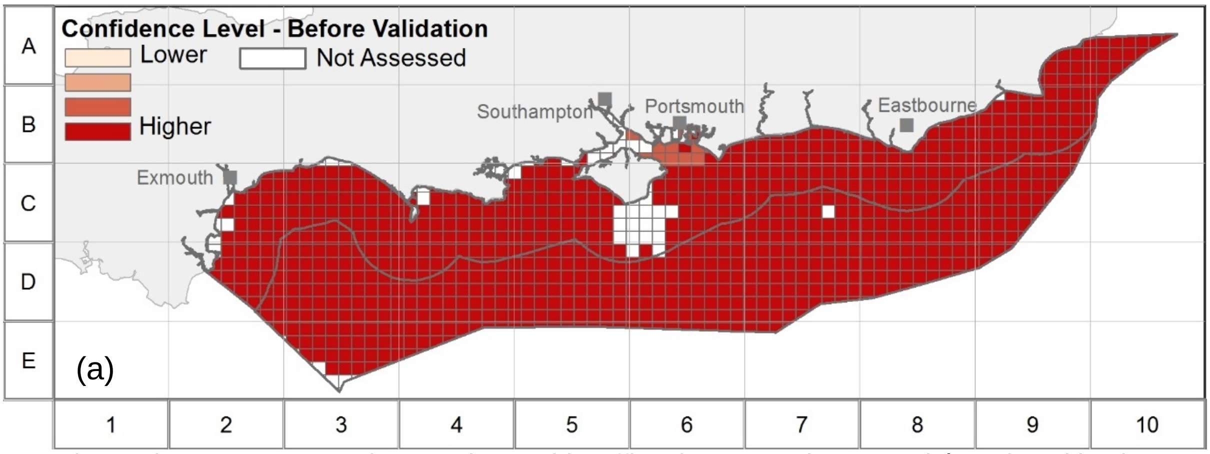
Figure 5: Confidence associated with the predicted nursery habitat of European plaice (*Pleuronectes platessa*) in the South marine plan areas: a) before validation (overall confidence: low); b) after validation (overall confidence: moderate).



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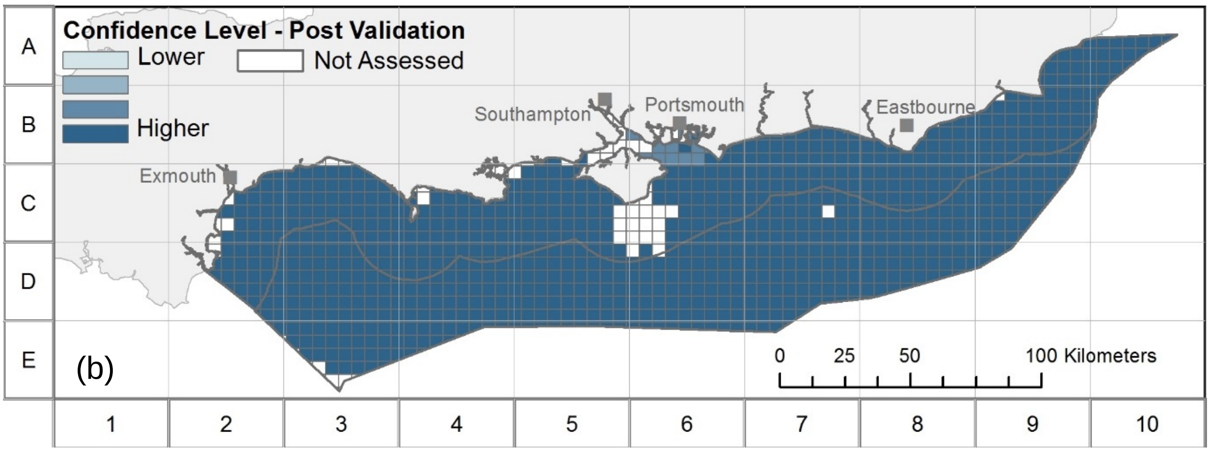

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European plaice eggs (spawning habitat)

Expert judgement:

- Cefas: Spawning habitat is generally restricted to the Eastern Channel and grounds extend from inshore to offshore (i.e. across UK/ France boundary)

Following these comments, specific areas were marked on the validated maps (Figure 6 and 7b):

1. Areas where the model underestimates the presence of plaice spawning grounds; these were also areas where high intensity plaice spawning grounds

were identified (Ellis *et al*., 2012); as a result a lower confidence is associated to the model output in these areas.

2. Areas where the model underestimates the presence of adult plaice; these were also areas where low intensity plaice spawning grounds were identified (Ellis *et al*., 2012); as a result a lower confidence is associated to the model output in these areas.

3. Areas where the model possibly overestimates the presence of plaice spawning grounds and as a result a lower confidence is associated to the model output in these areas; these were areas where no spawning grounds were identified by Ellis *et al*. (2012), although Coull *et al*. (1998) suggested the presence of this habitat on the eastern part of this area.

In the Western Channel, the model prediction indicates that suitable environmental conditions for the presence of plaice eggs are likely to occur in the offshore areas to the West of the South Offshore Marine Plan Area. Although this result seems not to agree with existing knowledge and evidence, it is noted that the supporting evidence available for this area consists mainly of data collected during the 1991 sole survey undertaken by Cefas.

The 1991 sole survey targeted in particular sole eggs, and therefore it was undertaken in spring, during the peak spawning season for the species (Ellis *et al*., 2012). However, this seasonality is less suitable for assessing the presence of plaice eggs at an early stage of development, as the peak spawning season for the species is centred around January and February (Ellis *et al*., 2012). Therefore this limits the knowledge of the actual distribution of plaice eggs in the Western Channel, and, although there is lower confidence in the predictions for this area, the potential for these areas to have plaice spawning grounds cannot be excluded.

Overall confidence:

The overall confidence associated with the map for this species life stage was **moderate-low**, as initially assessed during the model development (MMO, 2013; Figure 7a). No suitable independent dataset could be identified for the statistical validation of the model for plaice eggs distribution, therefore the validated confidence map is based only on the validation undertaken through expert judgement (Figure 7b).

Figure 6: Validated map of spawning habitat of European plaice (*Pleuronectes platessa*) predicted by classification tree modelling of the distribution of early stage eggs (1.75-2.28mm diameter) in the South marine plan areas. Spawning habitat is identified with probability of presence >50%.

The cells outlined in black indicate areas where: (1&2) the model underestimates the presence of plaice eggs; (3) the model possibly overestimates the presence of plaice eggs.

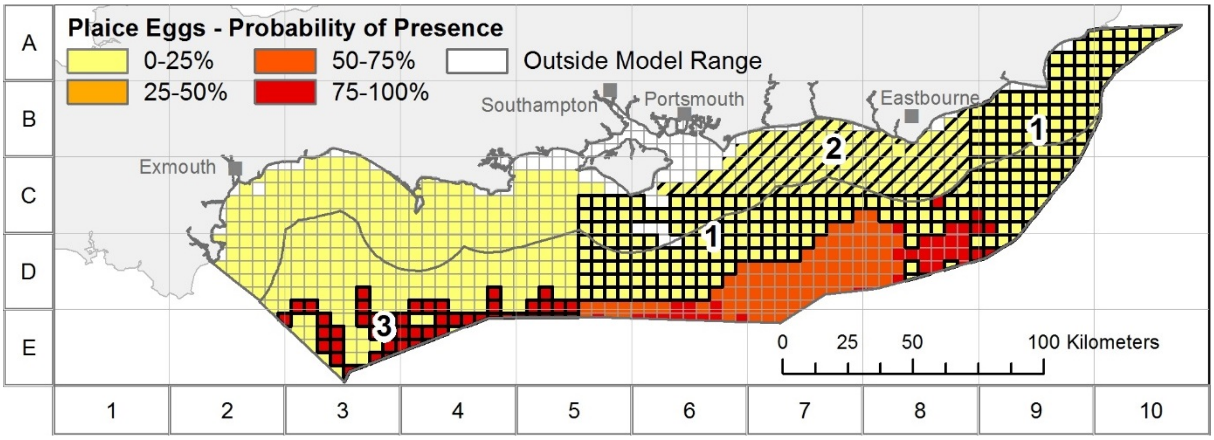

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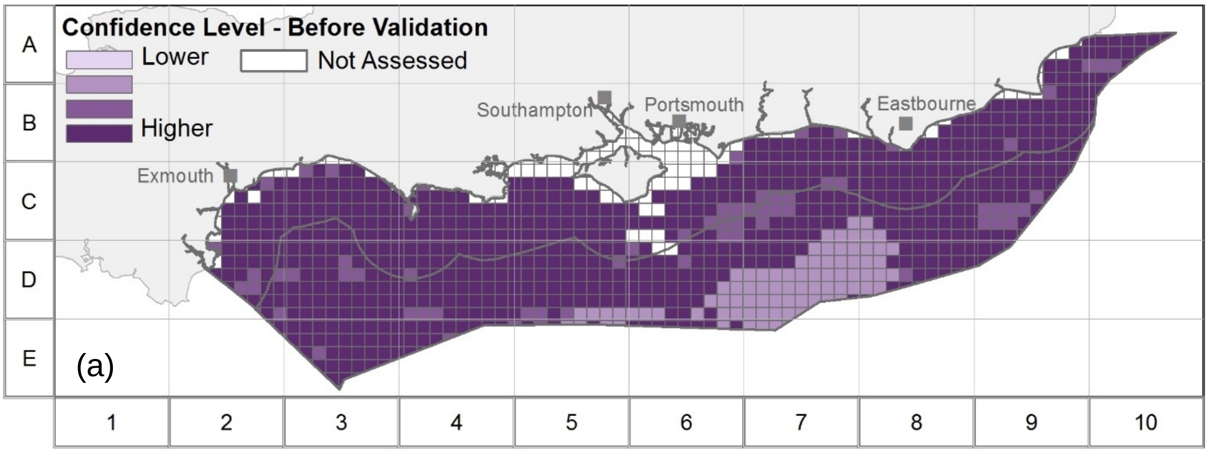
Figure 7: Confidence associated with the predicted spawning habitat of European plaice (*Pleuronectes platessa*) in the South marine plan areas: a) before validation (overall confidence: moderate-low); b) after validation (no statistical validation was possible therefore overall confidence remains moderate-low).

The cells outlined in black indicate areas where: the model underestimates or possibly overestimates the presence of plaice eggs.



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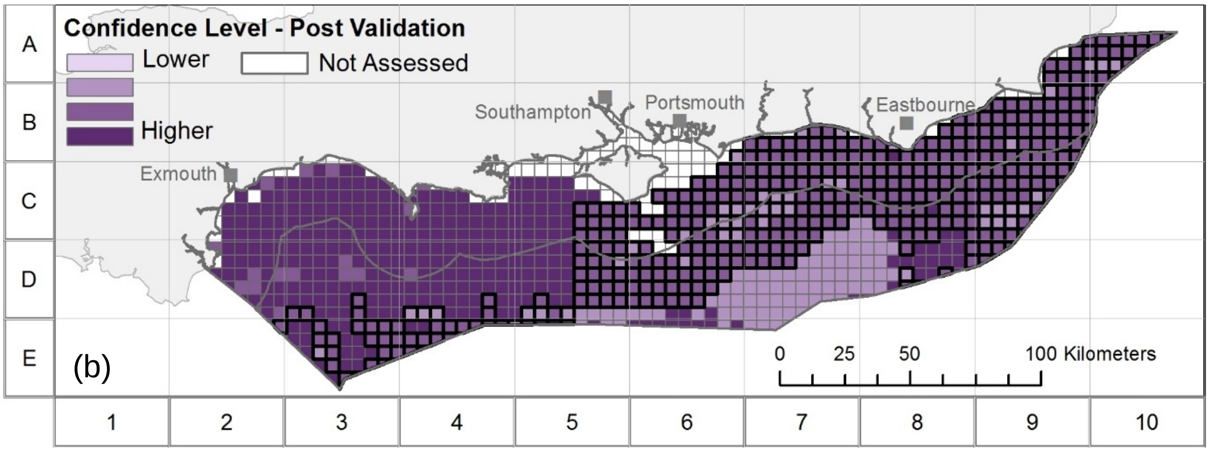

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As previously highlighted in MMO (2013), there is uncertainty in associating spawning habitats of a fish species with the distribution of eggs, particularly when the egg stage is pelagic as for plaice. This uncertainty is associated with the fact that during egg development (e.g. three to six days for the early stage eggs considered for plaice) eggs can be transported far from the spawning grounds, hence leading to a weaker link between presence of eggs and spawning grounds location.

Including information on the abundance of eggs might lead to a decrease in the uncertainty in this association. Abundance information may be included by modelling the presence of aggregations of eggs (i.e. using a density threshold to identify higher density aggregations) rather than the mere presence of eggs, as suggested in Aires *et al*. (2014). This approach might lead to an improvement of the approach resulting in more accurate spatial outputs.

3.2.2 Sole (*Solea solea*)

The life stages modelled for this species include juveniles (40-200mm total length; likely including also >1year old) and adults (210-470mm total length).

Adult sole (foraging habitat)

Expert judgement:

- No major issues were identified during consultation.

As a result, the validity of the original spatial output for this species life stage was confirmed (Figure 8).

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) resulted in a misclassification error of 34% when considering the predictions of all the combinations of presence/absence of juveniles and adults. This led to a moderate confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), did not lead to changes in the overall confidence in the spatial output, this remaining **low** (before and after validation; Figure 9a) and b)).

Figure 8: Validated map of adult foraging habitat of common sole (*Solea solea*) predicted by classification tree modelling of the distribution of adults (210-470mm total length) in the South marine plan areas.

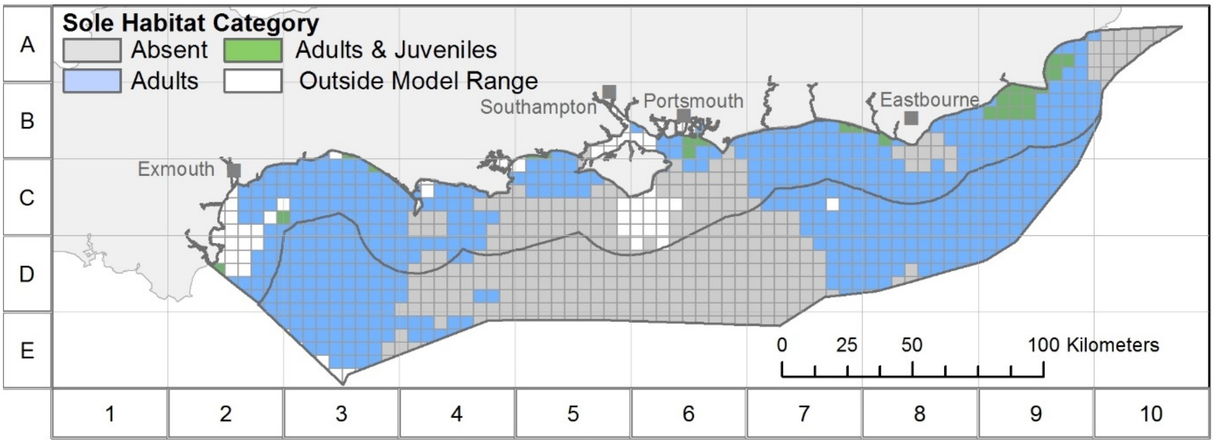
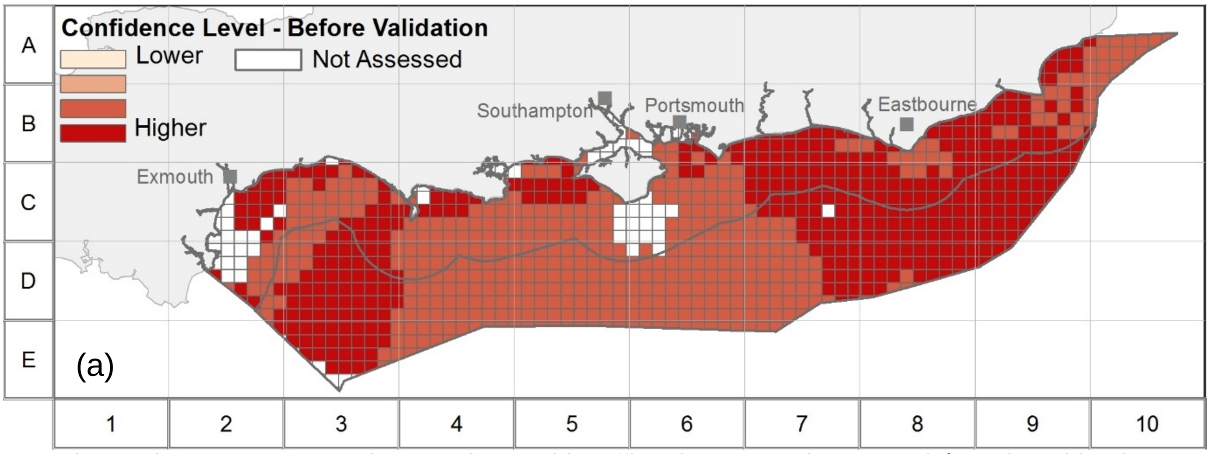


Figure 9: Confidence associated with the predicted adult foraging habitat of common sole (*Solea solea*) in the South marine plan areas: a) before validation (overall confidence: low); b) after validation (overall confidence: low).



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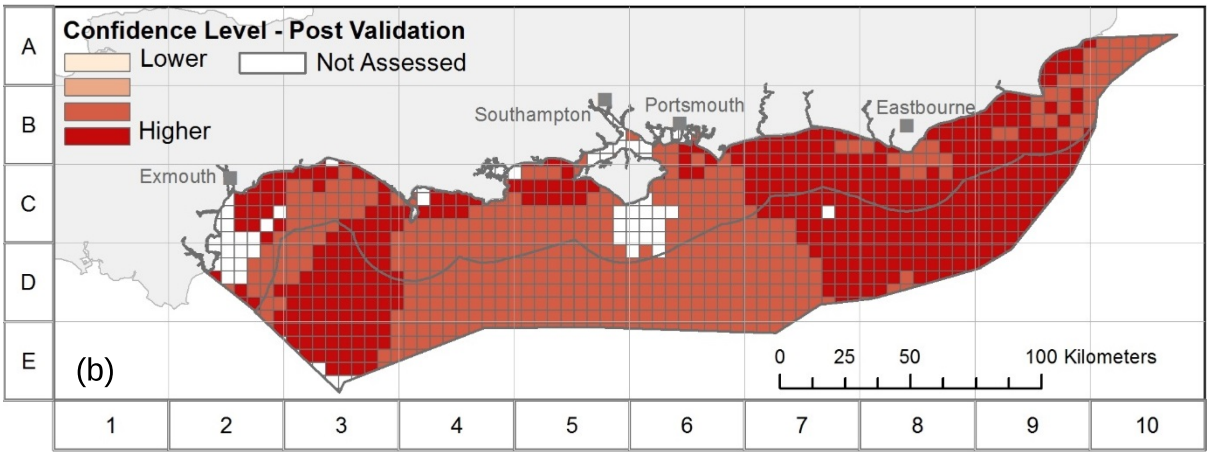

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Juvenile sole (nursery habitat)

Expert judgement:

- Cefas: Modelled nursery habitat in AB9&10 may be too extensive.
- Marine Science Scotland: The MSS model for 0-group sole shows a slightly higher probability to the coast north east of the MMO study area around the Dover-Folkestone area, this matches with the MMO “adults and juveniles” category. The Coull *et al*. (1998) sole nursery layers overlap with the MMO “adults and juveniles” category.

Following these comments, specific areas were marked on the validated maps (Figure 10 and 11b):

1. Areas where the model would appear to overestimate the presence of juvenile sole; notwithstanding this suggestion, no changes were made to the confidence level for the reasons explained below.

It is noted that the overestimation of nursery areas compared to Cefas data might be partly attributed to the fact that a larger cut-off size for juveniles was used in MMO (2013) (210mm total length, likely including also juveniles of >1y of age) compared to Ellis *et al*. (2012; 130mm, including 0-group only). Considering also that a lower confidence was already associated with most of the cells in the marked area, the confidence level was not lowered in that area (Figure 11b).

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data highlighted that the model tends to underestimate the presence of the species' life stage, with 44% of the actual presence data (based on survey data) being predicted as absence by the model (false negative rate).

When considering the overall model accuracy (i.e. considering its prediction of both presence and absence of sole juveniles), the total misclassification error measured during validation was 9%, hence leading to a high confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), led to an increase in the overall confidence in the spatial output from low (before validation; Figure 11a) to **moderate** (after validation; Figure 11b).

Figure 10: Validated map of nursery habitat of common sole (*Solea solea*) predicted by classification tree modelling of the distribution of juveniles (40-200mm total length) in the South marine plan areas. Nursery habitat is identified with probability of presence >50%.
The cells outlined in black (1) indicate locations where the model apparently overestimates the presence of juvenile sole.

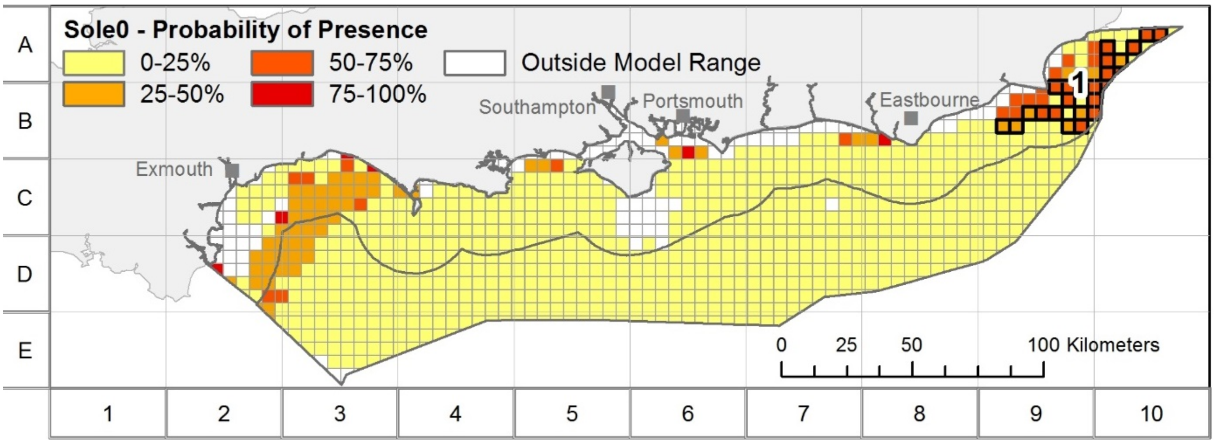

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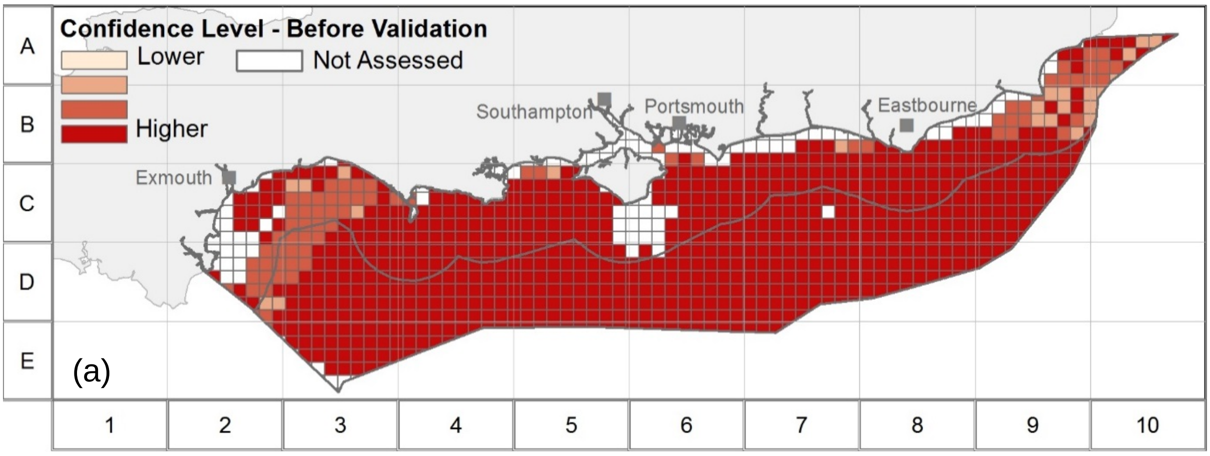
Figure 11: Confidence associated with the predicted nursery habitat of common sole (*Solea solea*) in the South marine plan areas: a) before validation (overall confidence: low); b) after validation (overall confidence: moderate). The cells outlined in black indicate locations where the model apparently overestimates the presence of juvenile sole.



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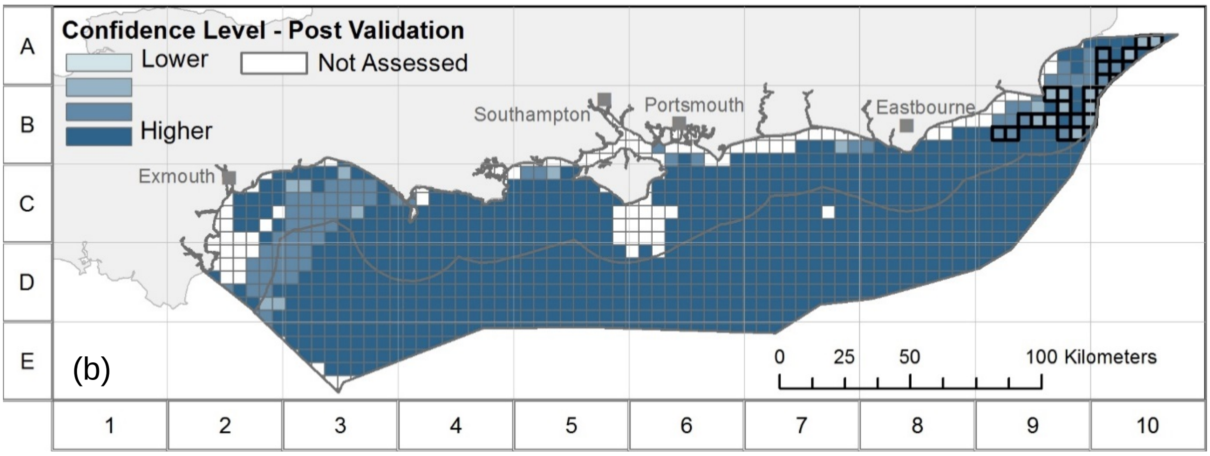

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3.2.3 Lemon sole (*Microstomus kitt*)

The life stages modelled for this species included juveniles (40-200mm total length; likely including also >1year old) and adults (210-400mm total length).

Adult lemon sole (foraging habitat)

Expert judgement:

- Cefas: Adult foraging distribution suggests a southerly extent in D&E2 that does not match survey data.

- MMO: There is a fishery for lemon sole near Newhaven (C8, further to the west of area where presence is predicted by the model) where the species absence is indicated on the map.

Following these comments, specific areas were marked on the validated maps (Figure 12 and 13b):

1. Area where the model overestimates the presence of adult lemon sole; the prediction of presence here should be considered as of lower confidence (note that lower confidence was already associated with this area).

2. Area where the model underestimates the presence of adult lemon sole; the prediction of absence here should be considered as of lower confidence.

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) resulted in a misclassification error of 59% when considering the predictions of all the combinations of presence/absence of juveniles and adults. This led to a low confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), led to a decrease in the overall confidence in the spatial output from moderate (before validation; Figure 13a) to **low** (after validation; Figure 13b).

Figure 12: Validated map of adult foraging habitat of lemon sole (*Microstomus kitt*) predicted by classification tree modelling of the distribution of adults (210-400mm total length) in the South marine plan areas.
The cells outlined in black indicate locations where: (1) the model overestimates the presence of adult lemon sole; (2) the model underestimates the presence of adult lemon sole.

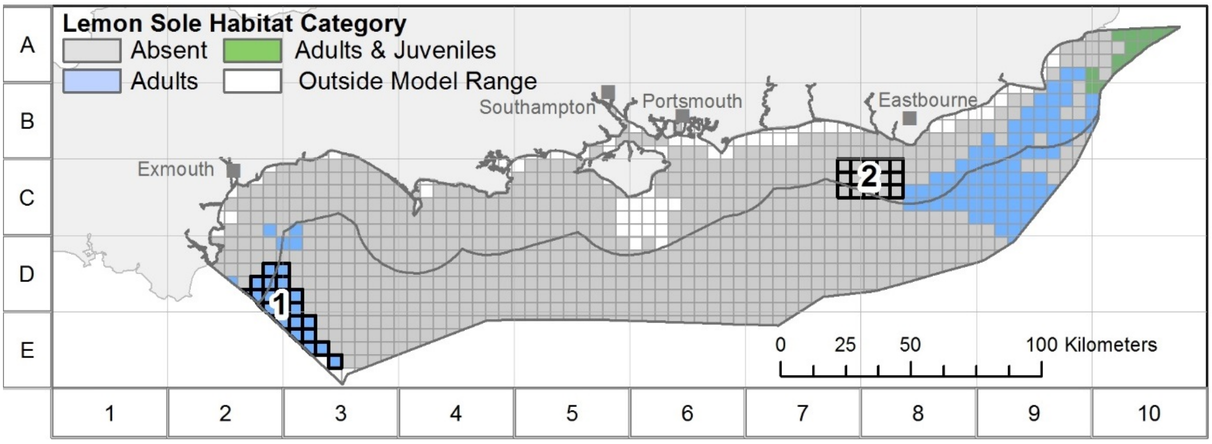
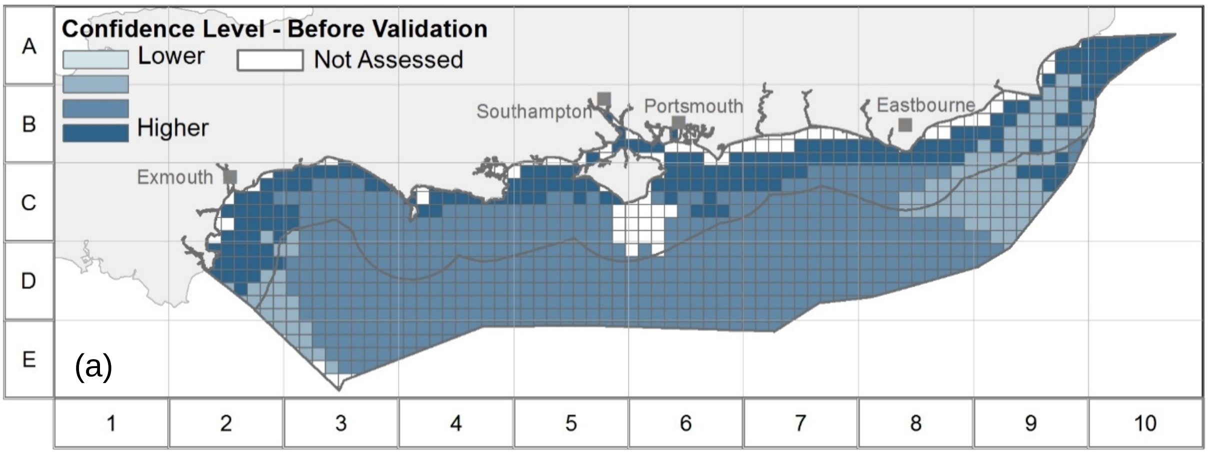


Figure 13: Confidence associated with the predicted adult foraging habitat of lemon sole (*Microstomus kitt*) in the South marine plan areas: a) before validation (overall confidence: moderate); b) after validation (overall confidence: low).
The cells outlined in black indicate locations where the model overestimates or underestimates the presence of adult lemon sole.



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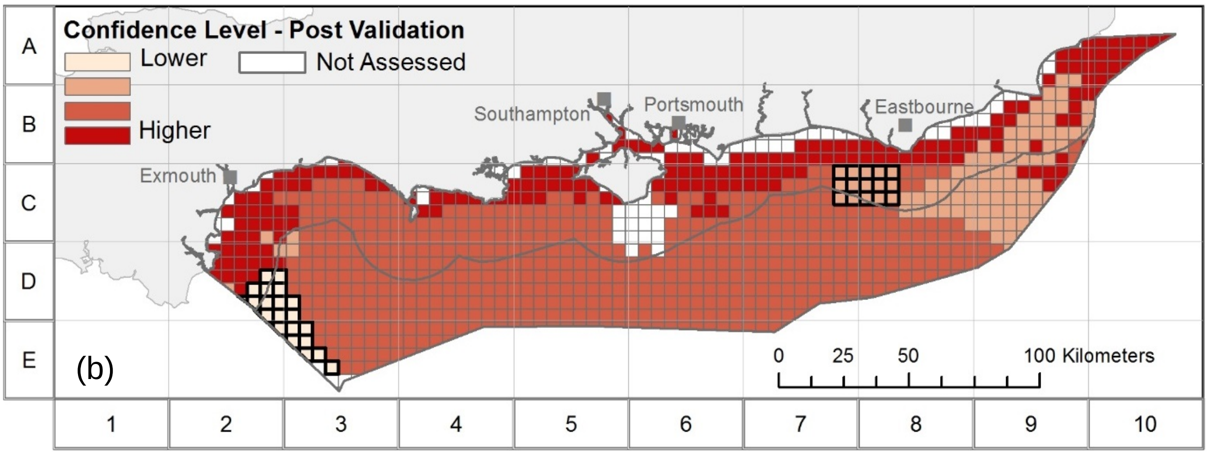

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Juvenile lemon sole (nursery habitat)

Expert judgement:

- Department of the Environment Northern Ireland: Nursery areas for lemon sole were identified by Coull *et al*. (1998) as inshore waters both to the east, which agreed with the current study, and also to the west of the study area, which was not identified in the current study.

Following this comment, specific areas were marked on the validated maps (Figure 14 and 15b):

1. Area where the model underestimates the presence of juvenile lemon sole, by comparison with Coull *et al*. (1998; this species was not included in most updated fish sensitivity maps by Ellis *et al*. 2012 and Marine Science Scotland, 2014); prediction of absence here should be considered as of lower confidence

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) highlighted that the model tends to underestimate the presence of the species' life stage, with all actual presence data in the western region of the study area (survey data) being predicted as absence by the model (false negative rate). This agreed with the underestimation of the presence of juveniles in the western region of the study area as highlighted during consultation, although it is of note that lemon sole juveniles were only sparsely occurring in the samples collected in this area (in 7 samples out of the 102 samples considered for validation of the model).

When considering the overall model accuracy (i.e. considering its prediction of both presence and absence of lemon sole juveniles), the total misclassification error measured during validation was 7%, hence leading to a high confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), led to an increase in the overall confidence in the spatial output from low (before validation; Figure 15a) to **moderate** (after validation; Figure 15b).

Figure 14: Validated map of nursery habitat of lemon sole (*Microstomus kitt*) predicted by classification tree modelling of the distribution of juveniles (40-200mm total length) in the South marine plan areas. Nursery habitat is identified with probability of presence >50%.
The cells outlined in black (1) indicate locations where the model underestimates the presence of juvenile lemon sole.

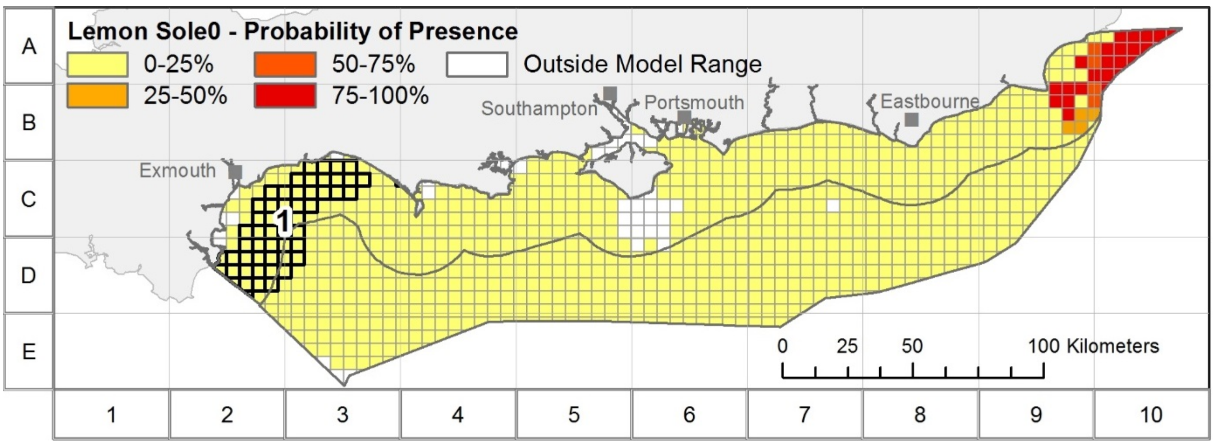

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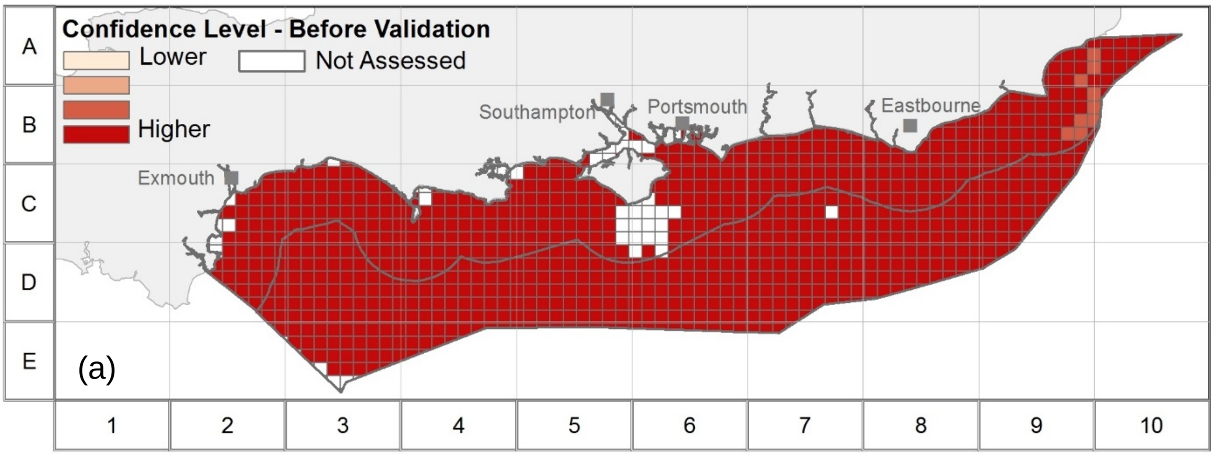
Figure 15: Confidence associated with the predicted nursery habitat of lemon sole (*Microstomus kitt*) in the South marine plan areas: a) before validation (overall confidence: low); b) after validation (overall confidence: moderate). The cells outlined in black indicate locations where the model underestimates the presence of juvenile lemon sole.



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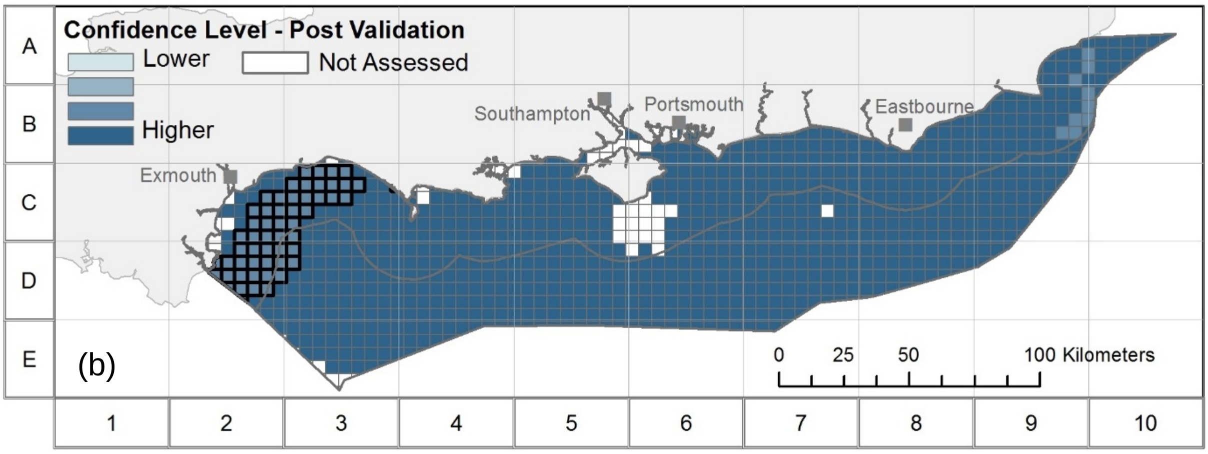

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3.2.4 Dab (*Limanda limanda*)

The life stages modelled for this species included juveniles (20-80mm total length; 0-group) and adults (90-380mm total length).

Adult dab (foraging habitat)

Expert judgement:

- Cefas: Adult foraging distribution maps show extensions of range into muddy areas in D&E3 and in C&D7 that are not matched by survey data (similar to plaice).

Following this comment, specific areas were marked on the validated maps (Figure 16 and 17b):

1. Areas where the model overestimates the presence of adult dab; the prediction of presence here should be considered as of lower confidence (note that lower confidence was already associated with prediction in some cells within these areas)

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) resulted in a misclassification error of 42% when considering the predictions of all the combinations of presence/absence of juveniles and adults. This lead to a moderate confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), led to a slight decrease in the overall confidence in the spatial output from moderate (before validation; Figure 17a) to **moderate-low** (after validation; Figure 17b).

Figure 16: Validated map of adult foraging habitat of dab (*Limanda limanda*) predicted by classification tree modelling of the distribution of adults (90-380mm total length) in the South marine plan areas.
The cells outlined in black (1) indicate locations where the model overestimates the presence of adult dab.

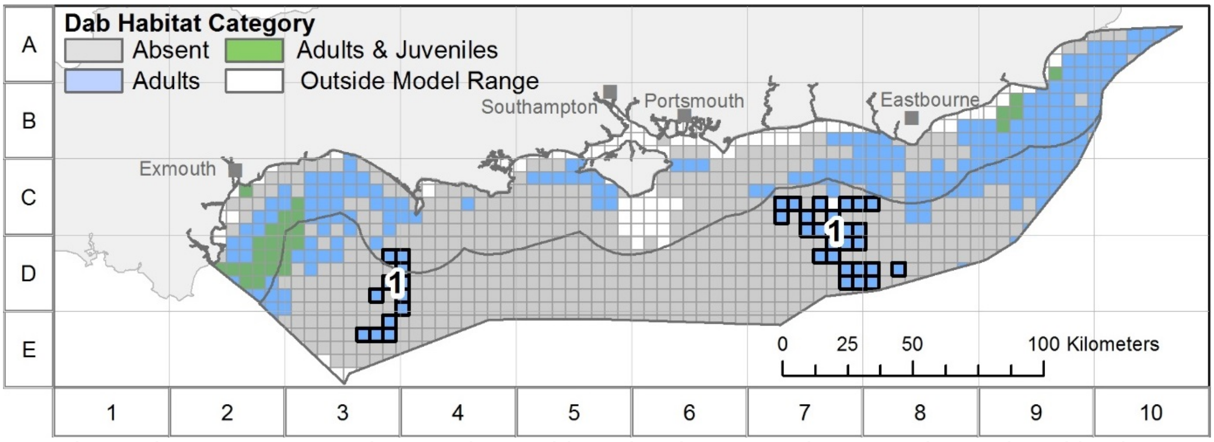

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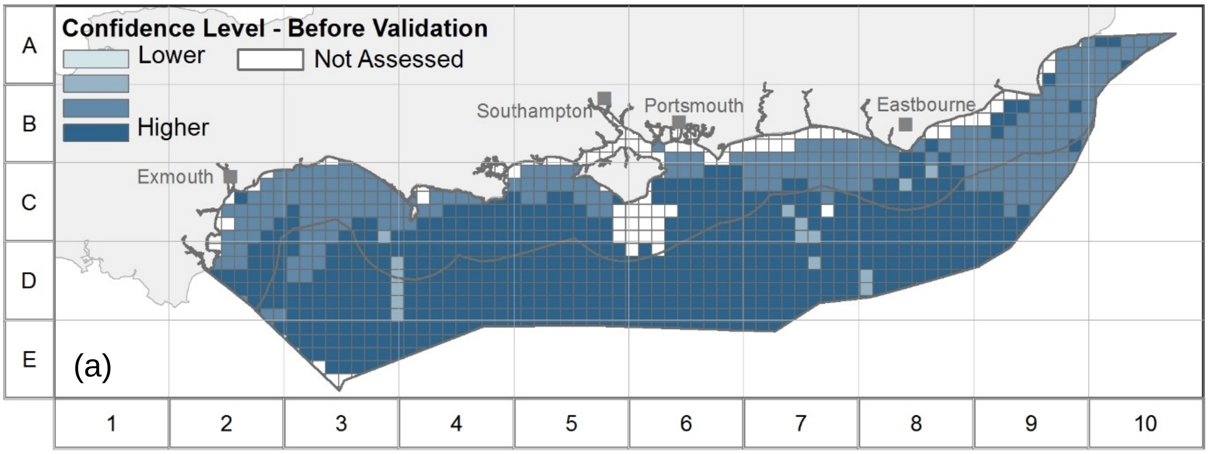
Figure 17: Confidence associated with the predicted adult foraging habitat of dab (*Limanda limanda*) in the South marine plan areas: a) before validation (overall confidence: moderate); b) after validation (overall confidence: moderate-low).
The cells outlined in black indicate locations where the model overestimates the presence of adult dab.



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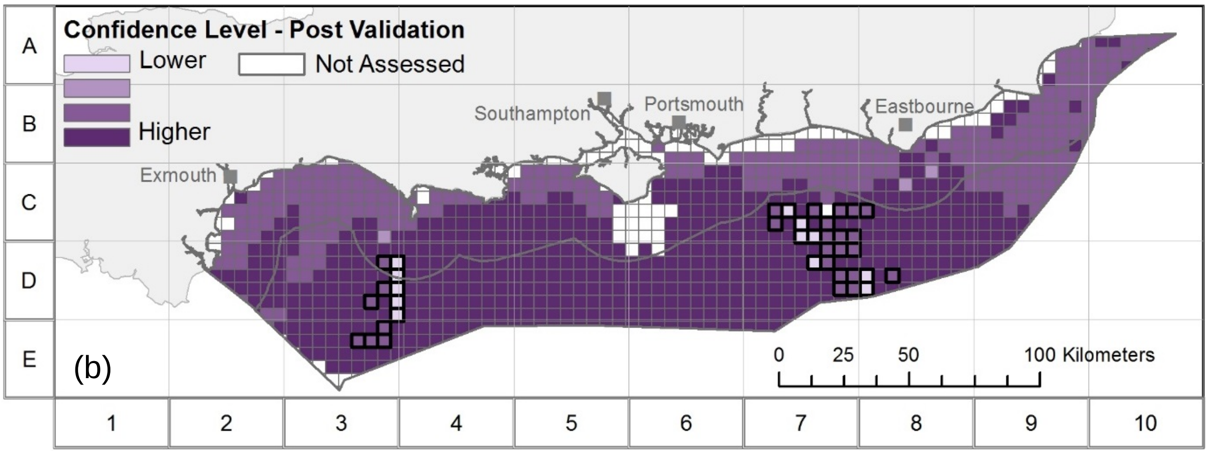

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Juvenile dab (nursery habitat)

Expert judgement:

- No major issues were identified during consultation.

As a result, the validity of the original spatial output for this species life stage was confirmed (Figure 18).

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) highlighted that the model tends to underestimate the presence of the species' life stage, with all actual presence data in the western region of the study area (survey data) being predicted as absence by the model (false negative). It is of note however, that dab juveniles only occurred sparsely in the samples collected in this area (in 17 out of the 102 samples considered for validation of the model).

When considering the overall model accuracy (i.e. considering its prediction of both presence and absence of dab juveniles), the total misclassification error measured during validation was 17%, hence leading to a high confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), led to an increase in the overall confidence in the spatial output from low (before validation; Figure 19a) to **moderate** (after validation; Figure 19b).

Figure 18: Validated map of nursery habitat of dab (*Limanda limanda*) predicted by classification tree modelling of the distribution of juveniles (20-80mm total length) in the South marine plan areas. Nursery habitat is identified with probability of presence >50%.

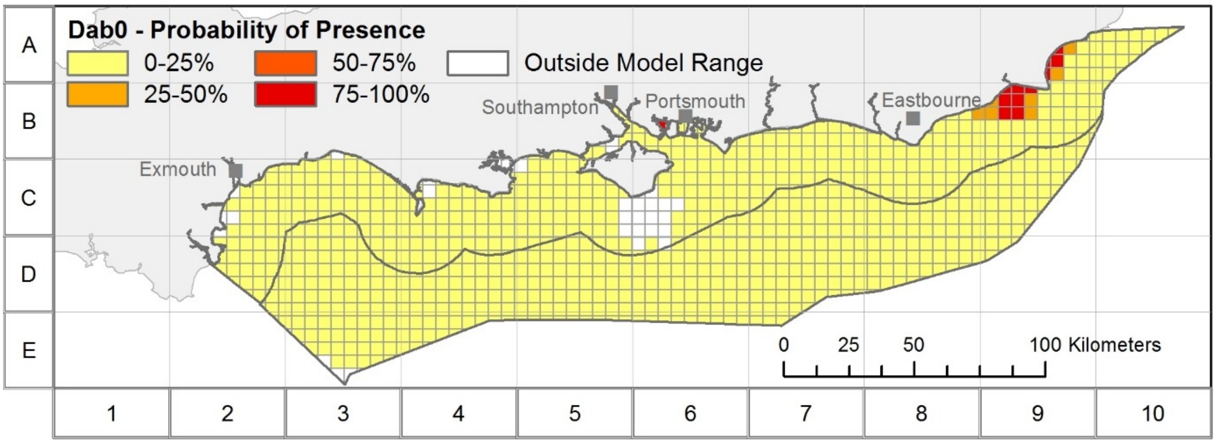

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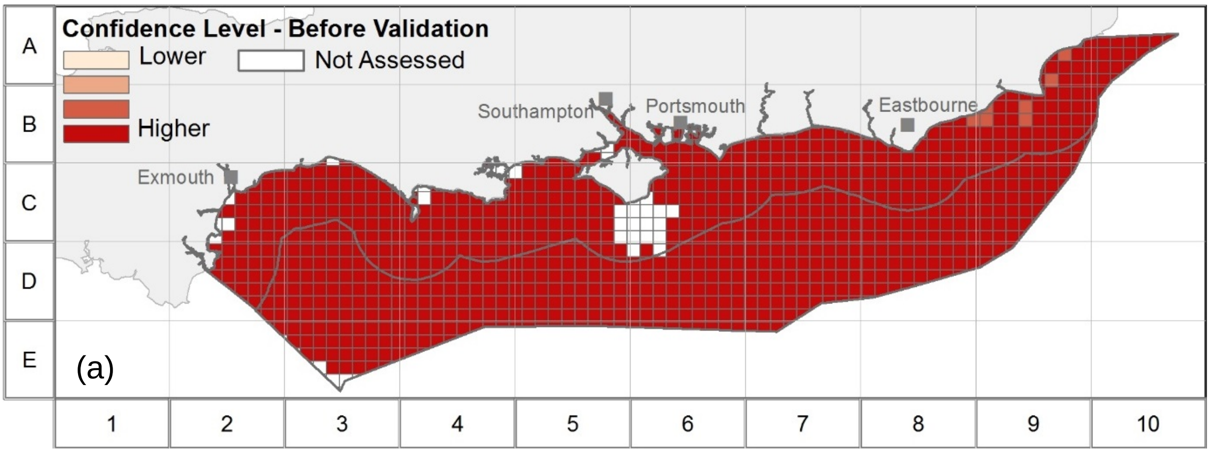
Figure 19: Confidence associated with the predicted nursery habitat of dab (*Limanda limanda*) in the South marine plan areas: a) before validation (overall confidence: low); b) after validation (overall confidence: moderate).



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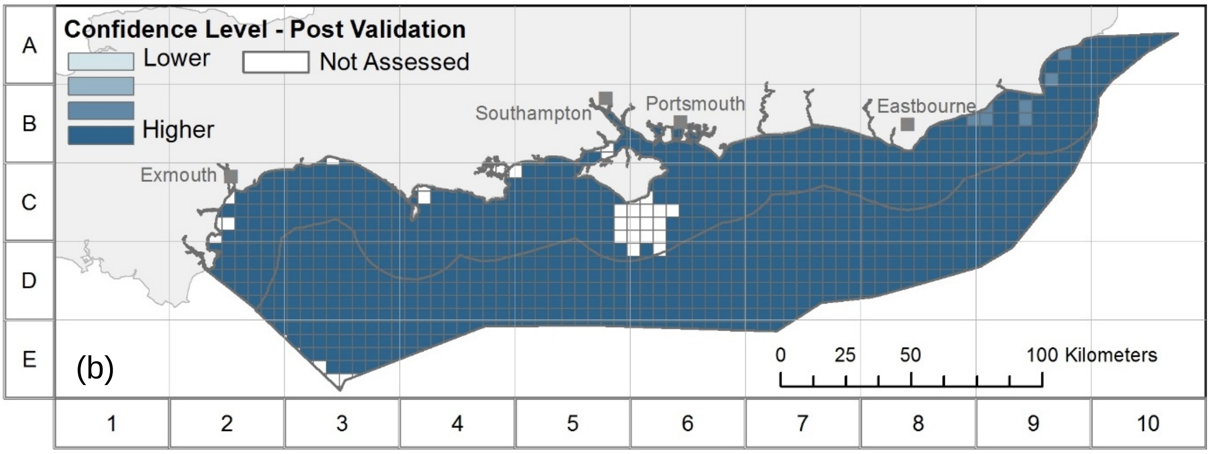

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3.2.5 Red gurnard (*Chelidonichthys cuculus*)

The life stages modelled for this species included juveniles (50-180mm total length; 0-group) and adults (190-420mm total length).

Adult red gurnard (foraging habitat)

Expert judgement:

- Cefas: Adult distribution in CDE5 is unlikely given sediment type (gravel/ rock).

Following this comment, specific areas were marked on the validated maps (Figure 20 and 21b):

1. Areas where the model likely overestimates presence of adult red gurnard; prediction of presence here should be considered as of lower confidence (note that lower confidence was already associated with the prediction in some cells within these areas).

It is noted that, according to the sediment map used for the model training and application, the relative coverage of mixed sediment was lower in this area. Also the relative coverage of coarse sediment and rocky substratum (as derived from EMODnet/EUSeaMap) were initially included in the analysis, but they were not selected by the model as relevant predictors. It is likely that errors/uncertainties in the sediment data layers used for modelling have led to errors in the model predictions.

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) resulted in a misclassification error of 76% when considering the predictions of all the combinations of presence/absence of juveniles and adults. This led to a low confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), led to a decrease in the overall confidence in the spatial output from moderate-low (before validation; Figure 21a) to **low** (after validation; Figure 21b).

Figure 20: Validated map for adult foraging habitat of red gurnard (*Chelidonichthys cuculus*) predicted by classification tree modelling of the distribution of adults (190-420mm total length) in the South marine plan areas. The cells outlined in black (1) indicate locations where the model overestimates the presence of adult red gurnard.

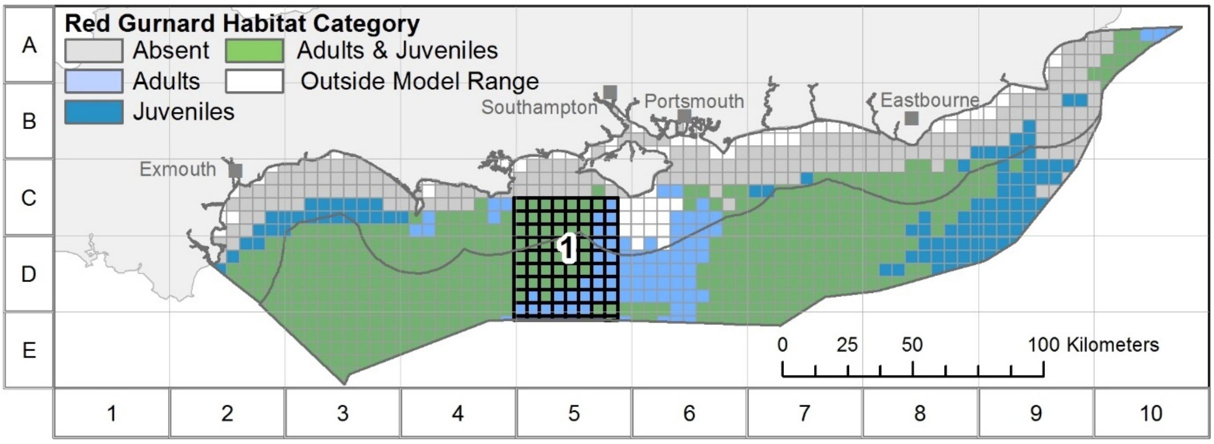
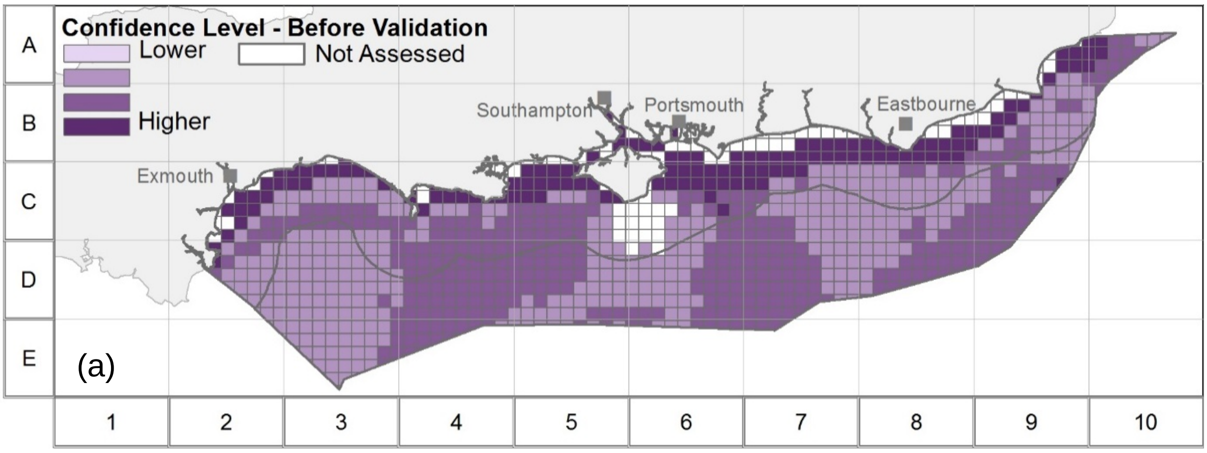


Figure 21: Confidence associated with the predicted adult foraging habitat of red gurnard (*Chelidonichthys cuculus*) in the South marine plan areas: a) before validation (overall confidence: moderate-low); b) after validation (overall confidence: low).

The cells outlined in black indicate locations where the model overestimates the presence of adult red gurnard.



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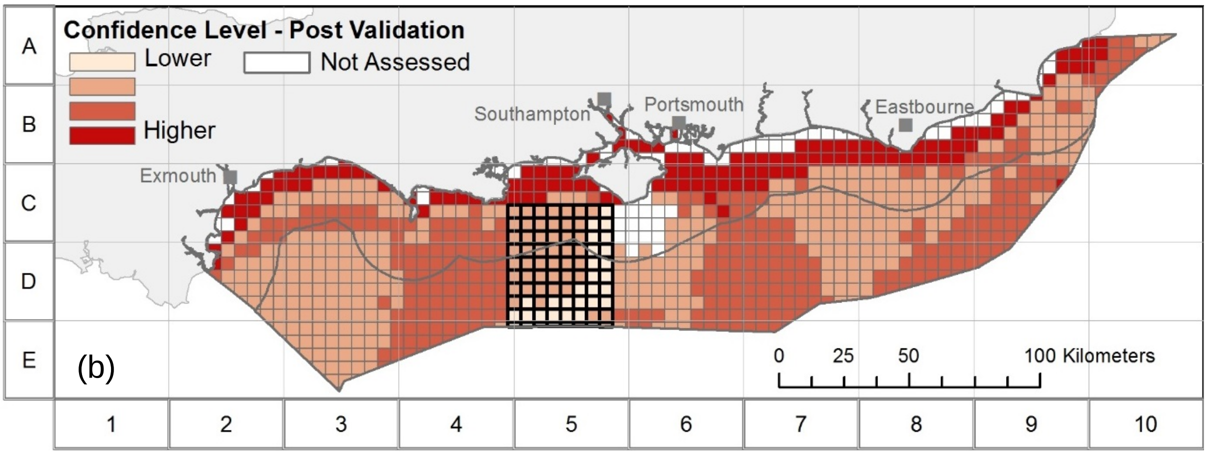

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Juvenile red gurnard (nursery habitat)

Expert judgement:

- No major issues were identified during consultation.

As a result, the validity of the original spatial output for this species life stage was confirmed (Figure 22).

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) highlighted that the model tends to overestimate the presence of the species' life stage, with all actual absence data in the western region of the study area (survey data) being predicted as presence by the model (false positive rate).

When considering the overall model accuracy (i.e. considering its prediction of both presence and absence of dab juveniles), the total misclassification error measured during validation was 41%, hence leading to a moderate confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), did not lead to changes in the overall confidence in the spatial output, this remaining **moderate-low** (before and after validation; Figure 23).

Figure 22: Validated map of nursery habitat of red gurnard (*Chelidonichthys cuculus*) predicted by classification tree modelling of the distribution of juveniles (50-180mm total length) in the South marine plan areas. Nursery habitat is identified with probability of presence >50%.

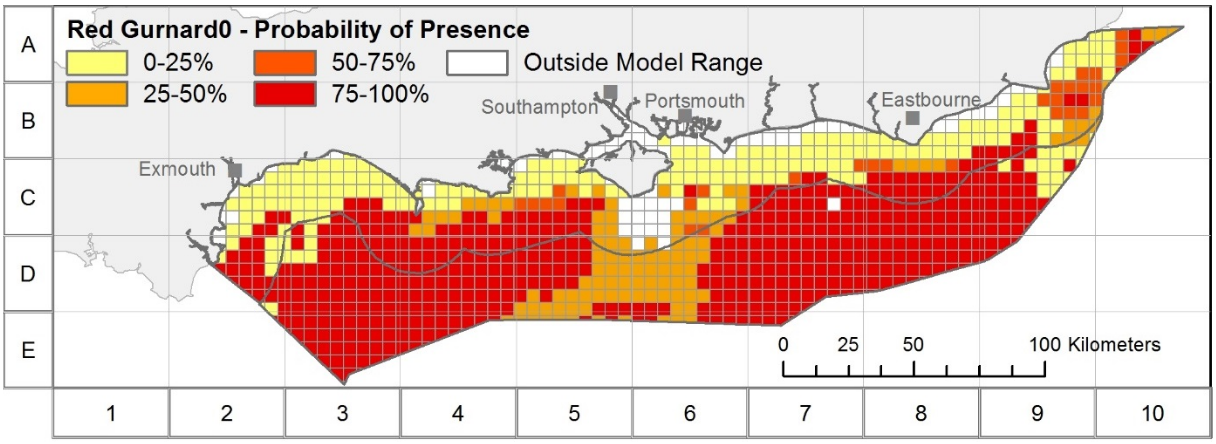

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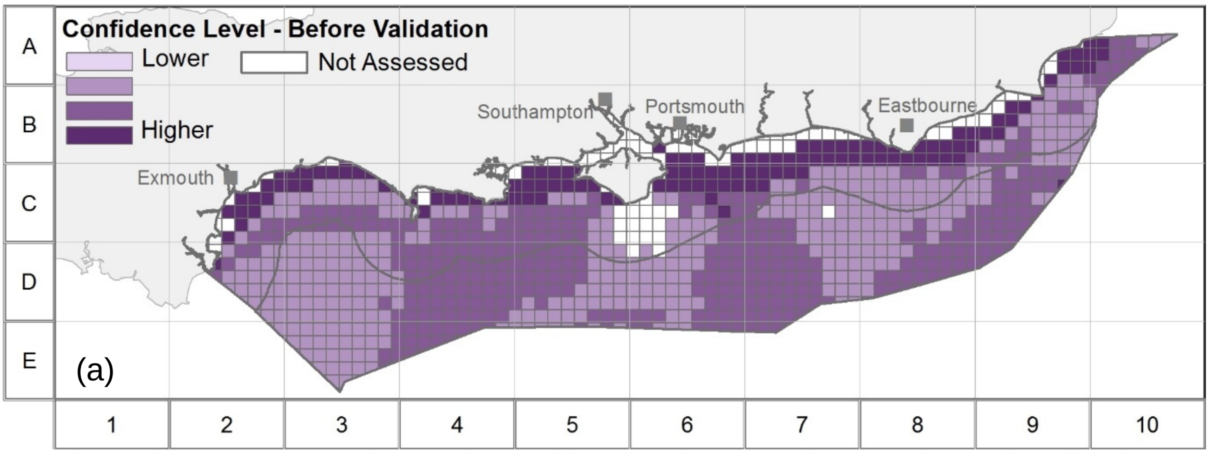
Figure 23: Confidence associated with the predicted nursery habitat of red gurnard (*Chelidonichthys cuculus*) in the South marine plan areas: a) before validation (overall confidence: moderate-low); b) after validation (overall confidence: moderate-low).



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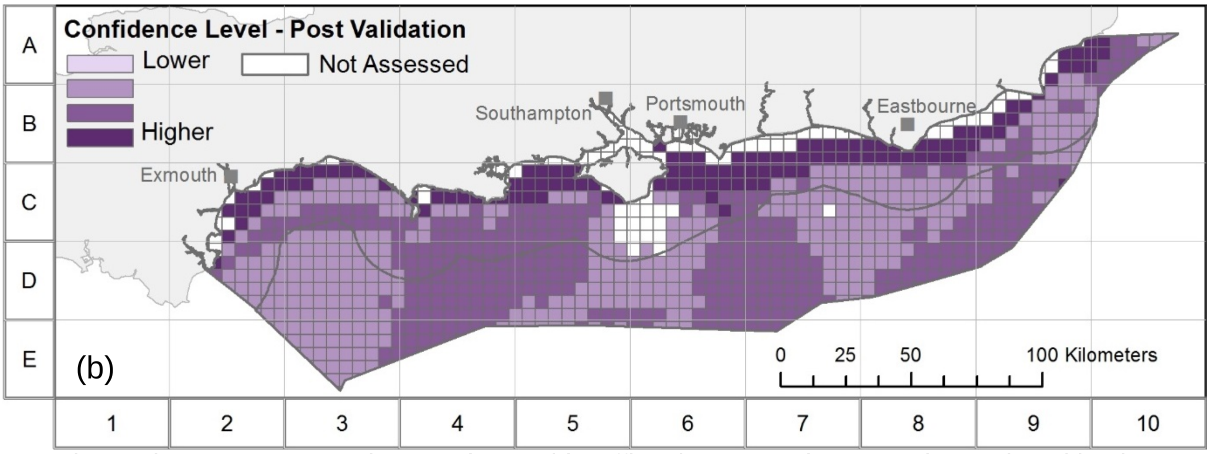

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3.2.6 Common dragonet (*Callionymus lyra*)

The life stages modelled for this species included juveniles (10-95mm total length; likely including also >1year old) and adults (100-290mm total length).

Adult common dragonet (foraging habitat)

Expert judgement:

- Cefas: Extent of habitat suitable for juvenile distribution should extend along coast; it is not solely restricted to C2, C3 and C4.

Following this comment, although no issues were identified in the predicted distribution of adults of the species, specific areas were marked on the validated maps regarding the identified issue with the distribution of juveniles (Figure 24 and 25b):

1. Inshore areas where the model likely underestimates the presence of juvenile common dragonet (in combination with adults of the species); the prediction of absence of juveniles here should be considered of lower confidence.

It is noted that the model was unable to predict the presence of the species in more inshore areas (white cells in Figure 24) where the species most likely occurs.

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) resulted in a misclassification error of 96% when considering the predictions of all the combinations of presence/absence of juveniles and adults. This led to a low confidence in the model predictive ability. This was mostly due to the fact that, according to the survey data, common dragonet adults are only sparsely present in the western region of the study area (in 4 out of the 103 samples considered for validation of the model), whereas the model predicts their presence at all survey stations.

This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), did not lead to changes in the overall confidence in the spatial output, this remaining **low** (before and after validation; Figure 25a and 25b).

Figure 24: Validated map of adult foraging habitat of common dragonet (*Callionymus lyra*) predicted by classification tree modelling of the distribution of adults (100-290mm total length) in the South marine plan areas.
The cells outlined in black (1) indicate inshore locations where the model underestimates the presence of adult common dragonet in combination with juveniles of the species.

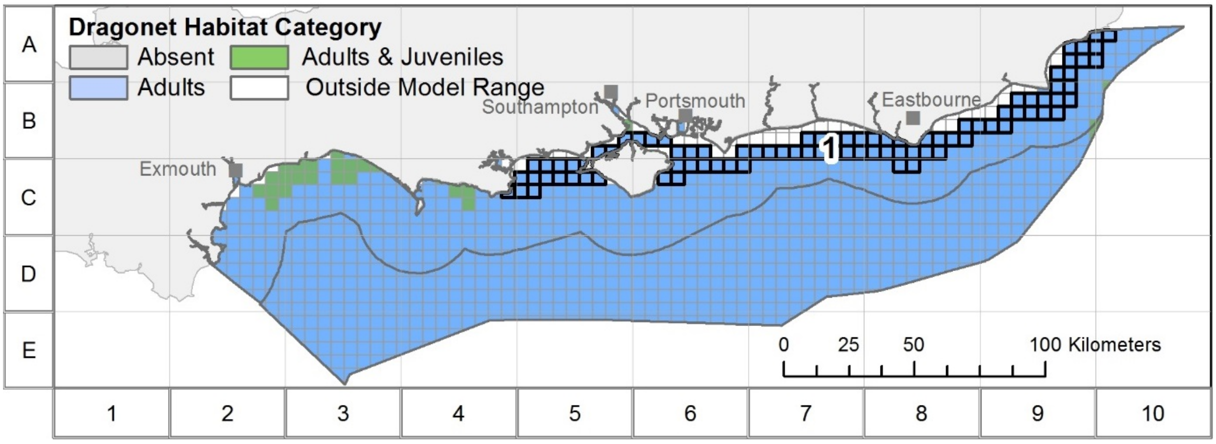
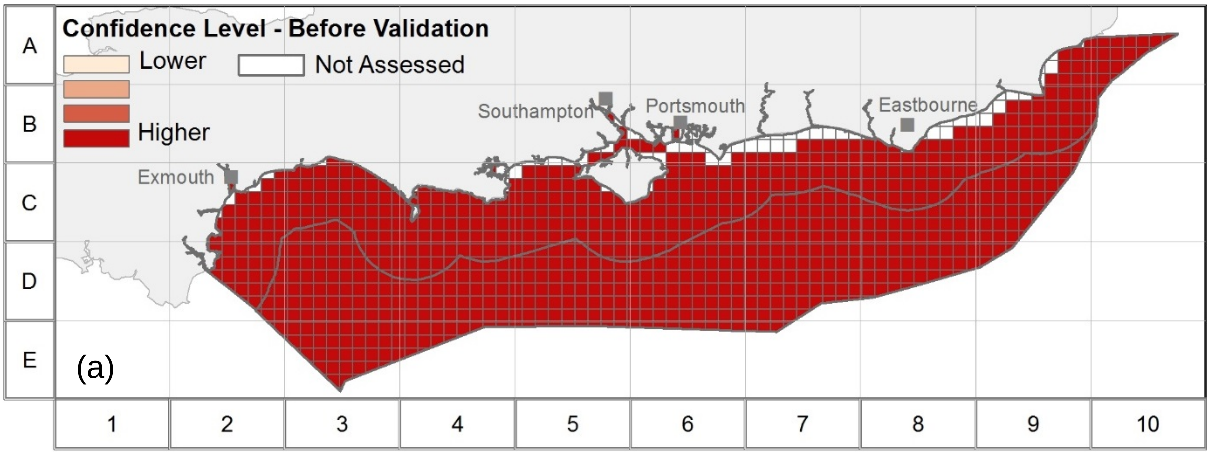


Figure 25: Confidence associated with the predicted adult foraging habitat of common dragonet (*Callionymus lyra*) in the South marine plan areas: a) before validation (overall confidence: low); b) after validation (overall confidence: low).
The cells outlined in black indicate inshore locations where the model underestimates the presence of adult common dragonet in combination with juveniles of the species.



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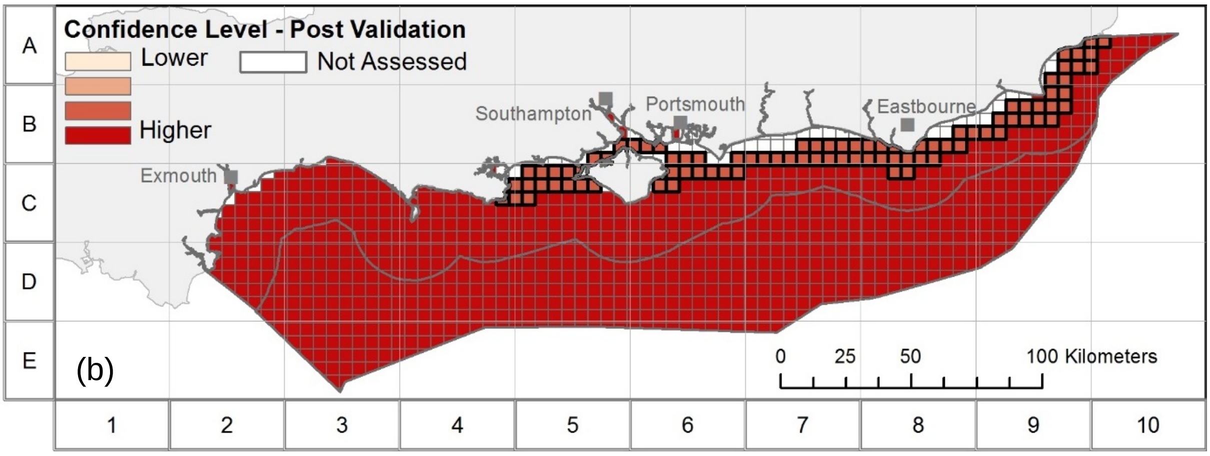

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Juvenile common dragonet (nursery habitat)

Expert judgement:

- Cefas: Extent of habitat suitable for juvenile distribution should extend along coast; it is not solely restricted to C2, C3 and C4.

Following this comment, specific areas were marked on the validated maps (Figure 26 and 27b):

1. Inshore areas where the model likely underestimates the presence of juvenile common dragonet; the prediction of absence of juveniles here should be considered of lower confidence.

It is noted that the model was unable to predict the presence of the species in more inshore areas (white cells in Figure 26) where the species most likely occurs.

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) highlighted that the model tends to overestimate the presence of the species' life stage, with all actual absence data in the western region of the study area (survey data) being predicted as presence by the model (false positive rate). This was mainly due to the fact that no juveniles were recorded in the validation survey dataset, but the false positive rate was low (5%).

In this case, this corresponded also to the overall misclassification error, hence leading to a high confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), led to an increase in the overall confidence in the spatial output from low (before validation; Figure 27a) to **moderate** (after validation; Figure 27b).

Figure 26: Validated map of nursery habitat of common dragonet (*Callionymus lyra*) predicted by classification tree modelling of the distribution of juveniles (10-95mm total length) in the South marine plan areas. Nursery habitat is identified with probability of presence >50%.
The cells outlined in black (1) indicate inshore locations where the model underestimates the presence of juvenile common dragonet.

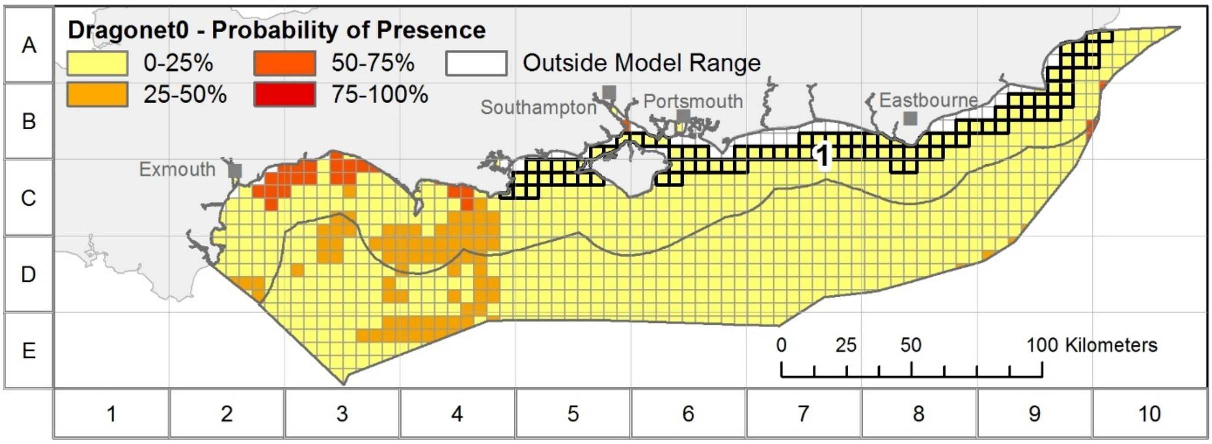

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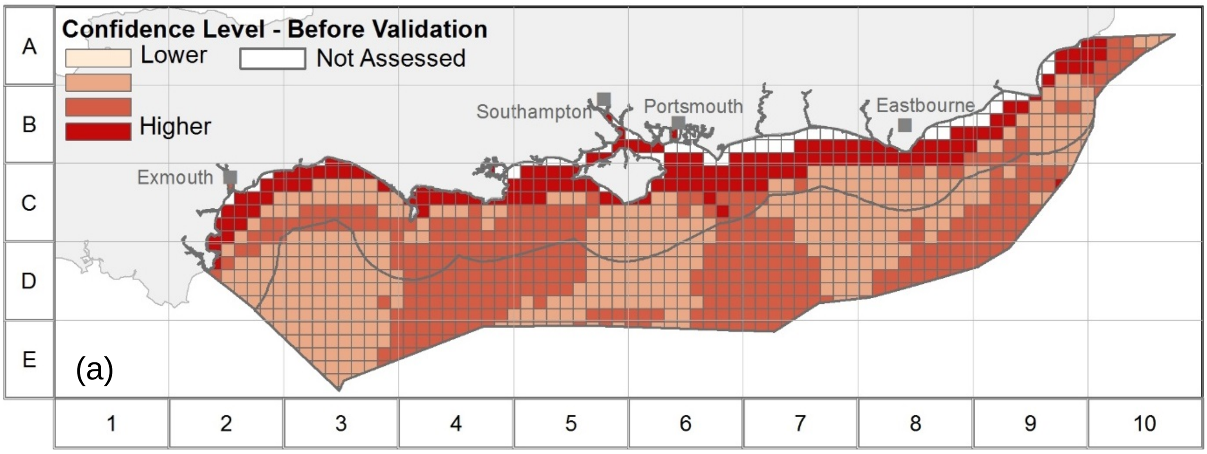
Figure 27: Confidence associated with the predicted nursery habitat of common dragonet (*Callionymus lyra*) in the South marine plan areas: a) before validation (overall confidence: low); b) after validation (overall confidence: moderate).
The cells outlined in black indicate inshore locations where the model underestimates the presence of juvenile common dragonet.



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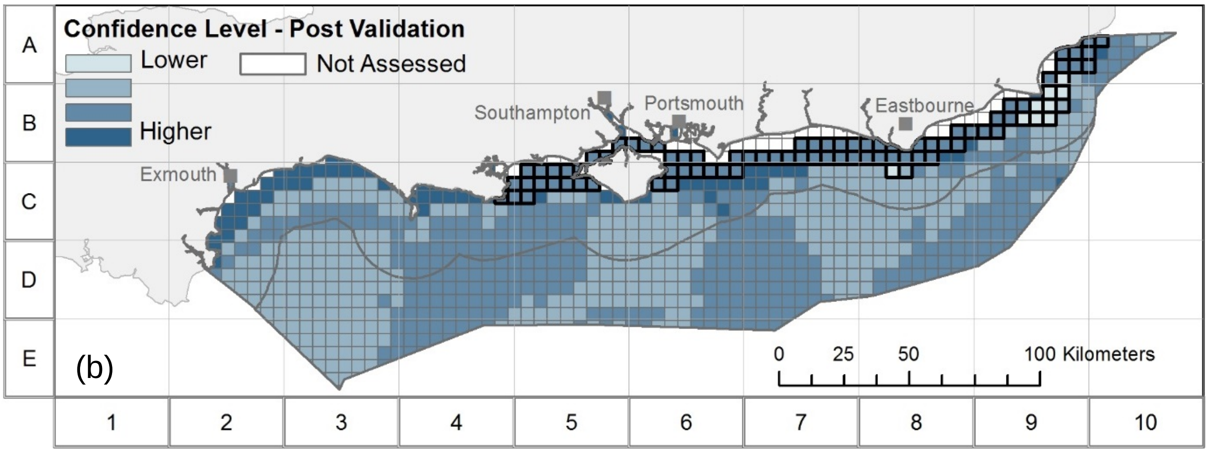

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3.2.7 Solenette (*Buglossidium luteum*)

The life stages modelled for this species included juveniles (10-70mm total length; immature) and adults (80-290mm total length).

Adult solenette (foraging habitat)

Expert judgement:

- Cefas: Predicted habitat for juvenile and adult distribution is too extensive. Likely limited to the west of Lyme Bay.

Following this comment, specific areas were marked on the validated maps (Figure 28 and 29b):

1. Areas where the model likely overestimates the presence of adult (and juveniles) solenette; prediction of presence here should be considered as of lower confidence (as lower confidence was already often associated with prediction in these areas).

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) resulted in a misclassification error of 33% when considering the predictions of all the combinations of presence/absence of juveniles and adults. This led to a moderate confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), did not lead to changes in the overall confidence in the spatial output, this remaining **low** (before and after validation; Figure 29a and 29b).

Figure 28: Validated map of adult foraging habitat of solenette (*Buglossidium luteum*) predicted by classification tree modelling of the distribution of adults (80-290mm total length) in the South marine plan areas.
The cells outlined in black (1) indicate locations where the model overestimates the presence of adult solenette.

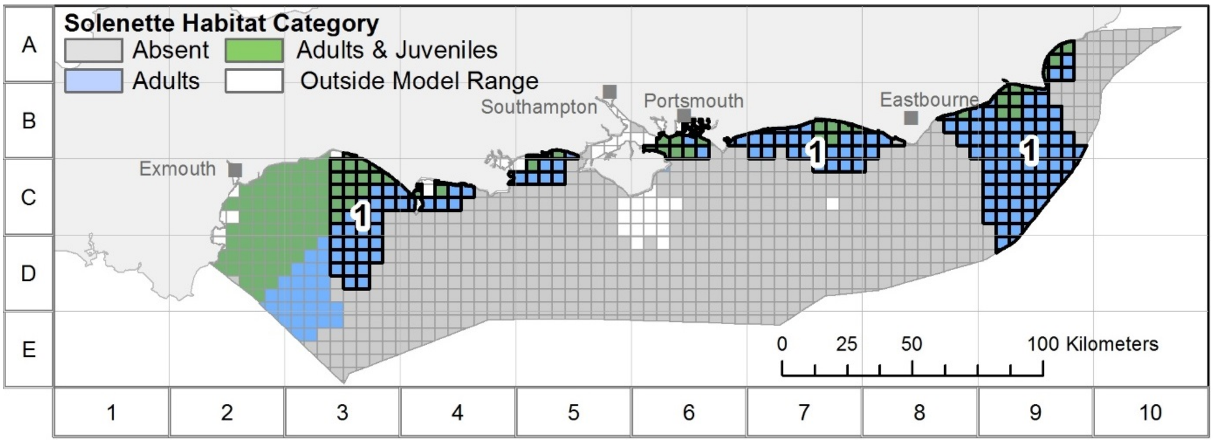

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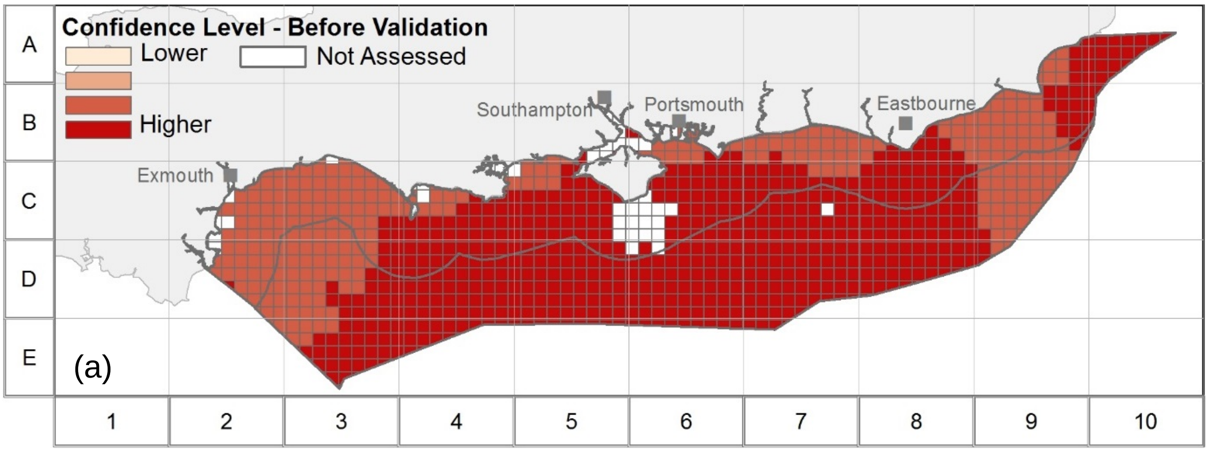
Figure 29: Confidence associated with the predicted adult foraging habitat of solenette (*Buglossidium luteum*) in the South marine plan areas: a) before validation (overall confidence: low); b) after validation (overall confidence: low).
The cells outlined in black indicate locations where the model overestimates the presence of adult solenette.



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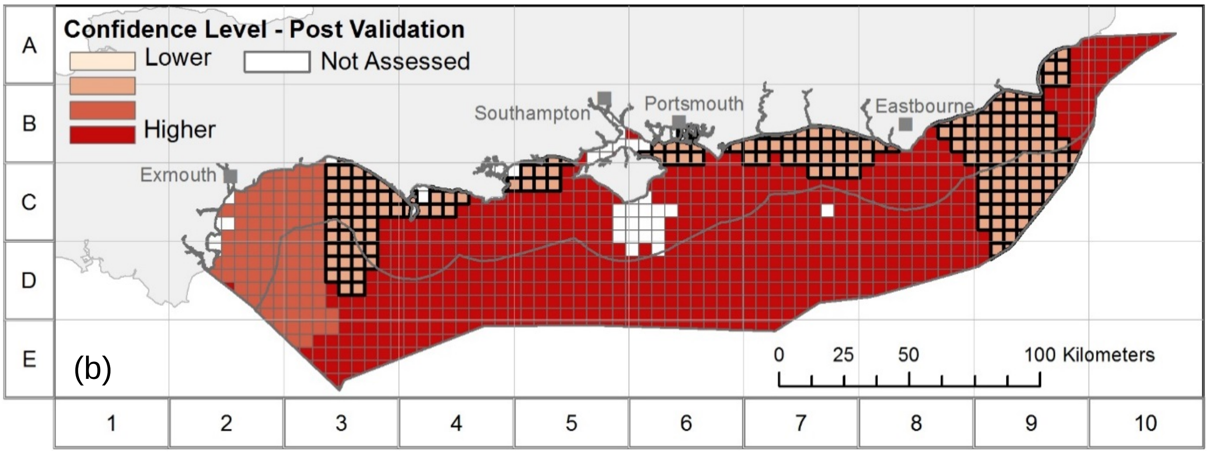

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Juvenile solenette (nursery habitat)

Expert judgement:

- Cefas: Predicted habitat for juvenile and adult distribution is too extensive. Likely limited to the west of Lyme Bay.

Following this comment, specific areas were marked on the validated maps (Figure 30 and 31b):

1. Areas where the model likely overestimates the presence of juvenile solenette; prediction of presence here should be considered as of lower confidence (as lower confidence was already often associated with prediction in these areas).

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) highlighted that the model tends to underestimate the presence of the species' life stage, with 53% of the actual absence data in the western region of the study area (survey data) being predicted as presence by the model (false positive rate).

When considering the overall model accuracy (i.e. considering its prediction of both presence and absence of solenette juveniles), the total misclassification error measured during validation was 24%, hence leading to a high confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), led to an increase in the overall confidence in the spatial output from low (before validation; Figure 31a) to **moderate** (after validation; Figure 31b).

Figure 30: Validated map of nursery habitat of solenette (*Buglossidium luteum*) predicted by classification tree modelling of the distribution of juveniles (10-70mm total length) in the South marine plan areas. Nursery habitat is identified with probability of presence >50%.
The cells outlined in black (1) indicate inshore locations where the model overestimates the presence of juvenile solenette.

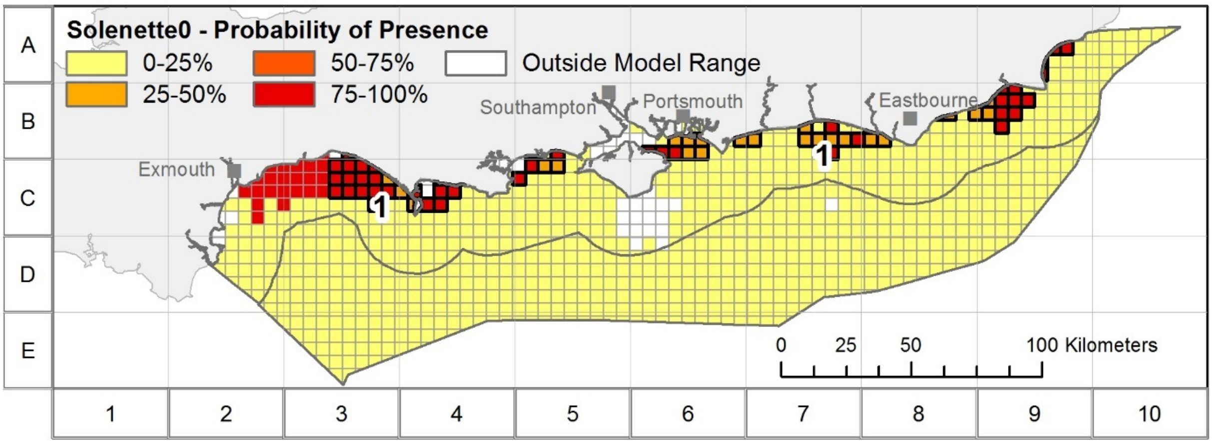
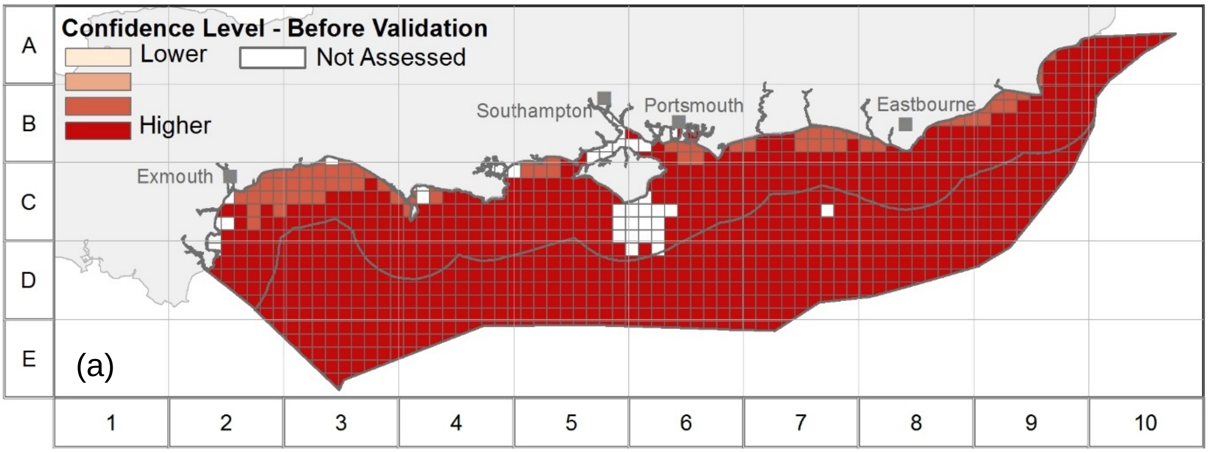


Figure 31: Confidence associated with the predicted nursery habitat of solenette (*Buglossidium luteum*) in the South marine plan areas: a) before validation (overall confidence: low); b) after validation (overall confidence: moderate).
The cells outlined in black indicate inshore locations where the model overestimates the presence of juvenile solenette.



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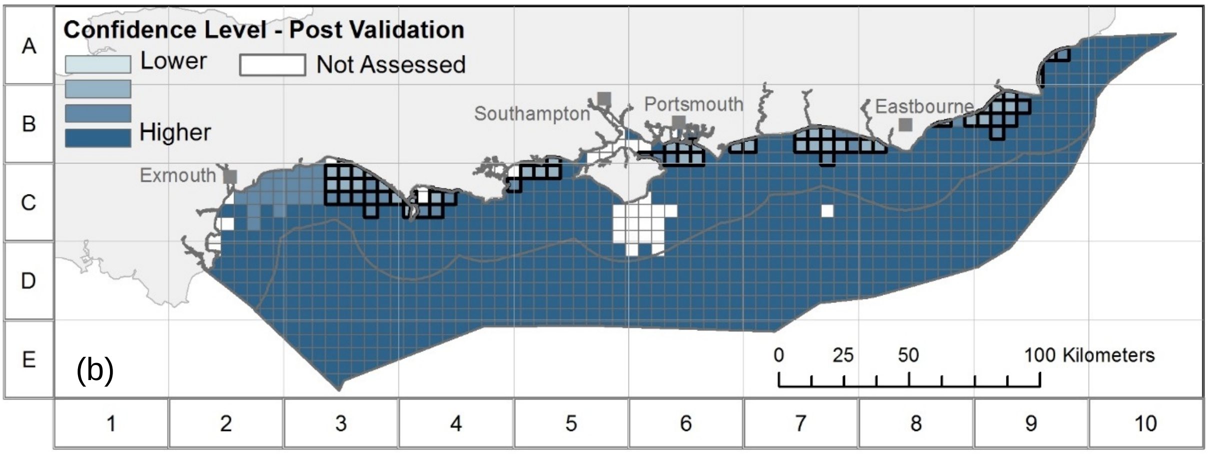

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3.2.8 Thickback sole (*Microchirus variegatus*)

The life stage modelled for this species was juveniles (30-200mm total length; likely including also >1year old).

Juvenile thickback sole (nursery habitat)

Expert judgement:

- Cefas: Length range for juveniles (30mm to 200mm) seems erroneous. Can be adult at sizes <200mm or so. Please check. Predicted habitat is too extensive. More of an inshore species.

The data were checked and the mistake on the juvenile size was confirmed (juvenile size <210mm total length instead of 120mm was considered; see Amara *et al*., 1998 for juvenile size). The model was re-calibrated based on the correct data (see Annex 3) and the resulting spatial output is shown in Figure 32.

Although the new map was not examined by the consultees, the extent of the predicted habitat was substantially smaller compared to the previous prediction, hence better suiting the expert knowledge provided during consultation.

Although the species was indicated as more of an inshore species, it is noted that Amara *et al*. (1998) reported that juvenile thickback soles settle offshore, where they reach the adult period in typically marine waters, therefore their nursery areas may possibly occur also offshore (compared for example to common soles which are dependent on coastal and estuarine nursery areas).

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data (beam trawl surveys from the West Channel) highlighted that the model tends to underestimate the presence of the species' life stage, with all actual presence data in the westernmost region of the study area (50% of the survey data) being predicted as absence by the model (false negative rate).

When considering the overall model accuracy (i.e. considering its prediction of both presence and absence of thickback sole juveniles), the total misclassification error measured during validation was 50%, hence leading to a low confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), did not lead to changes in the overall confidence in the spatial output, this remaining **low** (before and after validation; Figure 33).

Figure 32: Map of nursery habitat of thickback sole (*Microchirus variegatus*) predicted by classification tree modelling of the distribution of juveniles (30-120mm total length) in the South marine plan areas. Nursery habitat is identified with probability of presence >50%.

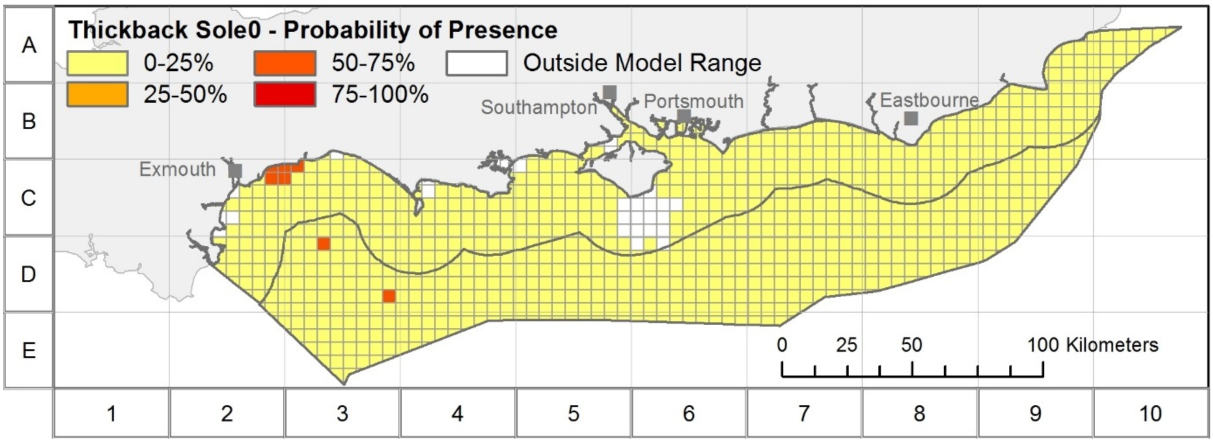

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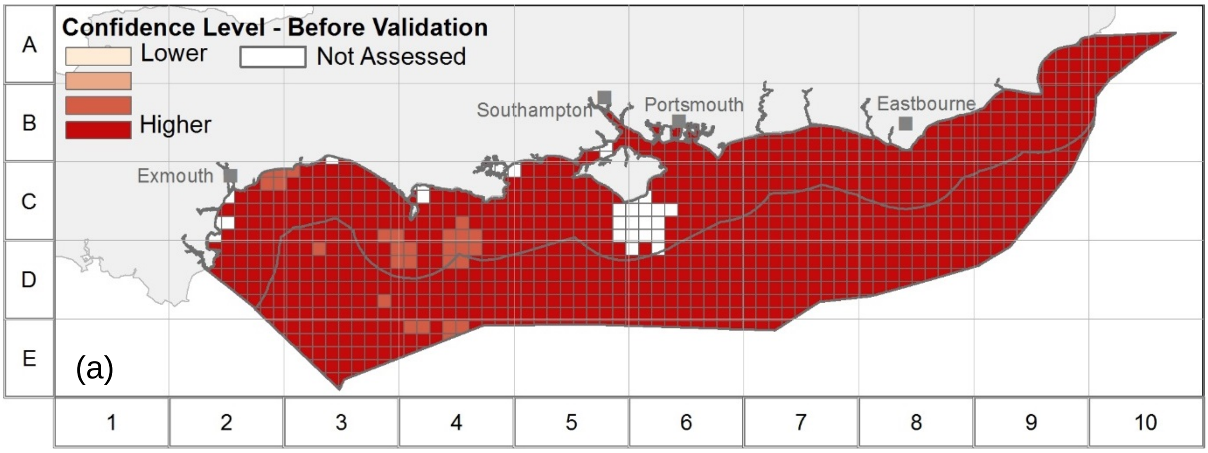
Figure 33: Confidence associated with the predicted nursery habitat of thickback sole (*Microchirus variegatus*) in the South marine plan areas: a) before validation (overall confidence: low); b) after validation (overall confidence: low).



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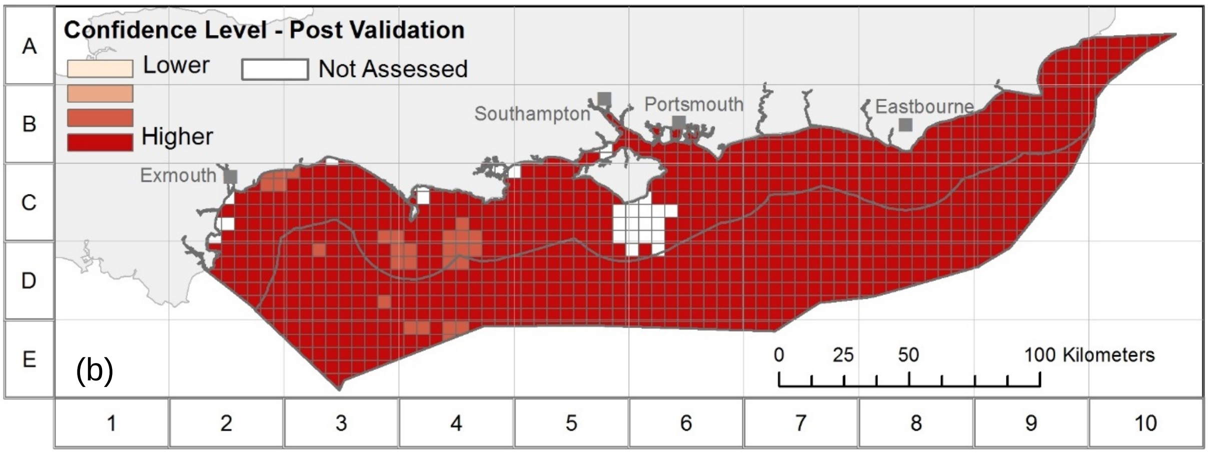

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3.2.9 Thornback ray (*Raja clavata*)

The life stage modelled for this species was juvenile (100-280mm total length; likely including also >1year old).

Juvenile thornback ray (nursery habitat)

Expert judgement:

- Cefas: More extensively distributed than predicted habitat suggests.

Following this comment, specific areas were marked on the validated maps (Figure 34 and 35b):

1. Areas where the model likely underestimates the presence of juvenile thornback ray in inshore areas; the prediction of absence here should be considered as of lower confidence.

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data highlighted that the model tends to underestimate the presence of the species' life stage, with 77% of the actual presence data (survey data) being predicted as absence by the model (false negative), confirming the results of the validation based on expert judgement. It is noted that the data on juvenile presence used for the model validation (as obtained from Ellis *et al*., 2012) were based on juveniles of smaller size (<180mm total length, including 0-group only) compared to those considered in MMO (2013) (<290mm total length, likely including also juveniles of >1y of age). Therefore the underestimation of the species juvenile presence by the model might be even higher than estimated by the false negative rate.

When considering the overall model accuracy (i.e. considering its prediction of both presence and absence of thornback ray juveniles), the total misclassification error measured during validation was 22%, hence leading to a high confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), led to an increase in the overall confidence in the spatial output from low (before validation; Figure 35a) to **moderate** (after validation; Figure 35b).

Figure 34: Validated map of nursery habitat of thornback ray (*Raja clavata*) predicted by classification tree modelling of the distribution of juveniles (100-280mm total length) in the South marine plan areas. Nursery habitat is identified with probability of presence >50%.
The cells outlined in black (1) indicate locations where the model underestimates the presence of juvenile thornback ray.

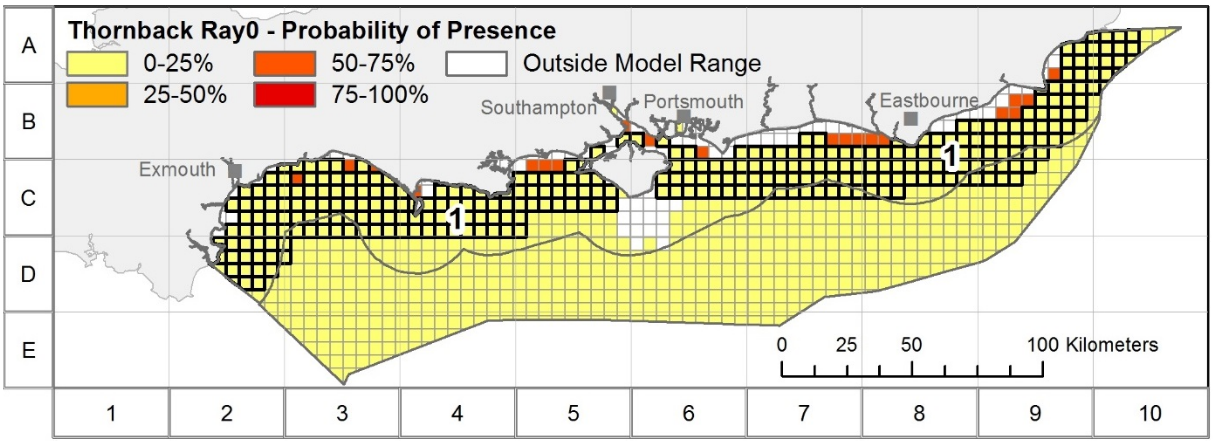

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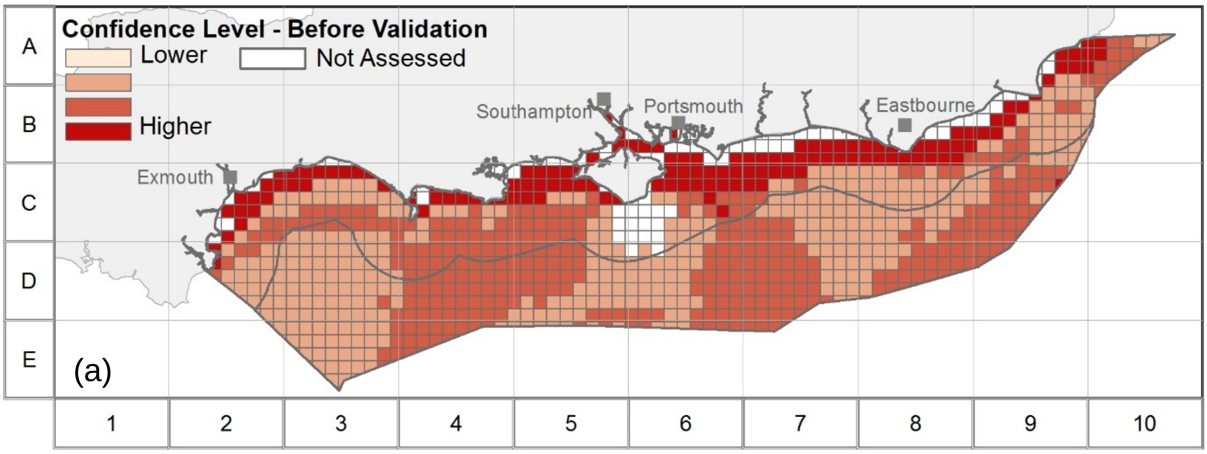
Figure 35: Confidence associated with the predicted nursery habitat of thornback ray (*Raja clavata*) in the South marine plan areas: a) before validation (overall confidence: low); b) after validation (overall confidence: moderate).
The cells outlined in black indicate locations where the model underestimates the presence of juvenile thornback ray.



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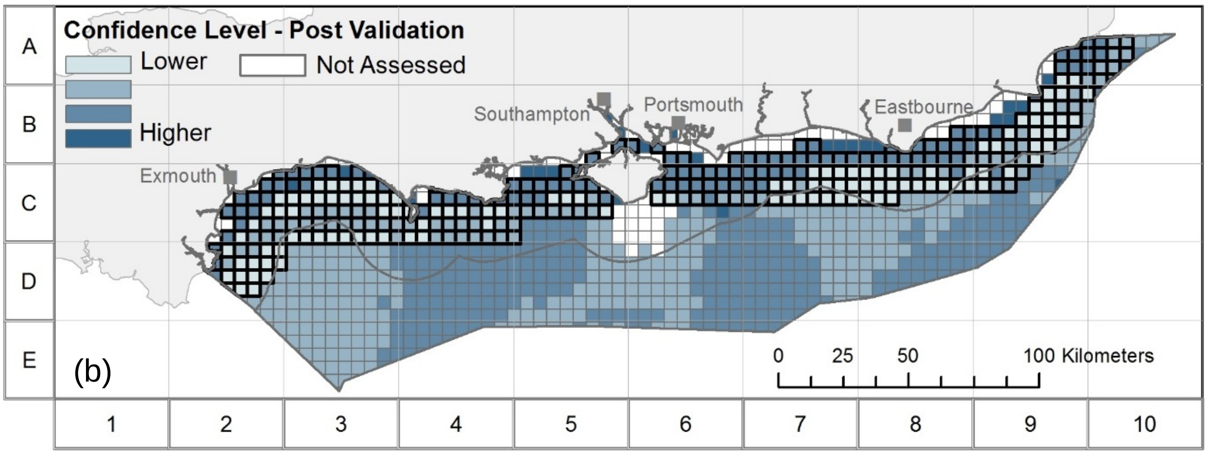

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3.2.10 Herring (*Clupea harengus*)

The life stage modelled for this species was larvae (<11mm total length; early stage).

Herring larvae (spawning habitat)

Expert judgement:

- Cefas: More extensively distributed than predicted habitat suggests.

- Cefas: Habitat model suggests that herring will be much more extensively distributed than survey data suggest. Spawning sites are inshore (often tightly inshore) and exclusive of muddy habitats. Herring spawning habitat is more common in the eastern channel than the west. For herring, the important factors probably include seabed type, current strength and stock identification, in addition to those factors used in the model.

- Department of the Environment Northern Ireland: The study area was not considered a nursery area for herring by Coull *et al*. (1998) and the main spawning area was identified to the west of the study area.

- MMO: The herring spawning habitat map presented identifies areas of high herring spawning habitat presence along the south coast. This seems to contradict work undertaken by the aggregates industry to inform their 15 year renewals, which identifies these areas of being of low habitat potential. This could however be due to the parameters used to assess suitable habitat. In the aggregates assessment the main datasets used were sediment composition data layers and larvae survey data, as well as VMS data. In contrast the area south of Eastbourne on the median line appears to be underrated. The Herring Spawning Assessment undertaken by the East Channel Association identifies these areas as medium to high and very high herring spawning potential areas. Again this could be due to the parameters used. Row C – areas of high probability of presence; C9, D7 and D9 – this has been identified in other reports as an area of high probability of presence of spawning.

- Marine Science Scotland: The distribution of this herring size range does agree with the Marine Science Scotland model outputs. There is a higher probability of finding herring larvae in the area that overlaps with the MMO area of study. The areas of lower probability of encounter also match the MSS model output. However, the probability is still low when taken in an all UK waters context according to the MSS output. There is a higher probability of finding larvae to the east-south-east of the MMO study area according to MMO outputs, this matches with the young larvae aggregation distributions from MSS.

Following these comments, as corroborated also by the examination of suggested supported evidence, specific areas were marked on the validated maps (Figure 36 and 37b):

1. Areas where the model likely underestimates the presence of herring spawning grounds (based on larval distribution); prediction of presence here should be considered as of higher confidence.

2. Inshore areas where the model likely overestimates the presence of herring spawning grounds (based on larval distribution); prediction of presence here should be considered as of lower confidence.

It is noted that the model prediction is based only on wave energy and depth data layers as environmental predictors, whereas other factors (including substratum characteristics) were not selected as relevant by the model, although these are expected to be important. This might explain the disagreement between the model predictions and the distribution of herring spawning grounds as indicated by the consultees and as assessed in other studies (Coull *et al*., 1998; ECA and RPS Energy, 2010; Ellis *et al*., 2012; MarineSpace *et al*., 2013).

A generally higher probability of presence was predicted by the model in MMO (2013) compared to other studies. This is most likely the result of the smaller spatial scale of the MMO (2013) study (covering only the South marine plan areas) compared to studies assessing fisheries sensitivity areas in an all UK waters context (Aires *et al*., 2014). The lower number of data used by the MMO (2013) model likely led to an overestimation of the probability of presence (measured as relative frequency of occurrence).

Overall confidence:

The statistical validation of the model accuracy against additional fish survey data highlighted that the model tends to overestimate the presence of the species' life stage, with 78% of the actual absence data (survey data) being predicted as presence by the model (false positive rate), confirming the results of the validation based on expert judgement.

When considering the overall model accuracy (i.e. considering its prediction of both presence and absence of herring larvae), the total misclassification error measured during validation was 60%, hence leading to a low confidence in the model predictive ability. This result, combined with the confidence assessed for the input data used in the model prediction (as in MMO, 2013), led to a decrease in the overall confidence in the spatial output from moderate (before validation; Figure 37a) to **low** (after validation; Figure 37b).

As previously highlighted in MMO (2013), there is uncertainty in associating spawning habitats of a fish species with the distribution of larvae (albeit at early development stage). During the pelagic larval stage, herring larvae can be transported far from the spawning grounds, hence leading to a weaker link between larval presence and spawning grounds location.

Including information on the abundance of larvae might lead to a decrease in the uncertainty in the association between larval distribution and location of spawning grounds. Abundance information may be included by modelling the presence of aggregations of larvae (i.e. using a density threshold to identify higher density aggregations) rather than the mere presence of larvae, as suggested in Aires *et al*. (2014). This approach might lead to an improvement of the approach and hence in the resulting spatial outputs.

Figure 36: Validated map of spawning habitat of herring (*Clupea harengus*) predicted by classification tree modelling of the distribution of early stage larvae (<11mm total length) in the South marine plan areas. Spawning habitat is identified with probability of presence >50%.

The cells outlined in black indicate locations where: (1) the model underestimates the presence of herring larvae; (2) the model overestimates the presence of herring larvae.

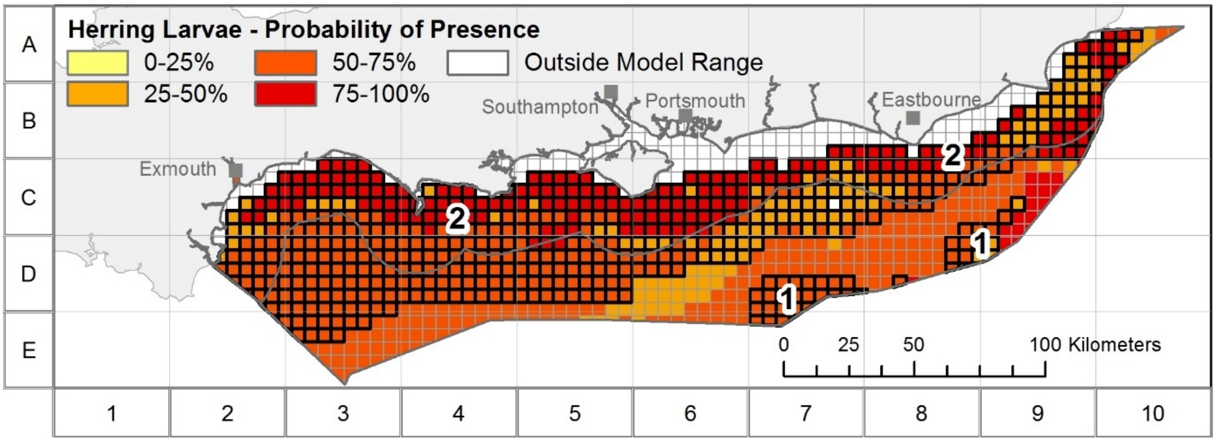

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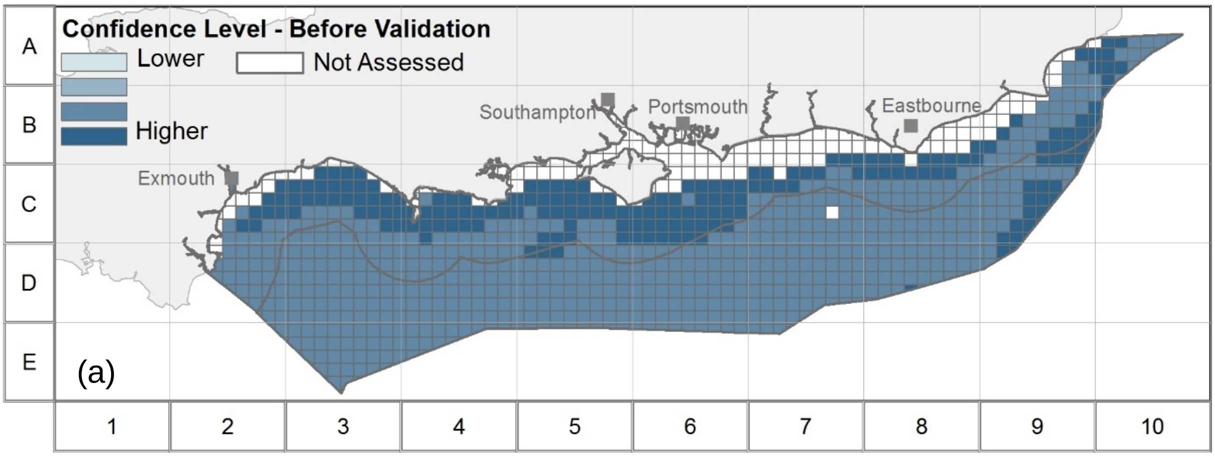
Figure 37: Confidence associated with the predicted spawning habitat of herring (*Clupea harengus*) in the South marine plan areas: a) before validation (overall confidence: moderate); b) after validation (overall confidence: low). The cells outlined in black indicate locations where the model underestimates or overestimates the presence of herring larvae.



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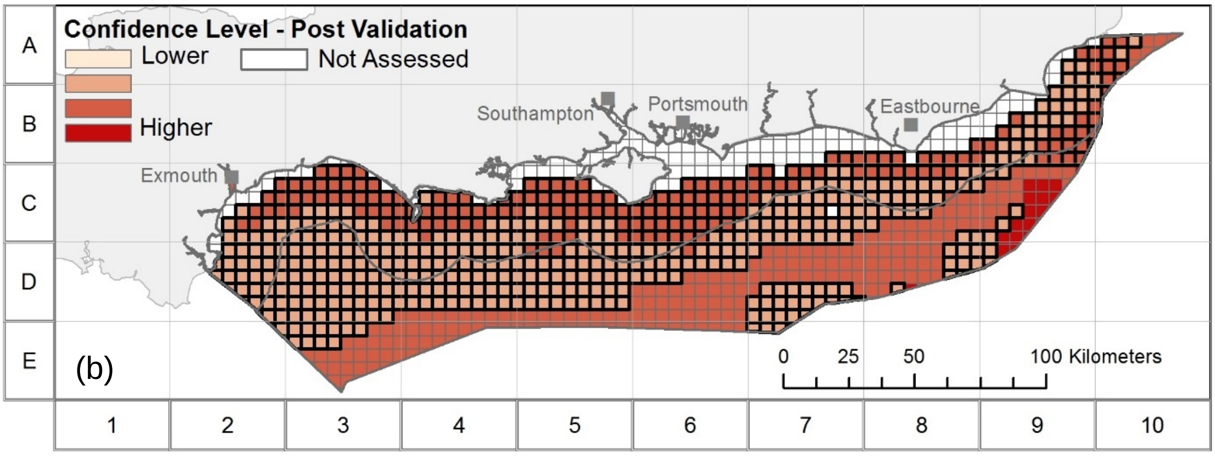

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3.3 Areas of improvement – Fish survey data

The consultees were also asked to suggest additional fish survey data that may be useful to:

- increase the species coverage in the modelling of South marine plan areas
- apply the model approach in other marine plan areas.

It was acknowledged by the consultees that the fish survey datasets identified and used in MMO (2013) were appropriate, and that they were consistent with those used in other studies mapping essential fish habitats (ECA and RPS Energy, 2010; Ellis *et al*., 2012; Stephens *et al*., 2012; MarineSpace *et al*., 2013; Aires *et al*., 2014). For example, the mapping of fish nursery and spawning grounds undertaken by Cefas in the Defra project MB5301 (Ellis *et al*., 2012) and the CHARM project (Stephens *et al*., 2012), both at lower spatial resolution, was mostly based on data from beam trawl surveys which were also included in MMO (2013).

An issue flagged by Natural England, IFCA and Defra was that not all important fish species were covered by the models for the South marine plan areas. In particular, bass, cod, brill and turbot were indicated by IFCA (as agreed also by Defra) as species of commercial importance that may be of value to include in the modelling, whereas Natural England highlighted the relevance of species with conservation importance (e.g. salmon, lamprey, black seabream). Shellfish catch data like *Nephrops* and scallop fisheries were also indicated by Marine Science Scotland as potentially useful to fill the gap regarding shellfish species.

Based on the comments and suggestions of the consultees, further data sets were explored and their suitability for the two purposes stated above was assessed. The detailed results are reported in Table 2 below and a discussion of these results follows it.

Table 2: Fish survey data identified with coverage of the study area.

Fish data	Source	Survey/data information	Suitability
UK Eastern English Channel and Southern North Sea Beam Trawl Survey (BTS) (used in MMO (2013))	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 pre-recruit 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 potential nursery grounds for these species. Additional aims include collection of water temperature and salinity and acoustic data. (Data used in MMO (2013): data between 2000-2012 within the English Channel)	***Increasing the species coverage in the modelling of South marine plan areas***: in particular juvenile turbot; brill and whiting. ***Applying the model approach in other marine plan areas***: the dataset has relatively good data coverage of the South East Inshore Marine Plan Area and of the East Inshore Marine Plan Area.

Fish data	Source	Survey/data information	Suitability
Other BTS on the East Coast of England	ICES, online fish trawl surveys database (DATRAS) (public access) Reference: ICES, 2009	Survey series starting in 1987 and ongoing. The survey is carried out by England, Germany, and Netherland under the coordination of ICES. English surveys within this programme include Eastern English Channel and Southern North Sea BTS as identified above. Fishing mostly during Quarter 3 (summer), covering the North Sea and the Eastern English Channel. Station, catch, length (all species) and biological data (selected species) for each of the annual surveys using research vessels and beam trawls in support of EU data regulations and as part of a research program coordinated by ICES.	***Applying the model approach in other Marine Plan Areas***: the dataset has relatively good data coverage of the South East Inshore Marine Plan Area, East Marine Plan Areas (particularly offshore) and North East Marine Plan Areas (particularly offshore). The data would be useful for mapping juveniles and adult life stages of demersal (near seabed) species like the pleuronectoids (flounders) and gadoids (cods).

Fish data	Source	Survey/data information	Suitability
Other BTS on the West Coast of England	ICES, online fish trawl surveys database (DATRAS) (public access) Reference: ICES, 2009	Survey series starting in 1987 and ongoing, carried out by Cefas, including Western English Channel BTS and English Near West Coast BTS (identified as BTS-VIIa in Aires *et al*., 2014) Fishing mostly during Quarter 3 and 4 (summer and autumn), covering the West Coast of England. Station, catch, length (all species) and biological data (selected species) for each of the annual surveys using research vessels and 4m beam trawl in support of EU data regulations and as part of a research program coordinated by ICES.	***Applying the model approach in other marine plan areas***: the dataset has relatively good data coverage of the North West marine plan areas, whereas there is limited coverage for the South West Inshore Marine Plan Area. The data would be useful for mapping juveniles and adult life stages of demersal (near seabed) species like the pleuronectoids (flounders) and gadoids (cods).
UK South Western BTS	Cefas	Survey series starting in 2006 and ongoing, carried out by Cefas. Fishing during Quarter 1 (Winter) over an allocated area (with random-stratified design) covering the ICES Division VII e-h (including Western English Channel) using two 4m beam trawls (with different mesh size). Station, catch, length and biological data for each of the annual surveys in support of EU data regulations and as part of a research program coordinated by ICES.	***Applying the model approach in other marine plan areas***: the dataset has relatively good data coverage of the South West Inshore Marine Plan Area (albeit limited to the southern part of this area) and only partial coverage of the South West Offshore Marine Plan Area (in southern-eastern region). For this latter area, data are available from groundfish surveys (see below) but covering most offshore regions. Exploration of the two datasets will be needed to choose the most suitable for modelling (e.g. the one including species of interest), as differences in the survey methodology would prevent the combined

Fish data	Source	Survey/data information	Suitability
			use of both dataset in a single model. The BTS data would be useful for mapping juveniles and adult life stages of demersal (near seabed) species like the pleuronectoids (flounders) and gadoids (cods).
International Bottom Trawl Surveys (IBTS) – EVHOE (Evaluation Halieutique Ouest Europeen)	ICES, online fish trawl surveys database (DATRAS) (public access) Reference: ICES, 2012	Groundfish surveys (GFS) starting in 1997, carried out by France (Ifremer). Surveys as part of the ICES programme of International Bottom Trawl Surveys in the Western and Southern Areas (WS-IBTS). These surveys aim to provide consistent and standardized data for examining spatial and temporal changes in the distribution and relative abundance of fish and fish assemblages and of the biological parameters of commercial fish species for stock assessment purposes. Surveys are undertaken during Quarter 4 (autumn).	***Applying the model approach in other marine plan areas***: the dataset covers westernmost region of South West Offshore Marine Plan Area. The data would be useful for mapping juveniles and adult life stages of demersal (near seabed) species like the pleuronectoids (flounders) and gadoids (cods). Data are likely to provide good coverage also of pelagic species (e.g. mackerel, horse mackerel, herring, and sprat).

Fish data	Source	Survey/data information	Suitability
International Bottom Trawl Surveys (IBTS) – Irish Groundfish Surveys (IE-IGFS)	ICES, online fish trawl surveys database (DATRAS) (public access) Reference: ICES, 2012	GFS between 2003 and 2008, carried out by England and Ireland. Surveys as part of the ICES programme of IBTS in the Celtic and Irish Sea. These surveys aim to provide consistent and standardised data for examining spatial and temporal changes in the distribution and relative abundance of fish and fish assemblages and of the biological parameters of commercial fish species for stock assessment purposes. Surveys are undertaken during quarters 3 and 4 (summer/autumn).	***Applying the model approach in other Marine Plan Areas***: the dataset covers the South West Offshore Marine Plan Area and the North West Marine Plan Areas. The data in the South West Offshore Marine Plan Area could be integrated with data from previous dataset (EVHOE) for a better coverage of this area. In the North West marine plan areas, it appears that a better coverage of the area is given by the IBTS data collected along the West Coast of England. However, although the IBTS and GFS datasets cannot be integrated in a single model due to difference in sampling method, modelling of GFS data might allow integration of spatial outputs with coverage of pelagic species (e.g. mackerel, horse mackerel, herring, and sprat) which are not covered in IBTS catches.

Fish data	Source	Survey/data information	Suitability
International Bottom Trawl Surveys (IBTS) – North Sea Groundfish Surveys (NS-IBTS)	ICES, online fish trawl surveys database (DATRAS) (public access) Reference: ICES, 2012	GFS starting in 1991, carried out by various countries (England, Scotland, Germany, Netherlands, Denmark, Norway, France, Sweden) under the coordination of ICES. Surveys are undertaken during quarters 3 and 4 (summer/autumn), as part of the ICES programme of IBTS in the North Sea. These surveys aim to provide consistent and standardized data for examining spatial and temporal changes in the distribution and relative abundance of fish and fish assemblages and of the biological parameters of commercial fish species for stock assessment purposes.	***Applying the model approach in other Marine Plan Areas***: the dataset covers the North East, East and South East marine plan areas, with better coverage offshore. There is spatial overlap between this dataset and the IBTS survey undertaken on the East Coast of England, but the two datasets cannot be integrated in a single model due to difference in sampling method. However, modelling of GFS data may allow integration of spatial outputs with coverage of pelagic species (e.g. mackerel, horse mackerel, herring, and sprat) which are not covered in IBTS catches.
Cefas Young Fish Surveys (YFS)	Cefas	Survey series carried out between 1981 and 2006 by Cefas. Fishing inshore with 2m scientific beam trawl (with 4mm mesh liner) in September each year. Surveys aim to provide indices of abundance of small demersal fish, in particular juvenile 0-group and 1-group plaice and sole, prior to their recruitment to the fishery. The data is in support of the EU Data Collection Regulation. Station, catch, length data for each of the annual surveys.	***Applying the model approach in other Marine Plan Areas***: the dataset cover inshore areas of the marine plan areas along the East Coast of England. Due to differences in sampling method the data cannot be integrated with BTS or GFS data for these areas. However they could be used to integrate information by mapping separately data for inshore (YFS) and offshore (BTS or GFS) marine plan areas. No further details could be found on this dataset, therefore exploration of the data and further consultation with the data provider (Cefas) are required to better assess coverage and suitability of these

Fish data	Source	Survey/data information	Suitability
			data. It is of note that these data were not included in nursery grounds maps developed by Cefas (Ellis *et al*., 2012), as they were on-going analyses.
ICES International Herring Larval Survey (IHLS) (used in MMO (2013))	ICES, online fish eggs and larvae database (public access) Data used in MMO (2013)	Survey series starting in 1967 and ongoing, with combined effort of different countries (UK, France, Germany, Netherlands), as part of a research programme 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 (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 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.	***Applying the model approach in other Marine Plan Areas***: the whole dataset covers the North East, East and South East marine plan areas.

Fish data	Source	Survey/data information	Suitability
ICES North Sea Cod and Plaice Egg Surveys in the North Sea (WGEGGS) (used in MMO (2013))	ICES, online fish eggs and larvae database (public access) (Data used in MMO (2013)	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 programme 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.	***Increasing the species coverage in the modelling of South marine plan areas***: in particular cod and whiting eggs obtained with surface sampling with continuous underway fish egg sampler. It is noted however that for whiting, only eggs at stage EG2 (none at early stage EG1) are present in the samples, and this might increase the uncertainty in the link between areas where eggs are present with the species spawning areas. A similar consideration is valid for cod eggs, for which development stage is mostly unidentified in the dataset. ***Applying the model approach in other Marine Plan Areas***: the whole dataset covers the North East, East and South East marine plan areas, with higher coverage offshore and in North East and South East marine plan areas.
Cefas Southern North Sea and English Channel Sole Egg Survey	Cefas	Four cruises were undertaken in 1991 (spring) collecting 70-80 samples to estimate the spawning stock biomass of the sole (*Solea solea*) in the English Channel and southern North Sea.	***Increasing the species coverage in the modelling of South marine plan areas***: the data might be used to map sole eggs in the English Channel. They were not included in MMO (2013) and they did not

Fish data	Source	Survey/data information	Suitability
		Abundance / density of fish eggs and fish larvae from plankton tows. Eggs from sole assigned to developmental stages. Associated environmental data (temperature salinity).	fulfil the criterion of being collected after 2000 (use of most recent data). These data could be used for modelling provided that relevant environmental data layers with similar temporal reference (i.e. data for spring 1991) are available for those environmental variables where seasonal and inter-annual variability is relevant (e.g. temperature, chlorophyll). ***Applying the model approach in other Marine Plan Areas***: the dataset covers also the South East Inshore Marine Plan Area.
Bristol Channel plankton surveys	Cefas	A series of five cruises (524 valid stations) conducted in the Bristol Channel in 1990 which were conducted primarily to provide data on sole and bass, but collected data for other fish species and edible crab larvae (Ellis *et al*., 2012).	***Applying the model approach in other Marine Plan Areas***: the dataset covers the South West Marine Plan Area, although its extent is mostly restricted to Inshore area. It could provide useful data on sole and bass egg/larval stages, assuming that a model is developed for inshore area only and considering temporal reference aspects as highlighted above.
Eastern Irish Sea plaice surveys	Cefas	A series of cruises undertaken in the eastern Irish Sea, in 2001 (5 cruises, 227 stations), 2002 (4 cruises, 158 stations) and 2003 (5 cruises, 345 stations). The survey primarily targeted plaice (eggs/larvae) (Ellis *et al*., 2012).	***Applying the model approach in other Marine Plan Areas***: the dataset covers the North East marine plan areas. It could provide useful data on plaice egg/larval stages, considering temporal reference aspects as highlighted above.

Fish data	Source	Survey/data information	Suitability
Irish Sea plankton surveys	Cefas	Series of cruises conducted in the Irish Sea (with data limited from the southern parts of St George's Channel) in 1995 (13 cruises, 1024 valid stations), 2000 (8 cruises, 804 valid stations), 2006 (5 cruises, 397 valid stations) and 2008 (5 cruises, 486 valid stations) (Ellis *et al*., 2012).	***Applying the model approach in other Marine Plan Areas***: the dataset covers the North East marine plan areas. It could provide useful data on fish egg/larval stages, considering temporal reference aspects as highlighted above.
Solent small bass survey	Cefas	A series of trawl surveys carried out in the Solent as part of a time series that commenced in the late 1970s. The purpose of the survey is to develop a time-series of pre-recruit indices for bass in and near the nursery areas within the Solent area (covering Chichester Harbour, Langstone Harbour, Southampton water, Lee-on-Solent, Isle of Wight, eastern section of the Solent). Sampling is undertaken in quarter 3 (summer) using a Cefas bass trawl of standard design. Surveys since 2013 are part of the Defra project MF1233 "Population studies in support of the conservation of the European sea bass".	***Increasing the species coverage in the modelling of South marine plan areas***: although the survey data provide useful information on small sea bass (mostly individuals aged 1 to 4 years old), and possibly additional information on juveniles of other species caught during the survey, the limited spatial coverage compared to the wider extent of the South marine plan areas makes these data unsuitable for the calibration of a model which has validity in These data might be useful to validate local predictions of the existing models, although some of the areas covered by the survey might not have valid predictions due to limitations of the model in inshore areas.
Langstone Harbour small fish survey	Langstone Harbour Board, Southern Inshore Fisheries and Conservatio	A series of annual surveys of the small fish population in Langstone Harbour undertaken since 2012 by the Langstone Harbour Board, in collaboration with the Southern IFCA and the University of Portsmouth. Survey are undertaken during quarter 2 (June) and 3 (September) by using two methods of fish capture	***Increasing the species coverage in the modelling of South marine plan areas***: although the survey data provide useful information on small fish (mostly sprat, sand smelt, sandeel, herring, common goby and bass), the limited spatial coverage of the survey compared to the wider extent of the South marine plan areas makes these

Fish data	Source	Survey/data information	Suitability
	n Authority (IFCA), University of Portsmouth	– a seine net and a beam trawl (survey methods comparable with EA methods). It is hoped the collection of data annually will provide increased understanding of the composition and dynamics of the fish population within Langstone Harbour, as well as monitoring population trends.	data unsuitable for the calibration of a model which has validity in the whole marine plan area. However, these data might be useful to validate local predictions of the existing models, although some of the areas covered by the survey might not have valid predictions due to limitations of the model in inshore areas.

The purpose of the essential fish habitat model approach was to provide higher resolution maps of the spatial distribution of nursery, spawning and foraging grounds for selected species within a marine plan area, with particular interest towards the offshore areas where information is more sparse compared to more inshore areas (which are better covered by the information gathered by the Environment Agency). The coverage of the fish survey dataset in the marine plan area was therefore one of the important criteria driving the dataset selection (MMO 2013). A wider spatial coverage was considered beneficial, allowing the model to better account for the environmental variability within the wider marine plan area hence likely increasing the spatial applicability of the model predictions.

Based on this criterion, a higher suitability was identified for explored datasets derived from broader sampling programmes, such as groundfish survey campaigns undertaken through the coordination of ICES (Table 2), compared to survey data collected at a smaller spatial scale (e.g. Solent small bass survey, Langstone Harbour small fish survey). It is noted, however, that these small scale surveys, although less suitable for the modelling and consequent spatial mapping of marine plan areas, might provide useful data for validating models for selected species life stages.

In order to fulfil the objectives of MMO (2013) within the project timescale, modelling was undertaken on a shortlist of fish species. This was determined based on the prioritisation of the species according to their importance and data availability in the study area and the confidence in the fish data (MMO 2013). The top ten ranked species were then selected for modelling.

The exploration of the beam trawl survey (BTS) dataset used in MMO (2013) highlighted that suitable data could also be obtained for modelling juvenile turbot as well as brill and whiting in the South marine plan areas, although these species occurred with lower frequency (<22%) in the samples compared with the species for which models were derived in MMO (2013). Similarly, additional data for cod and whiting eggs may be obtained from the ICES North Sea Cod and Plaice Egg Surveys dataset in the North Sea used in MMO (2013).

Most of the broad scale fish surveys indicated in Table 2 are those which have been commonly used to map fish life stages distribution around the UK, as in Ellis *et al*. (2012), Aires *et al*. (2014), and MarineSpace *et al*. (2013). The distribution of the survey points reported in these documents shows how finding a suitable dataset for modelling of the whole South marine plan areas was particularly challenging given that the English Channel represents a transition between the eastern and western survey programmes.

A similar problem might occur with the survey data for the South West Inshore and South West Offshore Marine Plan areas, where the surveys in the inshore and in the offshore areas are undertaken with different methodologies, therefore making it difficult to combine the data in a single model. In this particular case, it might be appropriate to model the South West Inshore Marine Plan Area (using beam trawl survey data) and the South West Offshore Marine Plan Area (using groundfish survey data) separately. Similar cases have been highlighted in the detailed commentary given in Table 2.

There appeared to be a more homogeneous distribution of the survey data collected within a single survey programme in other areas around the UK which may possibly improve the model application in these areas compared to the study area of MMO (2013). It is of note however that the poor coverage of these surveys in more inshore areas would still be a limitation of the data which would be reflected on the spatial outputs that can be obtained with the model approach.

Marine Science Scotland suggested that commercial discard data could be potentially useful to integrate fish data. These data could be sourced through the Cefas at-sea observer programme, whereby Cefas scientific observers are placed on a sample of UK-registered commercial fishing vessels in each quarter of the year to estimate the quantities and sizes of each species discarded at sea (the size composition of the retained catch is also recorded). The Cefas at-sea observer programme covers a wide range of gears, areas and times, and since 2002, the observer programme has covered most areas in ICES Areas IV (North Sea) and VII (English Channel and western waters).

These data could be considered suitable for the calibration of models predicting the occurrence of only adult life stages as they are collected using fishing gears that are designed to target fish of larger (commercial) sizes. In turn, they may lead to biases in the prediction of the distribution of juvenile fish (e.g. absence of juveniles of the species in the data might be ascribed to net selectivity rather than to an actual absence in the survey area). Given the differences in sampling methodology, the data cannot be integrated with other survey data for use in a single model; however, they might be useful to validate specific outputs (e.g. on adult foraging habitats for commercial species).

The possibility of modelling shellfish species in addition to fish species was highlighted during consultation. Marine Science Scotland suggested inclusion of shellfish catch data obtained from *Nephrops* and scallop fisheries. No additional information could be obtained on these data; and therefore their suitability could not be assessed. However these data obtained from fishery activities may contain similar biases as the Cefas at-sea observer programme described above, which would limit their suitability to model the distribution of juvenile shellfish, but could be used to identify adult essential habitat requirements.

3.4 Areas of improvement – Environmental data layers

Although a moderate to high confidence was often associated with the model's predictive ability (as confirmed during the validation activity), the overall confidence associated with the maps for a species' life stages was generally lower. This result was mostly ascribed to the low confidence associated with the environmental data layers used to map the model prediction in the study area, with particular reference to the data layers on tidal current and wave energy and seabed sediment types.

The consultees were asked to suggest additional environmental data layers that may be useful to:

- Improve the data quality, resolution and confidence for use in the modelling of the South marine plan areas.
- Apply the model approach in other marine plan areas.

The suggestions given by the consultees were integrated with additional input from the project team and a list of data layers was identified that could potentially be used to update, improve or integrate the existing data used in MMO (2013). Further information was sought on the data layers content, extent, resolution, availability and confidence, also in comparison with the data layers used in MMO (2013), where similar environmental parameters were covered. Detailed results of the assessment of the environmental data layers are given in Annex 5, and their possible suitability in essential fish habitat models is discussed below.

3.4.1 Bathymetry

There are several bathymetric data sources available for UK marine waters many of which are composites of similar raw data sources.

The bathymetry data archive centre is a collection of bathymetric data gathered around the British Isles. No interpolation has been applied and so coverage is restricted to survey areas, with a resulting patchy coverage across UK waters. There does however appear to be good coverage over inshore MMO marine plan areas although dates of collection may vary. Data is of good quality particularly those obtained from the United Kingdom Hydrographic Office (UKHO), British Geological Survey (BGS), and Seazone. Availability of data is variable and depends on source.

GEBCO_2014 (an updated and higher resolution version of GEBCO_08, released in 2014) uses data as recent as 2013 from various sources and is interpolated to provide complete coverage of UK waters. Detailed bathymetry for shallow areas is however not included. The European areas of this dataset have been based on the European Marine Observation and Data Network (EMODnet), 2013 data set.

DigBath250 is a vector product with bathymetry divided by depth contours of 10m, 20m or 100m as appropriate. All UK waters are included. The vectors are based primarily on historical data collected by the British Geological Society (BGS) and updated with UKHO Admiralty Charts and survey data. The data is however available at a cost of £300 a sector (six of which make up UK waters).

The EMODnet Digital Terrain Model (DTM) has been generated from selected bathymetric survey data sets and composite DTMs, and substituted with GEBCO Digital Bathymetry where there are gaps in the data. The data is free to download and includes details which could be used to assess confidence. The bathymetry data layer currently available is an update to that used in MMO (2013) (and assessed as being of moderate to high confidence; MMO, 2013). In addition, the resolution of the EMODnet DTM since early February 2015 has increased (grid size of 0.125 * 0.125 minutes) compared to the resolution of the data layer used in MMO (2013) (0.25 * 0.25 minutes).

The Marine Aggregates Levy Sustainability Fund Offshore Geographical Information System (Marine ALSF GIS) contains data from dedicated surveys from 2004 – 2009. Spatial coverage is restricted to regional environmental characterisation areas and data is available at a cost through Seazone.

Considering the data characteristics mentioned above and given in Annex 6, the current EMODnet Digital Terrain Model (DTM) is considered suitable to update the bathymetry data layer used in the essential fish habitat modelling in MMO (2013) and to further integrate the data for modelling or other marine plan areas. Due to the similarity with the data layer used in MMO (2013), the moderate-high confidence associated with the data layer is likely to be maintained (if not improved) in the current data layer. A significant benefit of using data from EMODnet is that several relevant data types are homogenised and provided from the same source. They have been processed with similar quality assurances and are provided with associated confidences.

The bathymetry data layer can also be used to derive information on the distribution of hard substrate in the study area which could be included as a possible additional predictor in essential fish habitat models. A measure of the texture of a bathymetric surface (the terrain ruggedness index) is being developed by the MMO as an indicator of hard substrate in the South marine plan areas (MMO, unpublished). This index expresses the average elevation change between any point on a grid and its surrounding area. The bathymetry data archive centre data layer is being used for MMO1065 for the index calculation, and it appears that the resulting output layer gives hard substrate predominantly with a medium confidence (depending also on ground truthing results).

3.4.2 Seabed substrate & bed forms

The British Geological Society's DigSBS250 layer of marine seabed sediments has good coverage and is believed to comprise of recent data (April 2011 to present). The sediment data is given as a Folk classification[4]. The cost of this product is £0.003 per km^2.

EMODnet includes a substrate layer classified to five Folk classes (Mud to muddy sand, Sand, Coarse substrate, Mixed substrate, Rock boulders) and is based on data from BGS (date unknown). The layer covers all UK marine waters with

[4] The Folk classification is a technical descriptive classification of sedimentary rocks.

additional information on confidence based on density of data. Although this layer is not freely available to download, a derivative of this product (EUSeaMap Seabed Habitats) includes sediment data reclassified into EUNIS sediment categories. This layer also includes the distribution of features such as biogenic reefs.

As with all Marine ALSF Regional Environmental Characterisation Surveys (RECs) the quality and confidence of the data is high but coverage is limited to the ALSF regions[5]. Data is available on seafloor sediments, seabed morphology, bed forms and enclosed deeps.

Environmental variables derived from seabed type data were often included as significant predictors of the essential fish habitats in MMO (2013), but a low confidence was associated with the data layer used (EMODnet for EUSeaMap) and this often influenced the resulting low confidence associated with the essential fish habitat outputs. Low confidence was attributed to this data primarily because survey dates were unknown. The EMODnet data was however a derivative of the BGS data (pre-2010 version) with the advantage of being freely available at an appropriate resolution, harmonised with other appropriate data and provided with a confidence layer.

If the most current sediment data was required (and used alongside post 2011 fish data) then the BGS DigSBS250 layer would be the most appropriate (subject to appropriate funds). However, the fish data used for MMO (2013) was for the years 2000-2012 and so the EMODnet product is deemed appropriate for the current purpose.

3.4.3 Currents

The National Oceanographic Centre has developed the High Resolution Continental Shelf Model (CS20) which computes currents at 32 different sigma depth levels through the water column and the lower resolution Continental Shelf Model (CS3) which provides currents averaged to six different sigma depths. The resolution of the CS3 model is 12km and is deemed too low for use in this project. The outputs of the CS20 model are considered to be of high temporal (hourly, 1992 to present) and spatial (1.8km) resolution. They include several variables characterising tidal currents and wave energy (e.g. overall speed and directional components), and therefore allow for highly specific spatial and temporal data to be extracted. The use of these data therefore has the potential to improve the confidence in the input data layers compared to the derivative data used in MMO (2013), and therefore increase the overall confidence in those spatial outputs which were generated by the models including average tidal current and/ or wave energy as environmental predictors.

The Atlas of UK Marine Renewable Energy provides mean tidal flows, tidal ranges and annual tidal power estimates. The 2008 version includes data from 10% sigma levels near the seabed. Although temporal resolution is poor, spatial resolution is high at 1.8km. The data is feely available online.

[5] These areas are the Outer Bristol Channel, Eastern English Channel, East Coast, Humber, South Coast and Outer Thames

Data of higher temporal resolution include the European North West Shelf- Ocean Physics REANALYSIS from METOFFICE (1985-2012) data product which uses the Forecasting Ocean Assimilation Model 7km Atlantic Margin Model (FOAM AMM7) to provide eastward and northward water velocities as monthly and daily means for the years 1985 and 2012, thus potentially allowing extraction of data with temporal variability (not included in the data used in MMO (2013)). However, the spatial resolution is 7km which is considered poor compared to other available products. The data is freely downloadable through MY OCEAN.

NORWECOM (the NORWegian ECOlogical Model system) provides monthly means at a higher resolution of 0.1 degrees, over 17 fixed depths for the years of 1985 to 2008. However, the spatial coverage of this product excludes the South West marine plan areas.

Similarly to the seabed type data, tidal current and wave energy were often included as significant predictors of the essential fish habitats in MMO (2013). The data used was the EUSeaMap energy layer which is a combined derivative of the National Oceanographic Centre current and wave models (ProWAM, CS20, CS3 and NEA). A low confidence was associated with this layer as insufficient information was available for some aspects of the data (timeliness, spatial confidence, completeness, and quality standards). The layer provides mean tidal and wave energy at the seabed and therefore it was considered suitable to provide a measure of energy particularly for the demersal species considered in the MMO (2013) models. However, other sigma depths could be useful for modelling more pelagic species or life stages. Furthermore, data with a higher temporal resolution would be useful to match fish survey data with seasonal, monthly or even daily variations in tidal currents. Therefore, considering the data characteristics of the alternative data layers mentioned above (see also Annex 6), using the detailed data obtained from CS20 (which contributed to the creation of the derivative data layers used in MMO (2013)) is considered as potentially beneficial to the improvement of the confidence in the outputs of MMO (2013). However, the information obtained during this project was not sufficient to allow a full assessment of the confidence associated with these data layers (hence the potential for outputs improvement) and further detailed assessment of the data is required (with possible consultation with data providers and or further discussion with the consultee suggesting use of these data, to clarify sources and confidence aspects).

3.4.4 Salinity

NORWECOM (the NORWegian ECOlogical Model system) provides salinity as monthly averages at a spatial resolution of 0.1 degrees, over 17 fixed depths for the years of 1985 to 2008. However, the spatial coverage of this product excludes the South West marine plan areas.

The European North West Shelf- Ocean Physics REANALYSIS from METOFFICE (1985-2012) considers precipitation fluxes and river inputs to provide a monthly and daily means for the years 1985 to 2012. This data covers all UK water at a resolution of approximately 7km.

Although the above data products are not supplied at a resolution as fine as that used for the MMO (2013) project, this is not deemed an issue as the resolution is considered sufficient for the variability of the feature in offshore areas.

For the initial MMO (2013) project, salinity was considered in a combined layer with temperature and front probability as 13 categories of Water column Features. This was a product of the UKSeaMap Project (2006) by JNCC and is no longer available. The successive products including UKSeaMap (2010) and EUSeaMap (Phase 1 (2009-2012) & Phase 2 (2013-2016)) do not consider salinity for UK offshore waters.

Considering the data characteristics of the alternative data layers mentioned above (see also Annex 6), the European North West Shelf- Ocean Physics REANALYSIS from METOFFICE (1985-2012) product would appear to be an appropriate alternative given its high temporal extent and resolution. However, although this might be particularly useful for more inshore areas, where steeper gradients are present, detailed mapping of salinity is considered less relevant in the offshore areas where fish survey data are mostly available and therefore where the essential fish habitat outputs would be applicable. In these areas, the broader seasonal classification of the water column based on salinity and vertical stratification (as used in MMO (2013)) is considered sufficient to represent the existing gradients, given also that a moderate confidence was associated to the data layer.

3.4.5 Temperature

NORWECOM (the NORWegian ECOlogical Model system) provides temperature as monthly averages at a high spatial resolution (0.1 degrees), over 17 fixed depths for the years of 1985 to 2008. However, the spatial coverage of this product excludes the South West marine plan areas.

Data of higher temporal resolution include the European North West Shelf- Ocean Physics REANALYSIS from METOFFICE (1985-2012) data product which uses the Forecasting Ocean Assimilation Model 7km Atlantic Margin Model (FOAM AMM7) to provide sea water potential temperature as monthly and daily means for the years 1985 to 2012. The spatial resolution is 7km which is considered poor compared to other available products. The data is freely downloadable through MY OCEAN.

The Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) system is run by the UK Met Office and produces a high resolution (1/20deg. - approx. 5km) daily analysis of the sea surface temperature (SST) for the global ocean. Data are available between 1985 and 2007. This data is based on both satellite data and in-situ observations. The data is freely available through MY OCEAN and was used for the MMO (2013) project.

Considering the data characteristics of the alternative data layers mentioned above (see also Annex 6), the most appropriate product for the purpose of essential fish habitat modelling is considered to be European North West Shelf- Ocean Physics REANALYSIS from METOFFICE (1985-2012). This product is more up to date compared to the one used in MMO (2013) although the spatial resolution of this product is lower. This is not however deemed to be an important limitation for its use considering that variability of this environmental parameter is more pronounced on a temporal rather than spatial scale.

3.4.6 Biogeochemistry

There are two Ocean Biogeochemistry non assimilative hindcast simulations for the Atlantic-European North West Shelf. The first is from NERCPOL (1967-2004) - this simulation is a coupled hydrodynamic-ecosystem model based on hydrodynamics supplied by the Proudman Oceanographic Laboratory Coastal Ocean Modelling System (POLCOMS) and the ecosystem component is supplied by the European Regional Seas Ecosystem Model (ERSEM), developed at Plymouth Marine Laboratory

The second simulation is from IMR (1985-2008). This product provides monthly means hindcast of Ocean biogeochemistry for the Northwest Shelf Sea from 1985 to 2009, issued from the NORWECOM system. NORWECOM, or the NORWegian ECOlogical Model system, is a coupled 3 dimensional physical, chemical, biological model system for studying of primary production and dispersion of particles (such as fish larvae and pollution). The model was originally developed for simulations in the North Sea and Skagerrak, but has also been used in the Norwegian Sea, the Barents Sea and the Benguela.

Both products are supplied at a resolution of 1/9 degree latitude x 1/6 degree longitude (approx. 12km) and provide hindcast products for the Northwest Shelf Sea as monthly means of the following parameters:

- mole concentration of nitrate in sea water
- mole concentration of phosphate in sea water
- volume beam attenuation coefficient of radiative flux in sea water
- mass concentration of chlorophyll in sea water

Of these variables, chlorophyll would be the most relevant to the current application in essential fish habitat models as this could be used as a proxy for food availability in spawning areas, hence affecting the distribution of fish eggs and larvae.

Other products specifically delivering chlorophyll data include North Atlantic Chlorophyll (Optimal Interpolation) and North Atlantic Surface Chlorophyll Concentration from Satellite observations. The temporal and spatial resolution of these products is good but the products only became available in 2013 and so would not be suitable for modelling essential fish habitat based on earlier fish data.

For a more comprehensive output the NORWECOM (the NORWegian ECOlogical Model system) could be used directly. This provides a full hindcast of salinity, temperature, currents, water elevation, phytoplankton, nutrients and oxygen for the years 1985 to 2008 as monthly means at a high resolution (0.1 degrees, covering 17 fixed depths).

The MMO (2013) project used a data layer for phytoplankton absorption coefficient (APH, 1997-2010) which was based on optical data layers from My Ocean (with a moderate confidence). This product is no longer available but as described above (see also Annex 6), other data is available which could be used as indicators of food availability to larvae (e.g. chlorophyll, phytoplankton).

4. Conclusions and Recommendations

This project was based on a consultation with Defra, its statutory advisers for the marine environment and other organisations with relevant expertise. The project obtaining their view on the MMO (2013) approach to understand if and how the model outputs can be used to support the development of marine plan policies in England. Due to the limited time available to the consultees to consider the work, Defra's acceptance relied on MMO and Cefas judgement and the fishery research scientist consulted in Cefas could not provide an organisation's acceptance of the method for marine planning. The Cefas expert, however, agreed to seek further discussion from directors of the relevant divisions in Cefas (a task not feasible within the project timeframe).

Discussion with Cefas, Defra and other organisations allowed identification of strengths and weaknesses associated with the MMO (2013) approach. It was therefore possible to formulate a series of recommendations that would allow to improve the robustness of the model, apply the approach in all marine plan areas and use it to develop marine plans for England. These are reported below.

4.1 Validation, improvement and confidence of outputs from MMO (2013 a-c)

Confidence in the data is a crucial element to determine whether spatial outputs can be used to generate policy maps for marine planning as opposed to their use as indicative maps. Therefore any improvement of such confidence likely increases the suitability of the spatial outputs as support tools for the development of prescriptive or spatially explicit marine plan policies.

The validation undertaken in the present study allowed the confidence assessment of the MMO (2013) spatial outputs to be improved. There was a good agreement of the accuracy of the maps with the expert knowledge and additional empirical evidence, and the statistical validation often gave for an increase in the overall confidence in the spatial outputs. This was particularly true for the maps of nursery grounds of the selected species, which showed for most species an increase in confidence from low to moderate after statistical validation.

Expert judgement and the detailed analysis of the model accuracy highlighted that in most cases the maps of fish nursery habitats tended to underestimate the occurrence of juvenile fish. Therefore, within a map, a higher uncertainty was generally associated with the areas where the nursery grounds were not shown. By contrast, the relatively higher confidence associated with the areas in the maps where these habitats occur was confirmed.

The confidence in the validated maps of fish adult foraging grounds and spawning grounds was generally low. In the former case, this was most likely due to the complexity of the model used to identify adult foraging grounds. This model actually predicted the combined presence of adult and juvenile life stages, hence leading to a higher uncertainty in the overall results.

When only the occurrence of adults was considered (this being indicative of the distribution of adult foraging grounds, irrespectively of whether juveniles were also present), a higher confidence was associated with this prediction. Therefore, revising these models by using data on the occurrence of adult individuals only would likely allow a higher confidence in the overall ability of the model in predicting adult foraging habitats. Although adult habitats are not commonly considered as essential fish habitats (Coull *et al*., 1998; Ellis *et al*., 2012; Aires *et al*., 2014), the knowledge of the distribution of this life stage is considered an important indicative layer to provide background to a species distribution in a marine plan area and to the distribution of its nursery and spawning grounds.

With regard to spawning habitat maps, the low confidence in the model predictions, as also confirmed with expert knowledge, is most likely attributed to the high uncertainty in the association between spawning habitats of a fish species and the distribution of pelagic egg and larval stages. This uncertainty is enhanced in particular when only the presence/absence of these life stages is considered, as in the MMO (2013) models. It is likely that including information on the abundance of these life stages would lead to improvement in the models predictive ability and the resulting confidence in the outputs. The approach used by Aires *et al*. (2014) to include this information in tree-based modelling of essential fish habitats, i.e. modelling the occurrence of aggregations of eggs and larvae, is considered valuable for this purpose.

Although the confidence in the predictive ability of the statistical models developed in MMO (2013) was generally good, a lower overall confidence was associated with the resulting spatial outputs. This was due mostly to the low confidence (or inability to assess it) attributed to some of the relevant environmental data layers that were used to spatially apply the model. Therefore, there is the potential to further increase the confidence in the MMO (2013) spatial outputs by using additional environmental data layers to replace or integrate the environmental variables used in the model. This represents a further step towards the use of these outputs in marine planning.

In particular, the use of detailed energy data layers instead of the derivative ones used in the MMO (2013) (with a low confidence associated) is considered as potentially beneficial to improve the model predictions of nursery and adult habitats and the associated confidence. Similarly, the integration of the seabed data with parameters characterising the substratum texture is likely to increase the model robustness. A detailed confidence assessment of these additional data layers would need to be undertaken to quantify the degree of change in the overall confidence.

The use of the detailed energy data layers is also likely to improve the models of fish spawning grounds, with the inclusion of variables that could potentially account for the transport of pelagic eggs and larvae away from these essential fish habitats (e.g. direction and speed of currents at different depth layers of the water column). The use of data layers indicative of water column productivity (e.g. chlorophyll, as a proxy of food availability for larval stages) might also increase the overall confidence in the maps of spawning habitats, although further exploration of these data layers is needed to fully assess their confidence.

As in most of these cases, new variables would be extracted from the identified data layers and models would need to be run with new parameters, as opposed to the replacement of a variable in the original model with the correspondent variable obtained from a new data layer. This might lead to possible changes in the selection of relevant environmental predictors (hence a change in the classification tree model).

New environmental data would be useful in developing the model for other marine plan areas. The expansion of the MMO (2013) approach to other marine plan areas would also depend on the identification of additional or alternative fish species as appropriate to the area (see Section 4.2) and their associated environmental requirements.

Given these results, the maps on fish nursery grounds in this report are considered at a more advanced stage of development than other essential fish habitat types A moderate confidence at best could be associated with these maps after validation, but it is noted that a conservative approach was adopted for confidence assessment (MMO (2013)) and validation (present study). Input data layers were assessed in MMO (2013) as low confidence when confidence assessment could not be thoroughly conducted due to lack of information. Such conservative approaches align with the MMO quality assurance process (MMO, 2013). In the present study, only negative feedback from the consultees was considered to validate the maps. This led to the reduction of the relative confidence associated with spatial predictions, whereas positive feedback (agreement between the maps and expert knowledge), where given, was only used to confirm (not to increase) the existing confidence levels.

In consideration of this, the validated maps on fish nursery grounds are considered as an acceptable product to use to support marine plan policies. The inclusion of additional data in the models is likely to lead to further improvement in the robustness of these outputs. A further enhancement of the confidence would therefore increase the suitability of these spatial outputs to possibly generate spatially explicit policy maps to be used to support marine plan policies.

4.2 Further improvement to the application of the original approach in marine plan areas

As highlighted during consultation, the few species included in the MMO (2013) may constitute an important limitation, particularly when an integrative assessment of the ecological value is undertaken by combining the information obtained from maps of essential fish habitats of individual species (as with hot spot maps; MMO, 2013). As a result, the assessment would likely underestimate the actual ecological value of an area, most notably if important species (for fisheries or conservation) are missing from the selection of species included in the modelling.

The application of the approach in the South marine plan areas could be improved by integrating the modelling with data on juvenile turbot, brill and whiting, and eggs of cod and whiting. These data are available in the fish survey datasets used in MMO (2013). This would facilitate filling some of the gaps in species coverage for the South marine plan areas as identified during consultation.

However, it is unlikely that the MMO (2013) approach would allow the full coverage of the fish species present in a marine plan area. This is dependent on the availability of fish survey data from broad scale survey programmes, a data requirement that would ensure as wide a spatial coverage as possible of a marine plan area. The fish survey data considered for this purpose have been identified as appropriate by representatives from Cefas and other consultees. However, this data requirement also limits the coverage of species that have been targeted in smaller-scale surveys (often targeting a particular species or life stage; e.g. Solent small bass survey).

A trade-off between species coverage and spatial coverage is present, and the MMO (2013) approach gave priority to the spatial aspects. Providing a consistent spatial assessment of the ecological value in a marine plan area was considered critical for marine planning purposes, as it would allow a better comparability of the ecological value of different areas, albeit based on a reduced number of species (hence possibly underestimating the actual value). The alternative approach (i.e. giving priority to the species coverage by using multiple fish survey datasets to generate models with reduced spatial applicability) was considered less suitable for spatial marine planning, as it may lead to a heterogeneous assessment of a marine plan area thus limiting the comparability of the ecological value of its different parts.

Although the limitation in species coverage and in the consequent assessment of the overall ecological value needs to be taken into account when using the information provided by the MMO (2013) outputs, it is believed that the spatial approach followed in MMO (2013) is better suited for supporting spatial marine planning activities.

It is acknowledged that, although the MMO (2013) outputs covered a wide spatial area of the South marine plan areas, there were gaps in the spatial validity of the obtained predictions. These were particularly evident in inshore areas and were ascribed to the poor coverage of these areas (hence of their environmental conditions) by the fish survey data used in the model (similar results are expected also in other marine plan areas).

As a result, fish species which are dependent on inshore and estuarine habitats for critical phases of their life cycle were poorly represented in the models developed in MMO (2013). These are also often species of high conservation value (e.g. migrant species). It is noted however that, contrary to offshore areas, there is high availability of information on species distribution at high resolution in inshore areas (e.g. from Environment Agency assessments). Therefore the essential fish habitat maps can be used to complement this information.

4.3 Recommendations

The following recommendations are given:

- The environmental data layers, as identified above, should be used to run the models developed for South marine plan areas with new, more detailed environmental parameters being included as possible predictors. In particular, current variables obtained from detailed energy data layers, Terrain

Ruggedness Index obtained from bathymetric data layers and chlorophyll concentration should be included. The use of these additional environmental data has the potential to also improve the prediction and confidence in the model outputs in other marine plan areas. A detailed confidence assessment of the new data layers needs to be undertaken as part of the approach application.

- Models of fish spawning grounds should be run including the information on the abundance of pelagic eggs and larvae, as done in Aires *et al*. (2014). This is likely to improve the model robustness and confidence in the prediction of spawning habitats.

- Cefas highlighted the importance of using expert knowledge in refining the model outputs, as confirmed in this study. The validation of the model outputs combining statistical validation and stakeholder consultation should be regarded as an integral part of the MMO (2013) approach. This procedure would make the model results more robust, improve the assessment of model confidence and hence likely increase their suitability as tools for marine planning purposes.

- Models should be applied to additional fish species in the datasets selected for the South marine plan areas (in particular juvenile turbot, brill and whiting; cod and whiting eggs) in order to increase the species coverage. This would allow a better confidence in assessment of the overall ecological value of habitats within marine plan areas (as with hot spot maps).

- Identification of critical fish species and detailed exploration of available fish survey data should be undertaken for other marine plan areas as applied in MMO (2013) in order to expand the MMO (2013) approach to these areas.

- Limitations in the fish survey data availability in a marine plan area might not allow the application of essential fish habitat models to all the species identified as important in that area (for commercial or conservation reasons). Is this case, hot spot maps would likely underestimate the actual ecological value of a marine plan area and therefore it is recommended that expert knowledge should be sought to validate also these maps.

- Given the gaps in the spatial validity of the MMO (2013) predictions in inshore areas, the MMO (2013) spatial outputs should be complemented and integrated with information from other sources better covering these areas (e.g. Environment Agency assessments of fish distribution inshore).

- A formal agreement should be obtained from Cefas on the MMO (2013) method and its possible use as a prescriptive tool in marine planning (Defra’s acceptance would depend on acceptance by MMO and Cefas).

- The confidence improvement that would likely result from addressing the recommendations above would further increase the suitability of the spatial outputs as supporting tools for the development of marine plan policies in England.

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Annex 1: Questionnaire

Dear Stakeholder,

Evaluation of essential fish habitat models for their operationalisation and subsequent development of marine plan policies in England
Stakeholder consultation, Tier 1: Statistical validation and identification of areas of improvement

Thank you for agreeing to contribute to this phase of consultation to assess the validity of the spatial outputs (essential fish habitat maps) developed for the MMO South Marine Plan Areas (project MMO (2013)) and to help us identify additional data to improve the existing model and to possibly extend the approach to all marine plan areas in England.

This document contains a few questions (Section 2) based on looking at the main spatial outputs of the project (the maps and their confidence rating) which constitute the bulk of the following pages (Section 3). We are interested in knowing if the model outputs agree with your knowledge of the species distribution in the study area, and if not, we would be grateful if you could provide empirical data for the model statistical validation. We would also appreciate if you could help us identify (and if possible provide) additional data to improve the model for the study area and to apply a similar approach to other marine plan areas (e.g. data on additional relevant fish/ shellfish species or life stages, additional environmental data layers relevant to the species in the study area or in other marine plan areas).

We are aware that the models, as calibrated in MMO (2013), have some limitations mostly ascribed to gaps and uncertainties associated with the input data (these can be found in the MMO (2013) Final Report (in Conclusions) and in the related Technical Annex (sections on data selection)). Confidence maps have been associated to model spatial predictions in order to account for these limitations and are shown as part of the spatial outputs below (Section 3). At the end of this document we also provide a summary of the data requirements and of the data layers we took into account to create the models (Section 4), and the main limitations we identified as associated with the outputs (Section 5). We hope this information will provide enough background for you to apply your expert judgement to the validation and evaluation of the approach.

We would appreciate it if you could complete this survey by Tuesday 24th February.

If you can't meet this deadline or need further information or clarifications, please don't hesitate to contact me (A.Franco@hull.ac.uk; tel. 01482466695).

Best regards,

Anita Franco

1. Background on the approach and outputs

Essential fish habitat (EFH) maps were produced for **10 fish species**, with different life stages taken into account, including juveniles, adults and eggs of Plaice, juveniles and adults of Sole, Lemon sole, Dab, Red gurnard, Dragonet and Solenette, juveniles of Thickback sole and Thornback ray, and Herring larvae. Species selection was based on a number of criteria, including:

- Relevance of the species for commercial exploitation or conservation.
- Confidence in the data available for the species to adequately represent their occurrence/abundance in the area (depending on gear selectivity, survey seasonality, taxonomic standards, suitability of the considered life stage as an indicator of the EFH).
- Availability of data across different life stages to provide appropriate information on specific essential fish habitats.

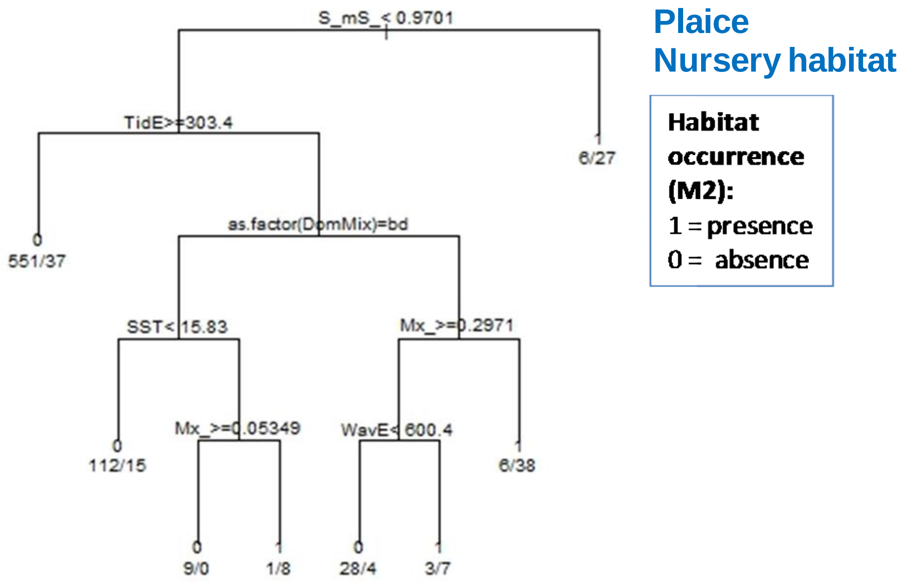
Existing literature/projects were used to inform the species selection and life history staging. The list of fish datasets considered in the project is given in Section 4.1 of this document.

Statistical models (classification tree models; Figure 1) were calibrated to identify the relationship between the presence of these fish species/life stages and a series of relevant environmental variables (a full list is given in Section 4.2 of this document). The potential distribution of the species' life stages was then mapped (at a spatial resolution of 5km x 5km) based on the combination of environmental characteristics identified by the models.

For each species, 1 to 3 **outputs** are provided (depending on the data available):

- an output showing the predicted distribution of the species, considering both adult foraging habitats and juvenile (nursery) habitats
- a more detailed output on the distribution of nursery habitat of the species showing the probability of presence of juveniles in the study area
- an output on the distribution of potential spawning habitat of the species, showing the probability of presence of egg or larvae in the study area.

Figure 1. Example of classification tree model as obtained for Plaice nursery habitats. The environmental conditions (see Section 4.2 for the list of environmental variables considered) selected by the model as relevant in predicting the distribution of plaice nursery habitats are indicated at each node of the tree, with the resulting prediction on the presence-absence (1-0) of plaice juveniles being indicated at each "leaf" of the tree. The actual number of observations of absence/presence of juveniles at the identified conditions is also indicated in the leaf label (this information was used to calculate the probability of presence associated to each leaf and the misclassification error associated with the model). Further details on classification models construction and interpretation can be found in the MMO (2013) Technical Annex.



A **confidence assessment** was undertaken, based on the combination of confidence ratings and maps (where available) and took into account the different elements contributing to the final output (including the predictive ability of the statistical model, the confidence in the fish survey data used to calibrate the model and the confidence in the environmental data layers used by the model as weighted by their importance in determining the final output).

The results of this confidence assessment are shown in Section 3 for each habitat map. These include:

- the **overall confidence** in the model prediction of essential fish habitats
- a **confidence map** showing the spatial distribution of the relative confidence in the predicted EFH distribution.

Further details on the methodology behind the calculation of confidence values can be found in the MMO (2013) Technical Annex.

2. Questionnaire

Before starting the survey, we would like you to tell us who you are. Please provide your name, the name of your organisation and your contact details.

Please note that what is most important for us is to seek an organisation view on the models, therefore your personal details will not be published in the project documents. These are only useful for us to get in contact with you during the consultation for further discussion or clarifications.

Insert Respondent details here

Model output validation

You will now be asked to comment on the outputs from the project (provided in Section 3 of this document). Please provide an answer to the following questions for any of the outputs of the project you feel that you have sufficient knowledge or experience to comment on. Please note that you will have the opportunity to provide general feedback at the end of the questionnaire.

1) Allowing for the uncertainty in the underlying models (as shown by the 'confidence' map) does the information on the distribution of the essential fish habitat shown by the maps agree with your personal experience, knowledge or data?

(Please, let us know which species/output(s) your comment(s) refer to)

Insert text here

2) In the case(s) your answer to the above question is No, could you please locate any specific areas of the mapped distributions that DO NOT agree with your personal experience or knowledge, and indicate the nature of the discrepancy

(Please use the column and row headings to locate the area of discrepancy)

Insert text here

3) We would appreciate it if you could provide empirical evidence in support of your comments above. Empirical evidence could be, for example, in the form of information on the occurrence or frequency of observation of a species life stage in a certain area.

In order to compare any such information with the outputs from the work undertaken so far we would need access to the relevant supporting data. Please indicate below if you are able to provide such data. Note that, in addition to information on the nature of the data itself, we would also ask you to provide a summary of supporting information (metadata) associated to these additional sources of data, including:

- An abstract of the data source (including information on the type of data, fish life stage covered by the data, spatial and temporal reference, methods of collection).

- Contact details for data provider.

If possible, we would appreciate if you could take into account the data requirements as specified in Section 4.1 while giving your suggestion.

Insert text here

Areas of improvement – additional data

We are aware that the model outputs have limitations, mostly associated with gaps and confidence in the input data layers. For example, as you will see from the output maps and associated information, on certain occasions issues of the overall confidence of the model prediction are associated to the low confidence in the input environmental data layers. Often this is due to a lack of information on the data layers that prevented us to assess their temporal and spatial confidence, completeness of the data/ information, and confidence in quality standards.

4) We would appreciate it if you could identify additional datasets (provided they fulfil the identified data requirements, as explained in Section 4) that you think would be useful to integrate/improve the model for the South Marine Plan Areas, but also for the calibration of similar models for other marine areas around England. Additional data sources may include:

- **additional fish survey data covering other relevant fish species or life stages not modelled in MMO (2013), with also consideration of possible inclusion of shellfish in the models;**
- **additional environmental data layers not available or not considered at the time MMO (2013) was undertaken (Summer 2014), that might replace or integrate data layers for variables already included in the existing model (e.g. data layers with higher confidence than those used) or which might be relevant to the modelling of additional species.**

We would be grateful if you could provide the additional data, but, where this is not possible, we would appreciate if you could give us as much information as possible on the type and characteristics of these data (e.g. spatial and temporal reference, survey method) and/or contact details for whoever would be able to provide the data.

The data sources that we used, or took into account, to obtain the outputs that have been presented are summarised in Section 4. These include the source of fish survey data as well as sources of environmental data.

Insert text here

General feedback

5) Finally, taking into consideration the possible areas of improvements of the model, we would like to know your opinion on the general validity of such an approach as a tool to support the development of marine plan policies in England.

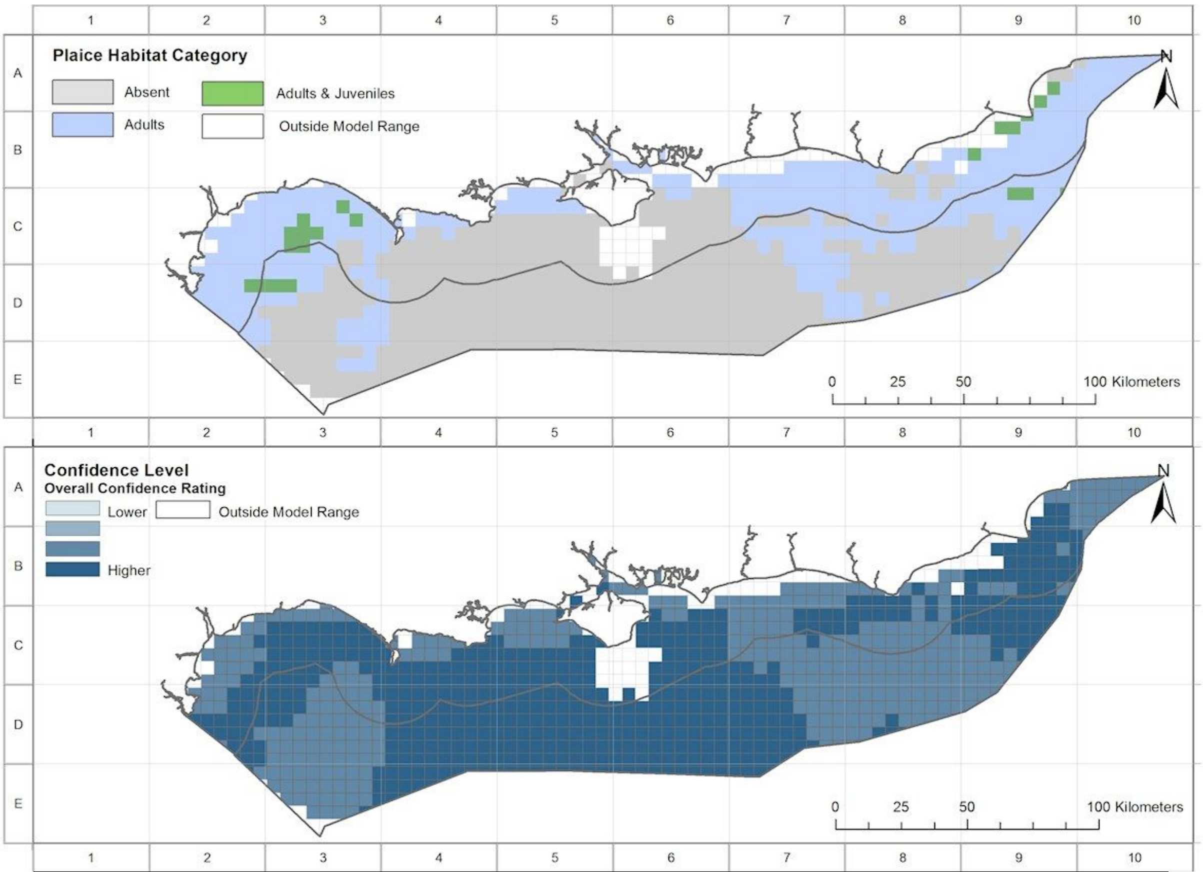
Insert text here

3. Project outputs

3.1. Plaice (*Pleuronectes platessa*)

Data on juveniles (40-180mm; 0-group), adults (190-640mm) and eggs (1.75-2.28mm; early stage, EG1) were used to model essential fish habitats of this species.

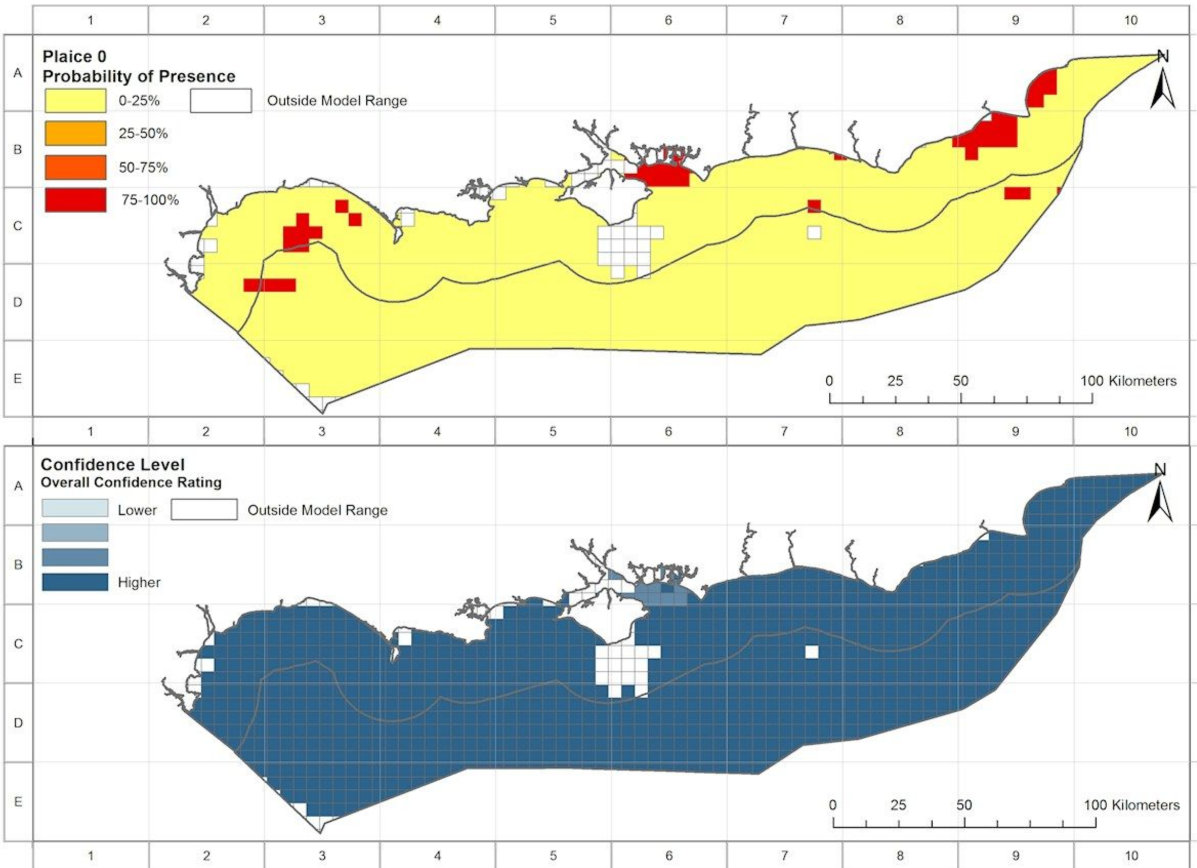
3.1.1. Predicted distribution of adult plaice foraging habitat.



	Model selection data	data Source*	data Confidence
Fish survey data:			
	Presence/absence of species life stages	BTS 2000-2012	High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
2	Type of mixing of the water column (categorical)	JNCC	Moderate
3	Sand to muddy sand relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
4	Coarse sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
5	Depth (m)	EMODnet	Moderate/ High
6	Mixed sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Moderate**

*See Section 4 for details on the data sources.

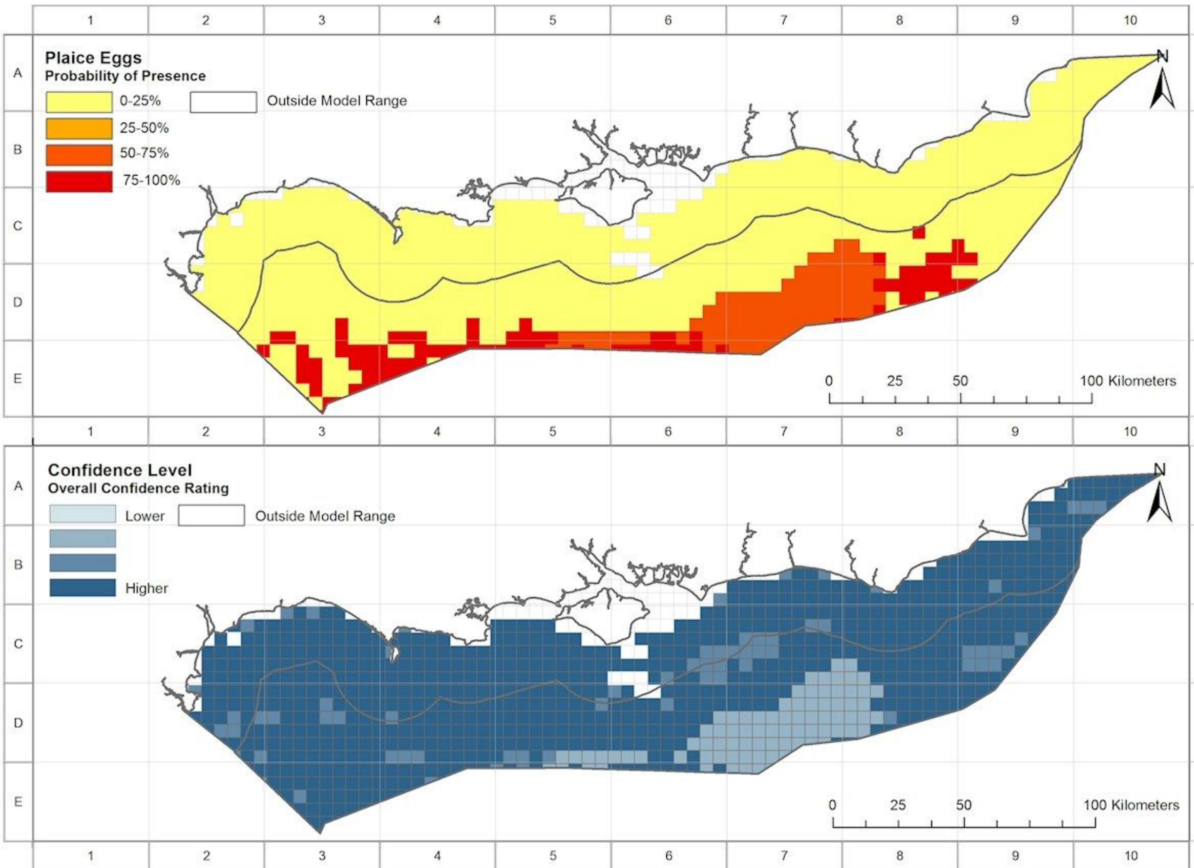
3.1.2. Predicted distribution of plaice nursery habitat (probability of presence of suitable habitat).



Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		BTS 2000-2012	High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Sand to muddy sand relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
2	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
3	Type of mixing of the water column (categorical)	JNCC	Moderate
4	Sea surface temperature (summer, ^{o}C)	My Ocean	Moderate
5	Mixed sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
6	Wave energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Low**

*See Section 4 for details on the data sources.

3.1.3. Predicted distribution of plaice spawning habitat (probability of presence of suitable habitat).



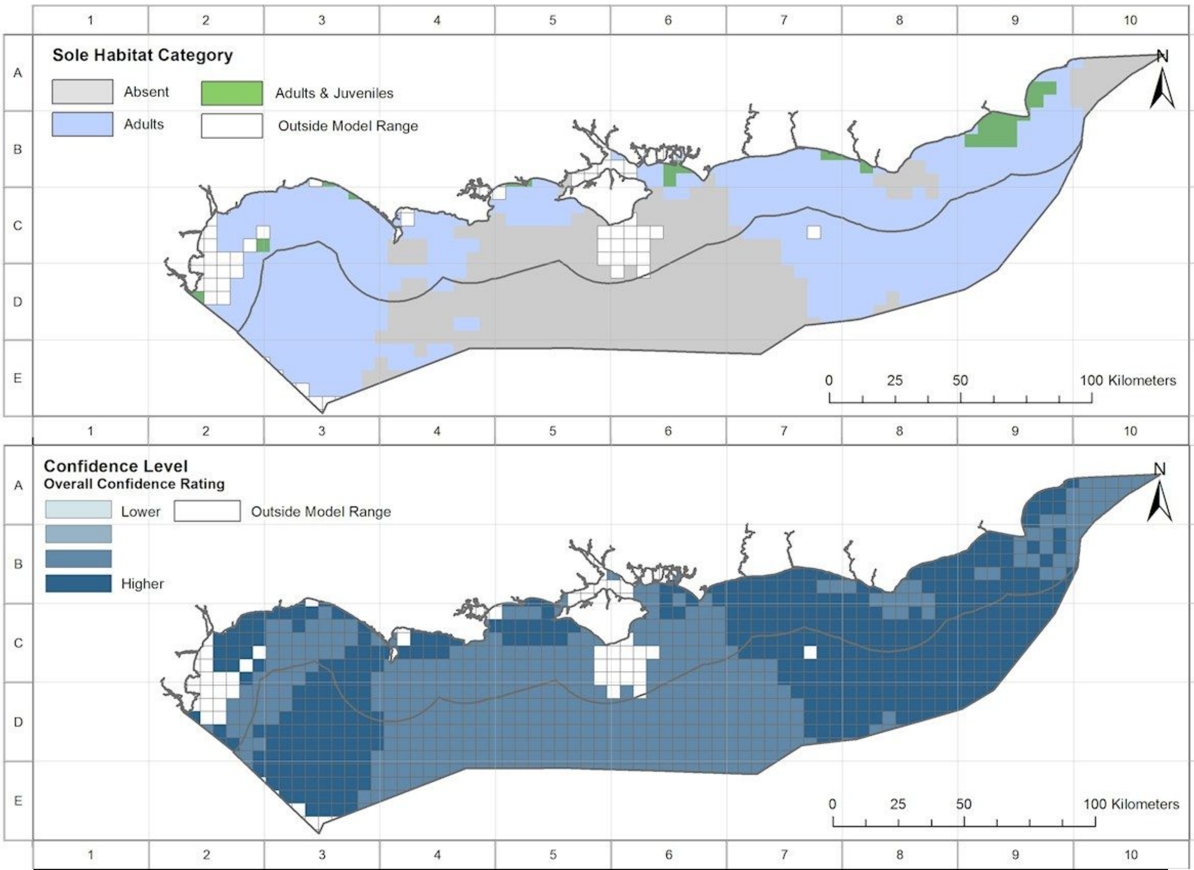
Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		WGEGGS* 2003/4 and 2008/9	Moderate-High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Phytoplankton absorption coefficient (January, m-1)	My Ocean	Moderate
2	Sea surface temperature (winter, OC)	My Ocean	Moderate

*See Section 4 for details on the data sources.

3.2. Sole (*Solea solea*)

Data on juveniles (40-200mm; likely including also >1year old) and adults (210-470mm) were used to model essential fish habitats of this species.

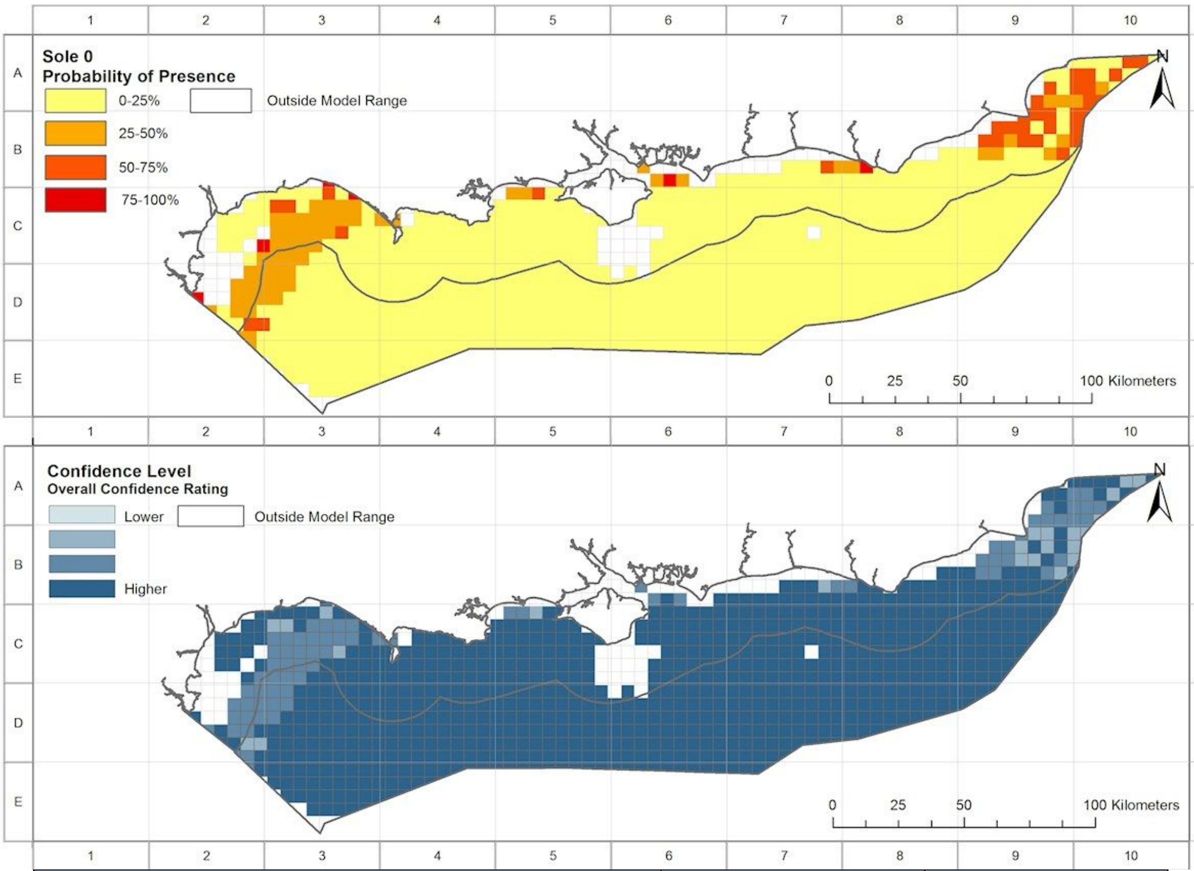
3.2.1. Predicted distribution of adult sole foraging habitat.



Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		BTS* 2000-2012	Moderate-High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
2	Mixed sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
3	Sand to muddy sand relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
4	Type of mixing of the water column (categorical)	JNCC	Moderate
5	Mud to sandy mud relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
6	Wave energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Low**

*See Section 4 for details on the data sources.

3.2.2. Predicted distribution of sole nursery habitat (probability of presence of suitable habitat).



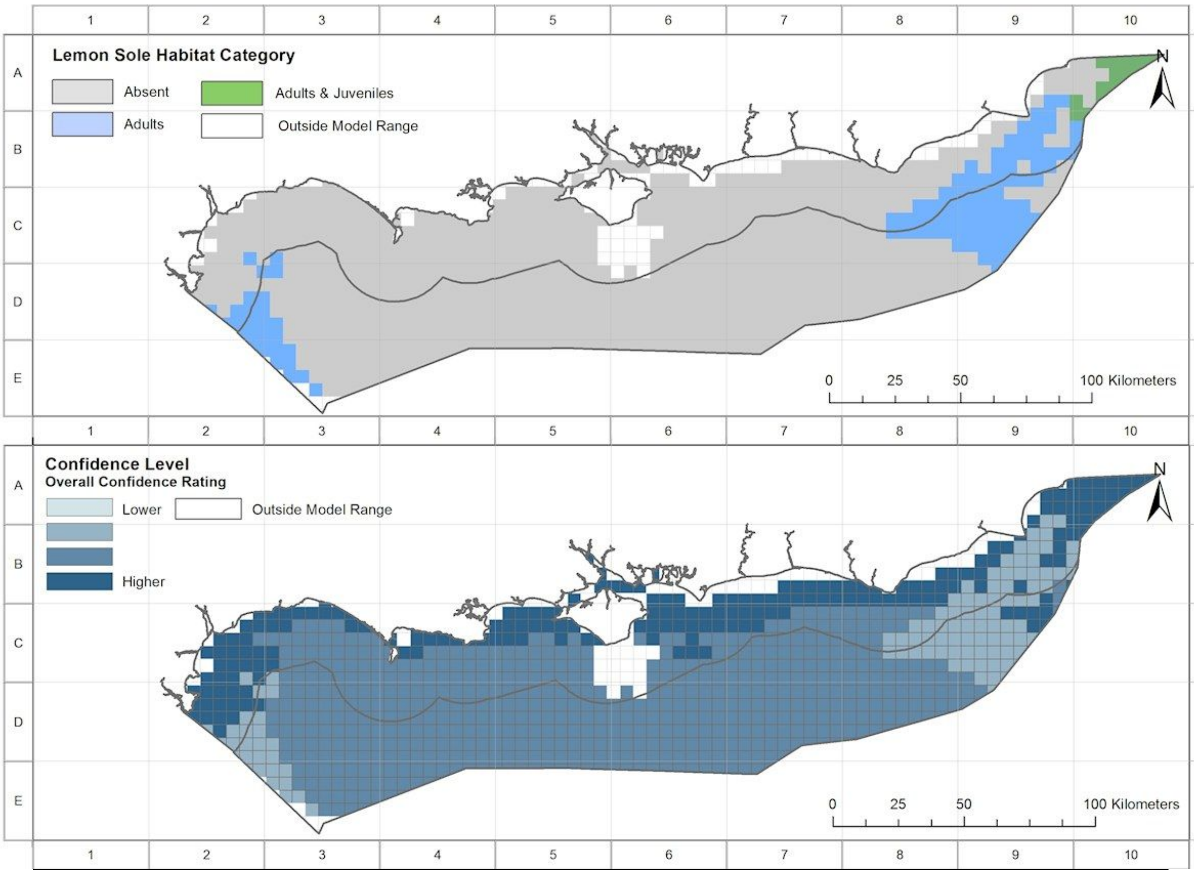
	Model selection data	data Source*	data Confidence
Fish survey data:			
	Presence/absence of species life stages	BTS 2000-2012	Moderate-High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Sand to muddy sand relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
2	Mixed sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
3	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
4	Depth (m)	EMODnet	Moderate/ High
5	Mud to sandy mud relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
6	Wave energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Low**

*See Section 4 for details on the data sources.

3.3. Lemon sole (*Microstomus kitt*)

Data on juveniles (50-200mm; likely including also >1year old) and adults (210-400mm) were used to model essential fish habitats of this species.

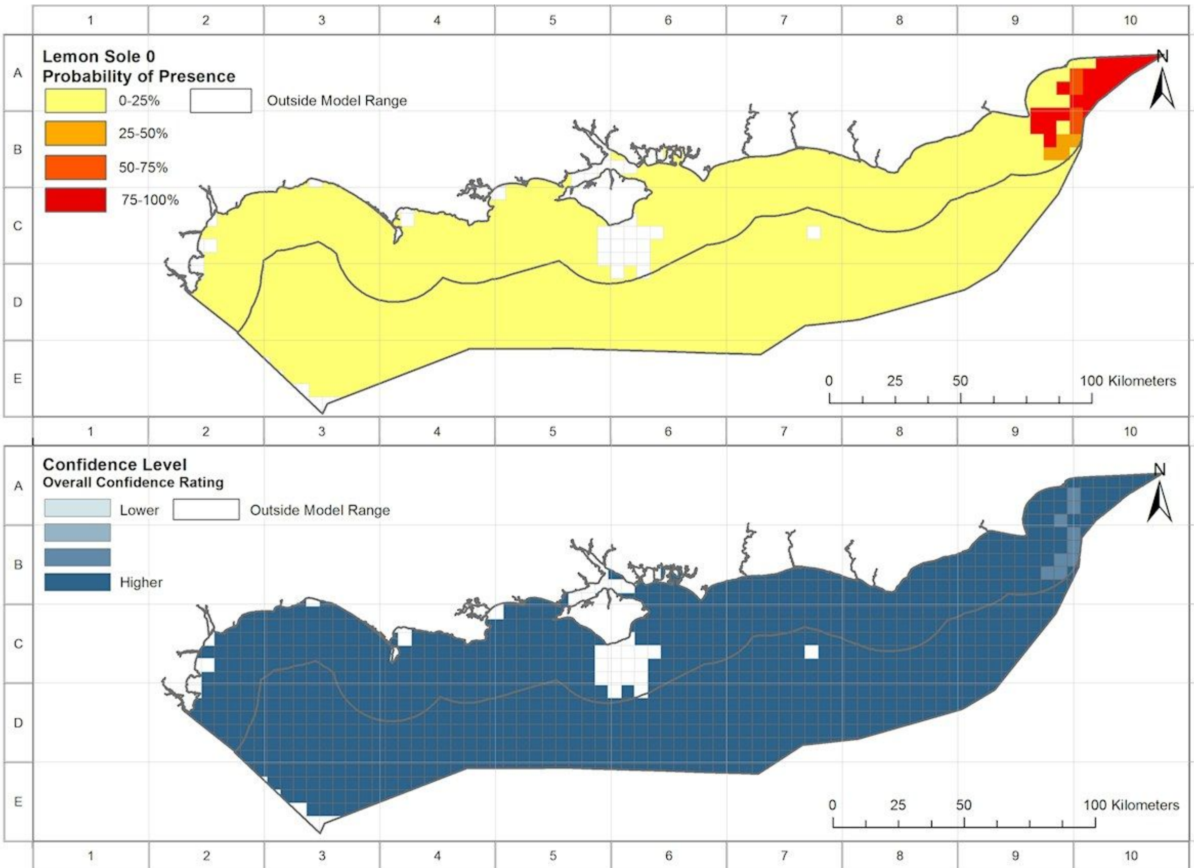
3.3.1. Predicted distribution of adult lemon sole foraging habitat.



Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		BTS 2000-2012	Moderate-High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Depth (m)	EMODnet	Moderate/ High
2	Type of mixing of the water column (categorical)	JNCC	Moderate
3	Coarse sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
4	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Moderate**

*See Section 4 for details on the data sources.

3.3.2. Predicted distribution of lemon sole nursery habitat (probability of presence of suitable habitat).



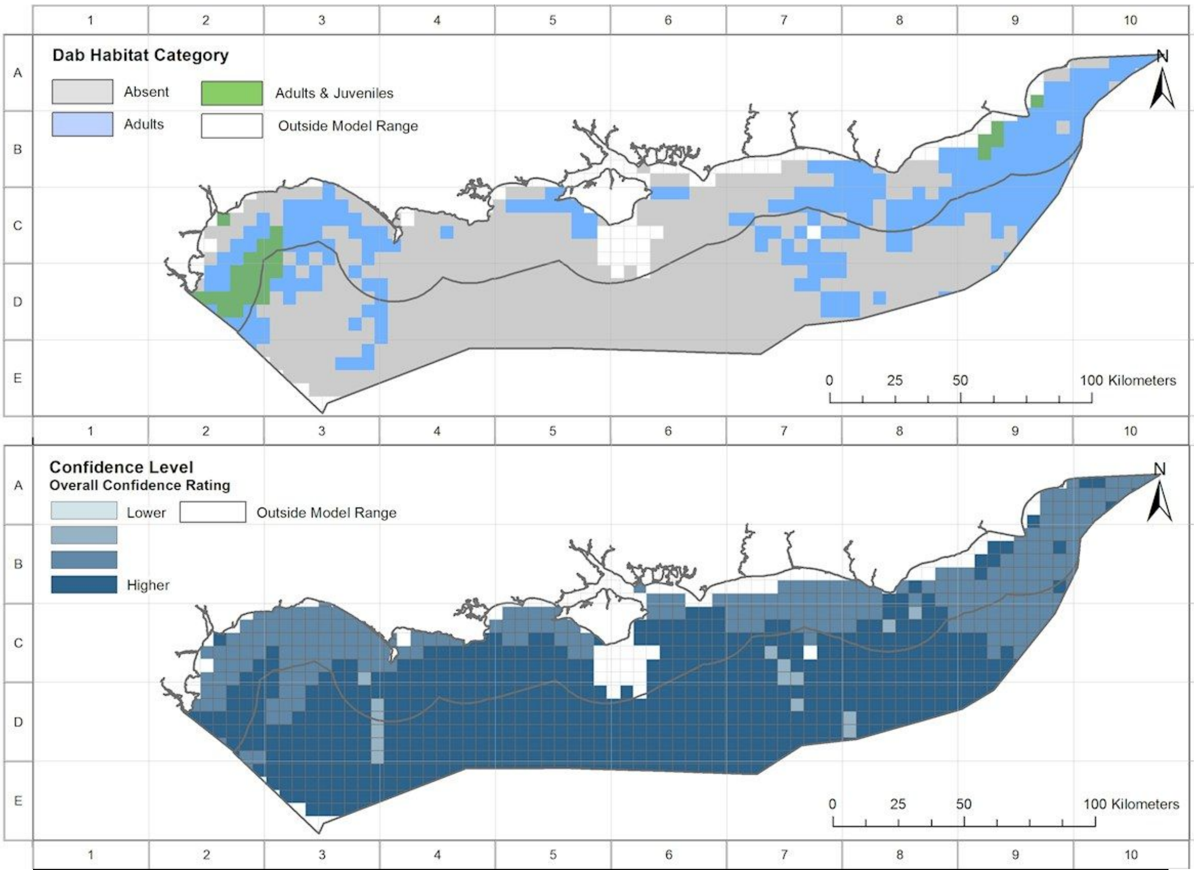
Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		BTS 2000-2012	Moderate-High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
2	Type of mixing of the water column (categorical)	JNCC	Moderate
3	Sand to muddy sand relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
4	Wave energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Low**

*See Section 4 for details on the data sources.

3.4. Dab (*Limanda limanda*)

Data on juveniles (20-80mm; 0-group) and adults (90-380mm) were used to model essential fish habitats of this species.

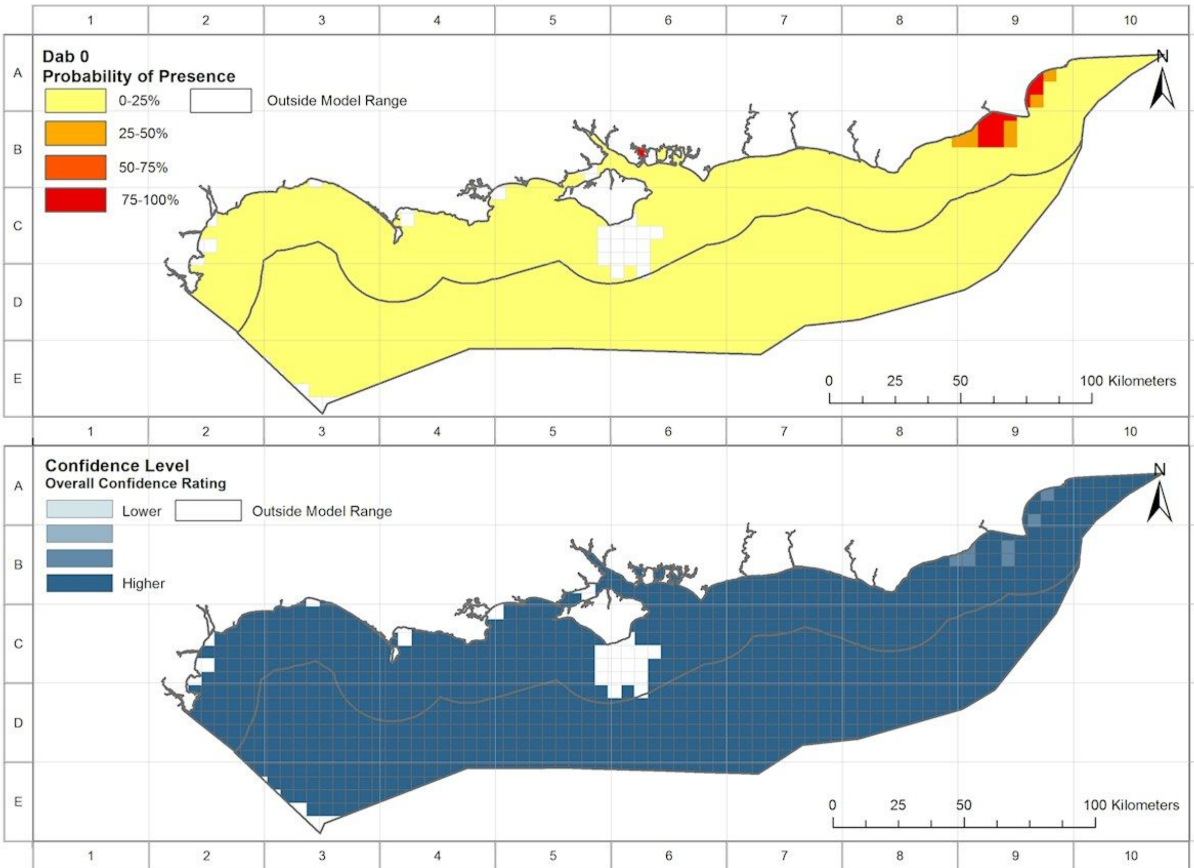
3.4.1. Predicted distribution of adult dab foraging habitat.



	Model selection data	data Source*	data Confidence
Fish survey data:			
	Presence/absence of species life stages	BTS 2000-2012	High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Sand to muddy sand relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
2	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
3	Depth (m)	EMODnet	Moderate/ High
4	Coarse sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
5	Type of mixing of the water column (categorical)	JNCC	Moderate
6	Wave energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Moderate**

*See Section 4 for details on the data sources.

3.4.2. Predicted distribution of dab nursery habitat (probability of presence of suitable habitat).



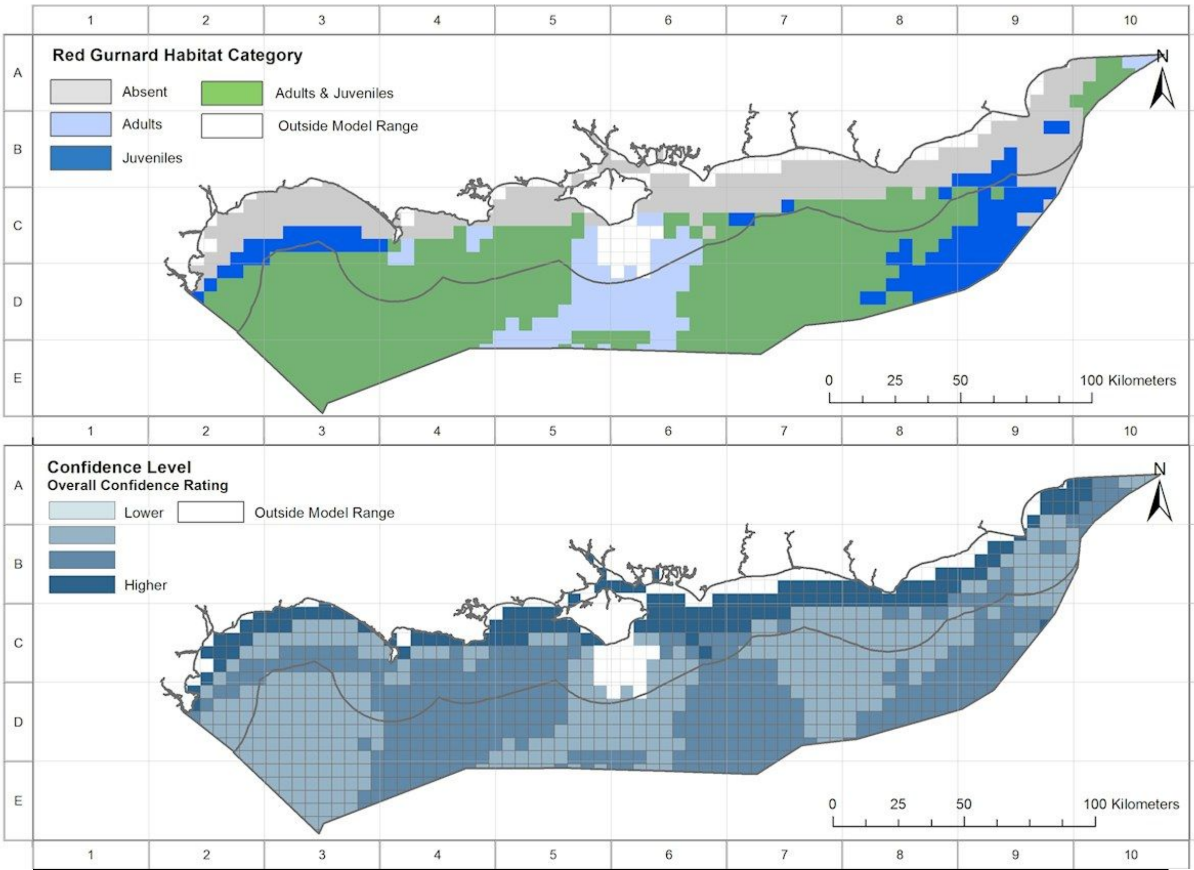
Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		BTS 2000-2012	High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
2	Type of mixing of the water column (categorical)	JNCC	Moderate
Overall confidence in the model prediction of essential fish habitats			**Low**

*See Section 4 for details on the data sources.

3.5. Red gurnard (*Chelidonichthys cuculus*)

Data on juveniles (50-180mm; 0-group) and adults (190-420mm) were used to model essential fish habitats of this species.

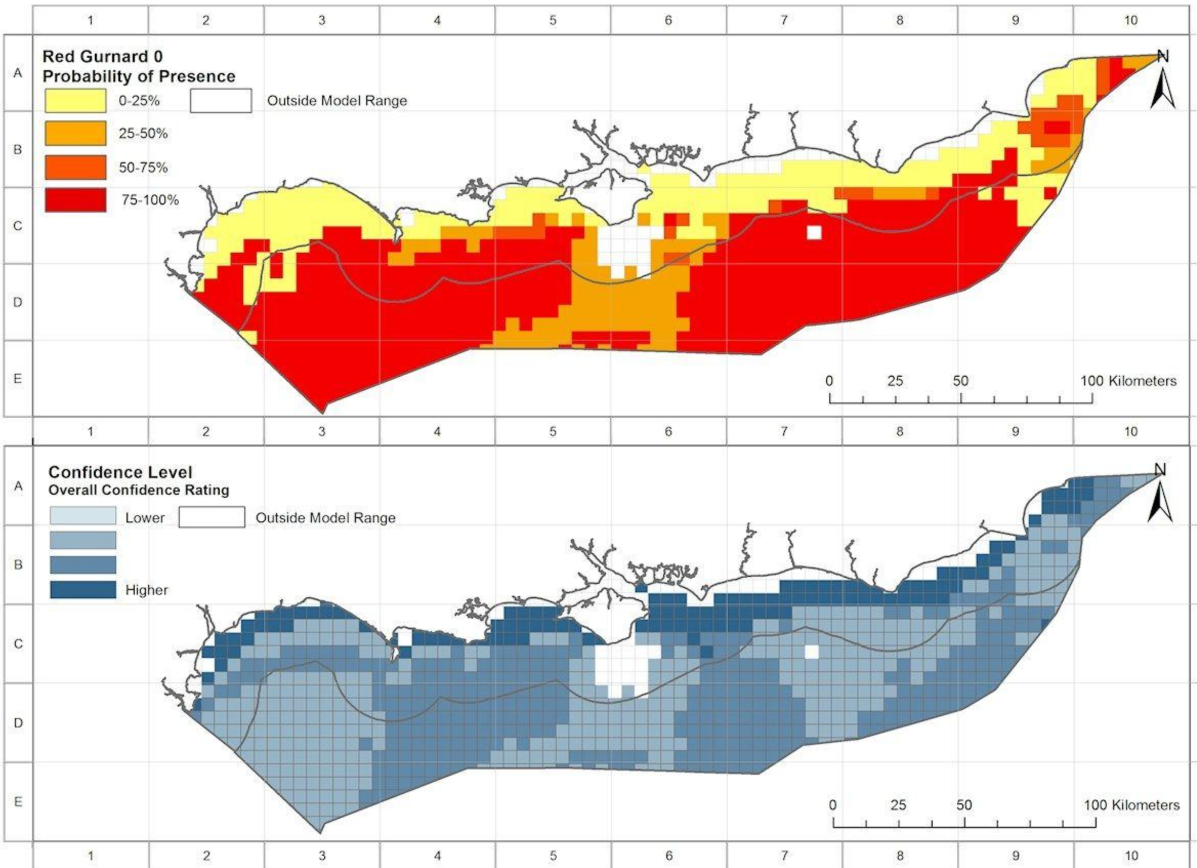
3.5.1. Predicted distribution of adult red gurnard foraging habitat.



Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		BTS 2000-2012	High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Depth (m)	EMODnet	Moderate/ High
2	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
3	Mixed sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Moderate-Low**

*See Section 4 for details on the data sources.

3.5.2. Predicted distribution of red gurnard nursery habitat (probability of presence of suitable habitat).



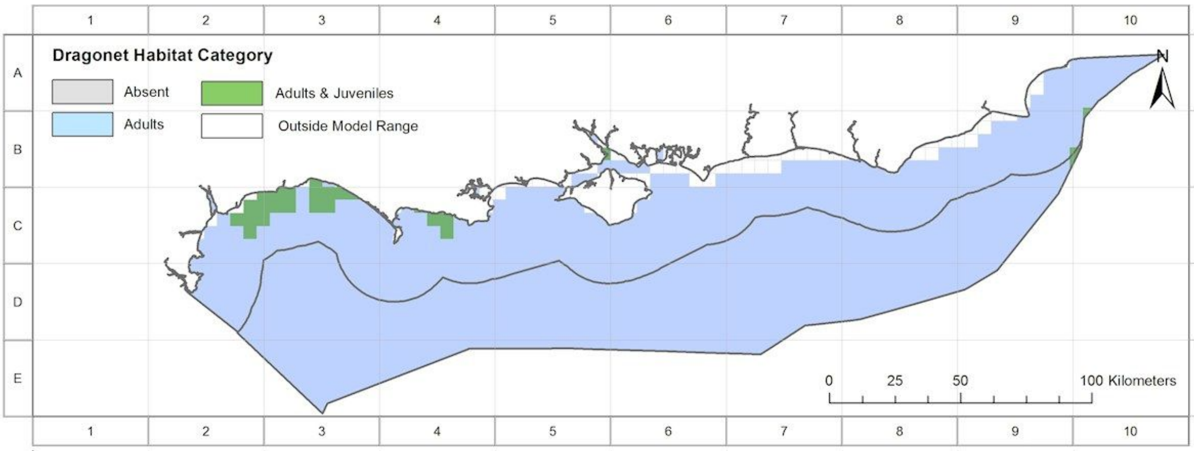
	Model selection data	data Source*	data Confidence
Fish survey data:			
	Presence/absence of species life stages	BTS 2000-2012	High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Depth (m)	EMODnet	Moderate/ High
2	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
3	Wave energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
4	Sand to muddy sand relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Moderate-Low**

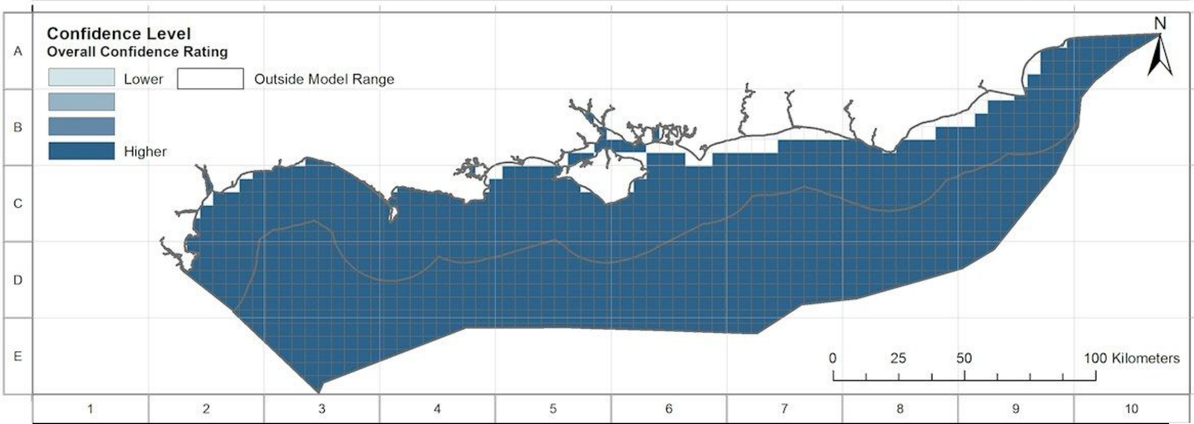
*See Section 4 for details on the data sources.

3.6. Common dragonet (*Callionymus lyra*)

Data on juveniles (10-95mm; likely including also >1year old) and adults (100-290mm) were used to model essential fish habitats of this species.

3.6.1. Predicted distribution of adult common dragonet foraging habitat.

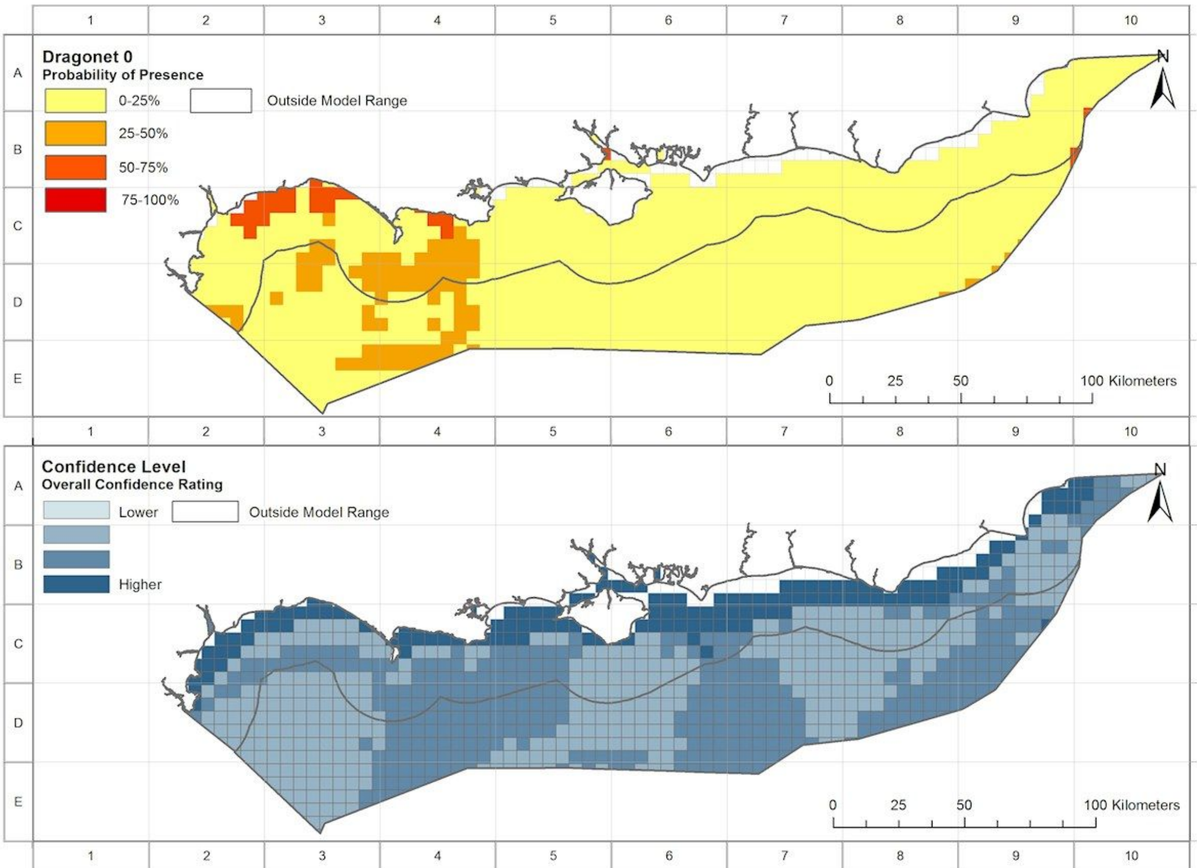




Model selection data	data Source*	data Confidence
Fish survey data:		
Presence/absence of species life stages	BTS 2000-2012	Moderate-High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)		
1 Mixed sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
2 Depth (m)	EMODnet	Moderate/ High
Overall confidence in the model prediction of essential fish habitats		**Low**

*See Section 4 for details on the data sources.

3.6.2. Predicted distribution of common dragonet nursery habitat (probability of presence of suitable habitat).



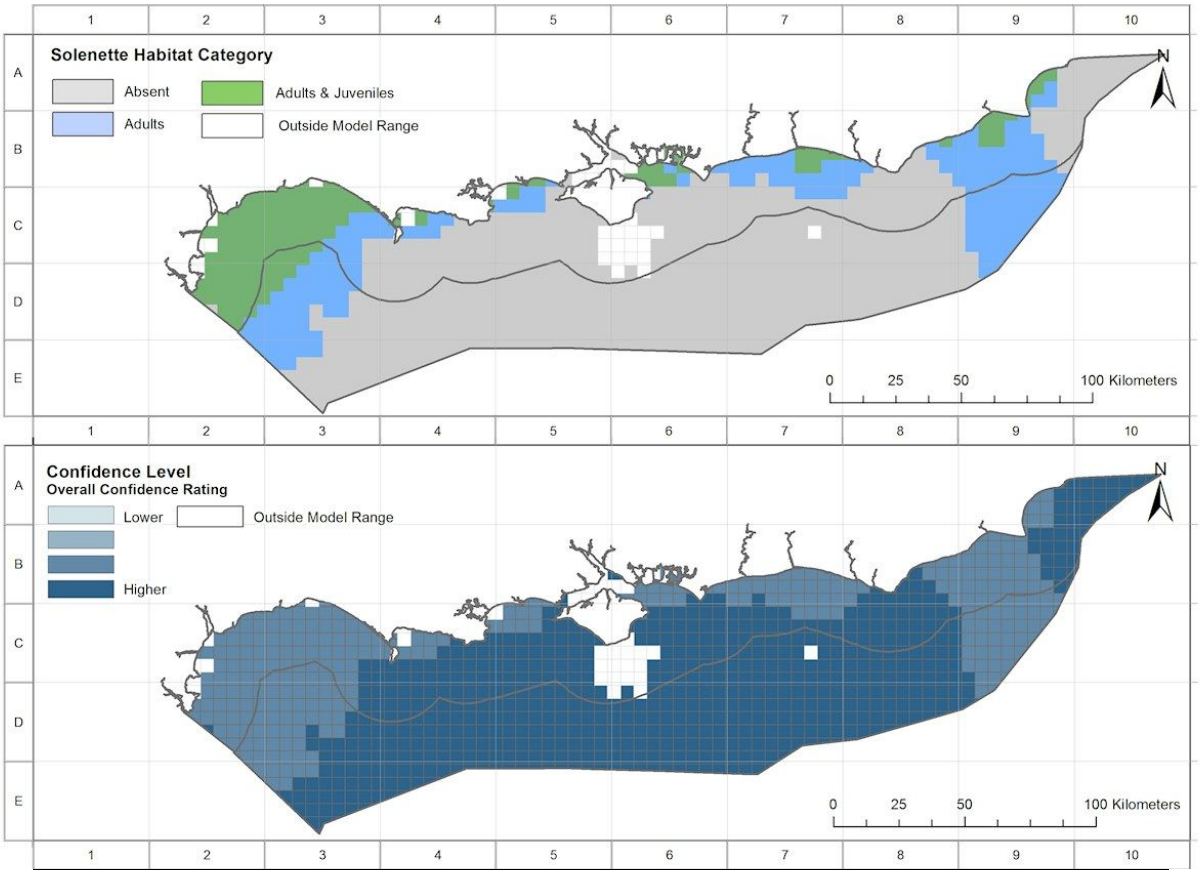
Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		BTS 2000-2012	Moderate-High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Mixed sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
2	Depth (m)	EMODnet	Moderate/ High
Overall confidence in the model prediction of essential fish habitats			**Low**

*See Section 4 for details on the data sources.

3.7. Solenette (*Buglossidium luteum*)

Data on juveniles (10-70mm; immature) and adults (80-290mm) were used to model essential fish habitats of this species.

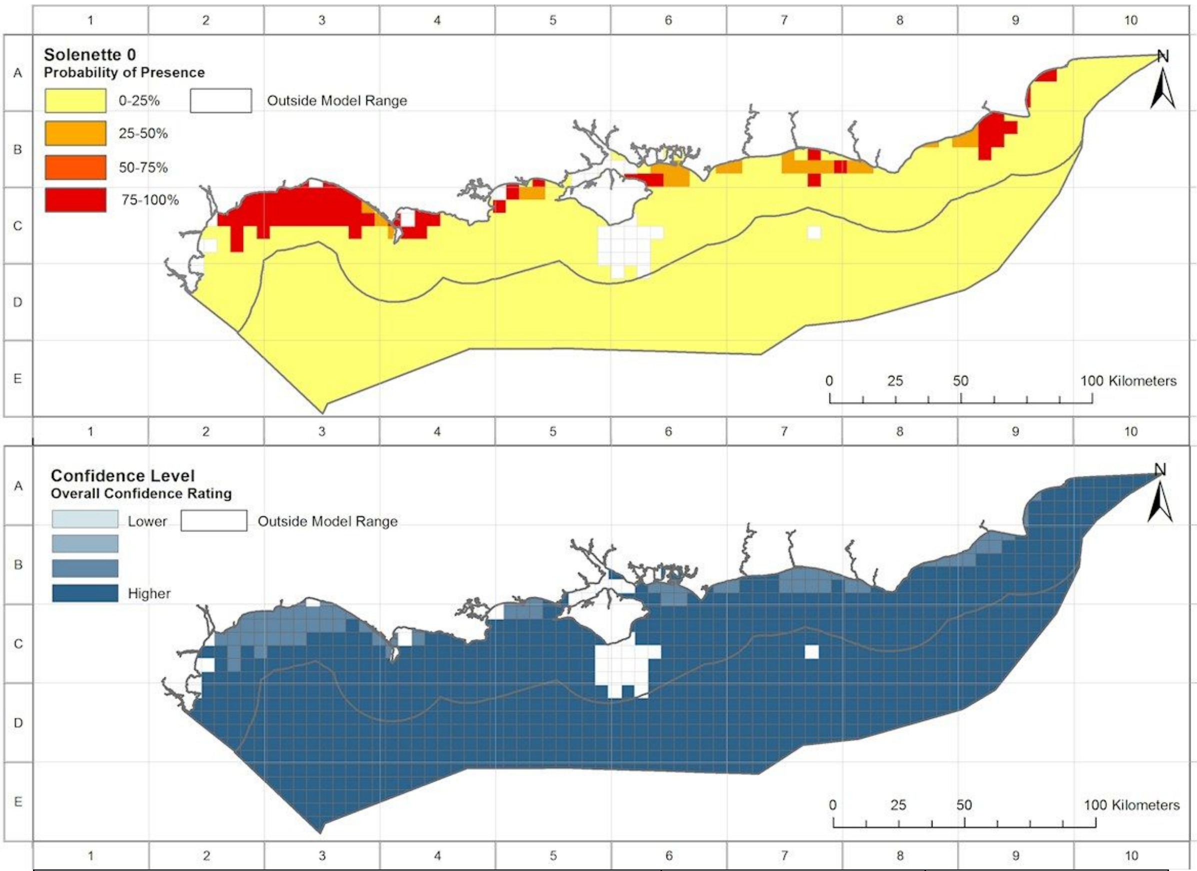
3.7.1. Predicted distribution of adult solenette foraging habitat.



Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		BTS 2000-2012	Moderate-High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
2	Wave energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Low**

*See Section 4 for details on the data sources.

3.7.2. Predicted distribution of solenette nursery habitat (probability of presence of suitable habitat).



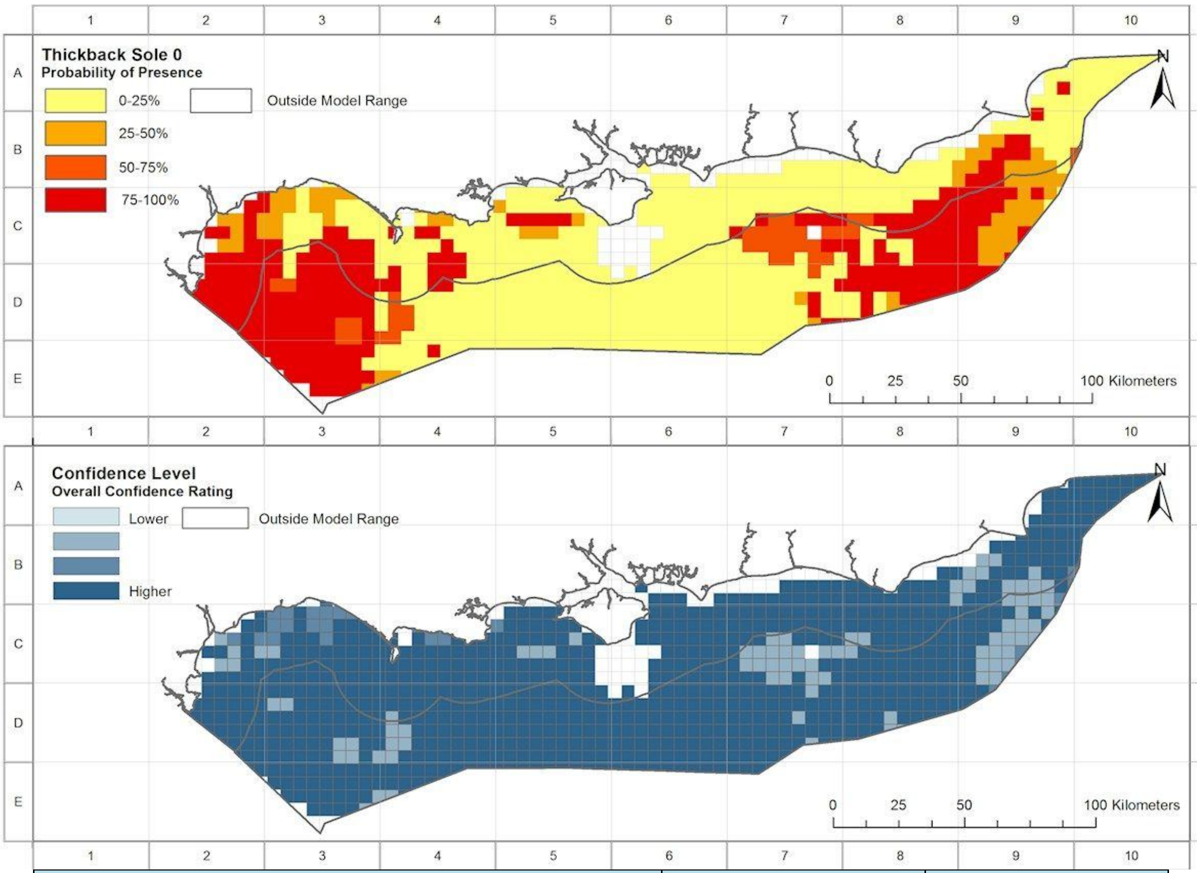
Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		BTS 2000-2012	Moderate-High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
2	Wave energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
3	Coarse sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Low**

*See Section 4 for details on the data sources.

3.8. Thickback sole (*Microchirus variegatus*)

Data on juveniles (30-200mm; likely including also >1year old) were used to model essential fish habitats of this species.

3.8.1. Predicted distribution of thickback sole nursery habitat (probability of presence of suitable habitat).



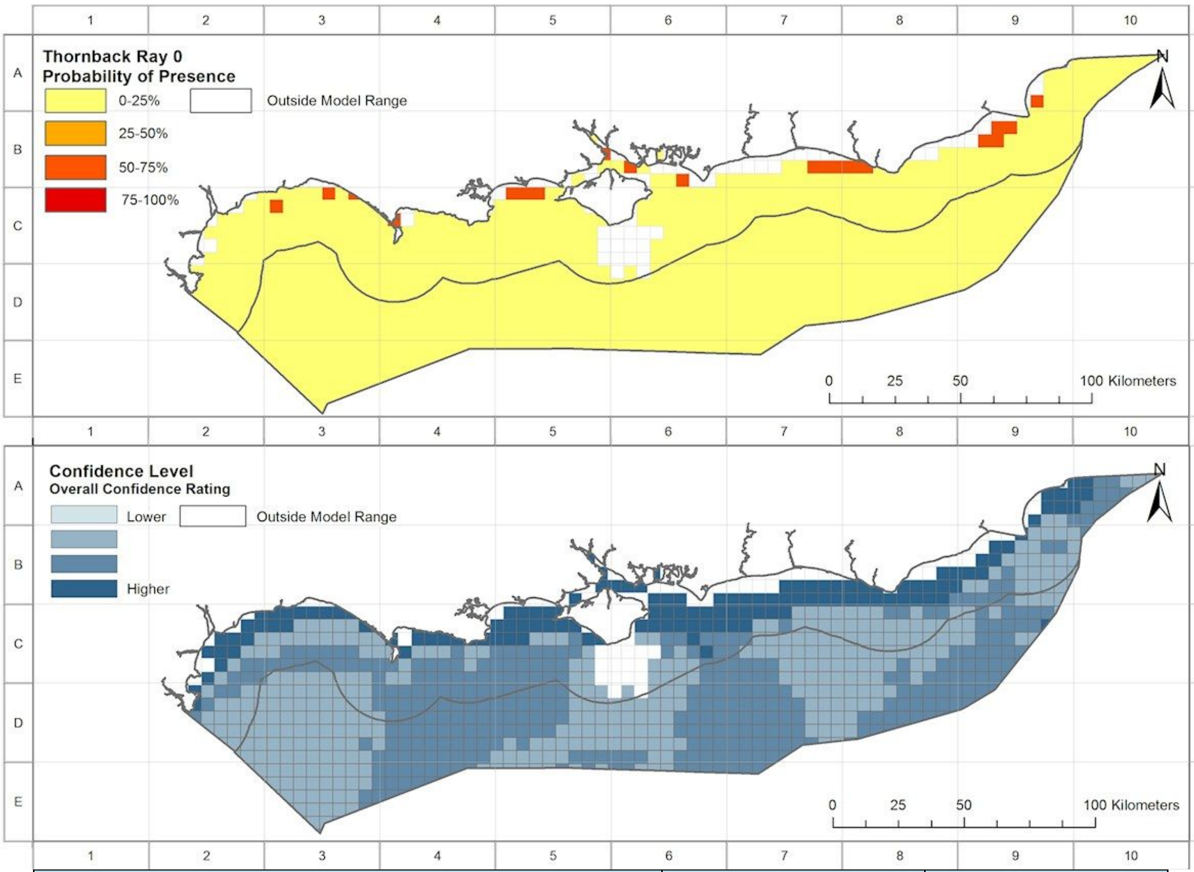
Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		BTS 2000-2012	Moderate
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Mixed sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
2	Type of mixing of the water column (categorical)	JNCC	Moderate
3	Depth (m)	EMODnet	Moderate/ High
4	Wave energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
5	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
6	Coarse sediment relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
Overall confidence in the model prediction of essential fish habitats			**Low**

*See Section 4 for details on the data sources.

3.9. Thornback ray (*Raja clavata*)

Data on juveniles (100-280mm; likely including also >1year old) were used to model essential fish habitats of this species.

3.9.1. Predicted distribution of thornback ray nursery habitat (probability of presence of suitable habitat).



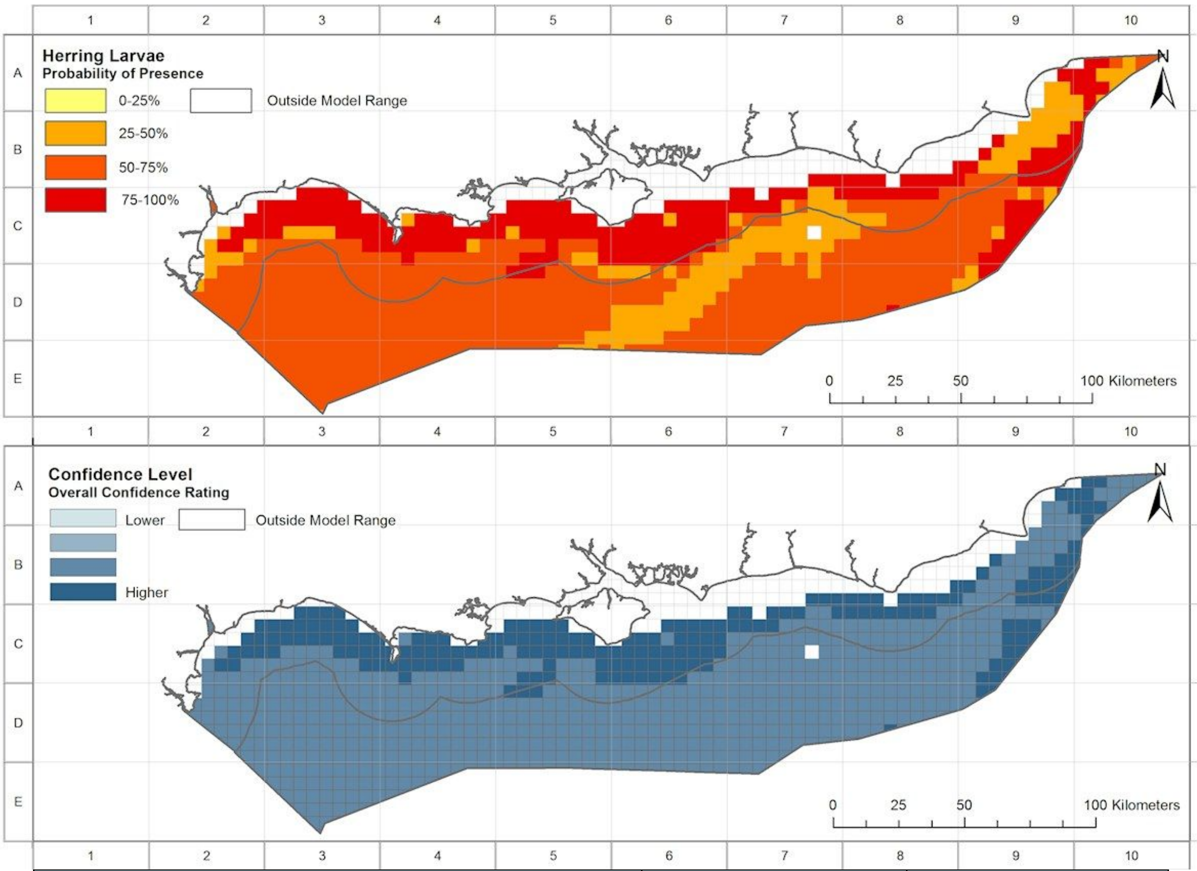
Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		BTS 2000-2012	Moderate
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Tidal current energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
2	Depth (m)	EMODnet	Moderate/ High
3	Sand to muddy sand relative coverage of the seabed (proportion)	EMODnet (for EUSeaMap)	Low/ unable to assess
4	Sea surface temperature (summer, OC)	My Ocean	Moderate
Overall confidence in the model prediction of essential fish habitats			**Low**

*See Section 4 for details on the data sources.

3.10. Herring (*Clupea harengus*)

Data on larvae (<11mm; early stage) were used to model essential fish habitats of this species.

3.10.1. Predicted distribution of herring spawning habitat (probability of presence of suitable habitat).



Model selection data		data Source*	data Confidence
Fish survey data:			
Presence/absence of species life stages		IHLS 2000-11	Moderate-High
Environmental predictors: (in order of decreasing importance in affecting the species habitat distribution)			
1	Wave energy on the seabed (N m-2)	EUSeaMap	Low/ unable to assess
2	Depth (m)	EMODnet	Moderate/ High
Overall confidence in the model prediction of essential fish habitats			**Moderate**

*See Section 4 for details on the data sources.

4. Datasets used

In this section you will find additional information on the data sources that we used or took into account to obtain the outputs displayed previously. These include the source of fish survey data as well as sources of environmental data. A brief summary of the general data requirements is also provided.

4.1. Fish data

Requirements identified for the collation of fish data were:

- 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 selected in the project.
- Distribution of fishing stations within the study area (South inshore and offshore marine plan areas, and, if possible, in the wider English Channel).
- 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 following table summarises the fish datasets that have been collated by the project and indicate which data have been used in the modelling process.

Fish data	Source	Survey/data information	Used for model calibration
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 an ICES funded research program. 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. (Data 2000-2012 within English Channel: N=852)	Yes

Fish data	Source	Survey/data information	Used for model calibration
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 an ICES funded research programme. 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. (Data 2000-2011 within English Channel: N=1503)	Yes
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 an ICES funded research programme. 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. (Data 2003/4 and 2008/09 within English Channel: N=172 with high-speed plankton sampler 280um mesh; N=93 (Jan 2009 only) with continuous underway fish egg sampler)	Yes

Fish data	Source	Survey/data information	Used for model calibration
French groundfish survey in the Eastern English Channel (FR_CGFS)	Ifremer	Survey series Survey series starting in 1989 and ongoing (October, Quarter 4), carried out by Ifremer using GOV trawler. Surveys as part of the ICES programme of International Bottom Trawl Surveys in the Western and Southern Areas (WS-IBTS). These surveys aim to provide consistent and standardized data for examining spatial and temporal changes in the distribution and relative abundance of fish and fish assemblages and of the biological parameters of commercial fish species for stock assessment purposes. Fish CPUE per haul per species per length class. (Data 2000-2010 within English Channel: N=1111)	No (no complete data obtained)
Cefas Southern North Sea and English Channel Sole Egg Survey	Cefas	Four cruises were undertaken in 1991 (Spring) collecting 70-80 samples to estimate the spawning stock biomass of the sole (*Solea solea*) in the English Channel and southern North Sea. Abundance / density of fish eggs and fish larvae from plankton tows. Eggs from sole assigned to developmental stages. Associated environmental data (temperature, salinity).	No (time constraints; no data after 2000)
National Fish Population Dataset (inshore fish data)	Environment Agency	Collation of data obtained by the EA between 2004 and 2012 from different fish surveys of inshore/estuarine water bodies (Adur, Arun, Cuckmere, Dart, Exe, Lime Bay West, Pool Harbour, Rother, Southampton Water) for WFD assessment purposes. Surveys combine different methods (e.g. beam trawls, fyke nets, otter trawls, seine nets) and sampling months (March to December). Station, catch (counts), length for each survey. Additional information on sampling event (gear used, date, effort, the latter not recorded for all data and with inconsistencies) (Data 2000-2010 within English Channel: N=730)	No (time constraints; non comparable data (multiple methods/strategies), missing/inconsistent data on sampling effort)
UK South West Beam Trawl Survey (Q1SW)	Cefas	Survey series starting in 2006 and ongoing, carried out by Cefas. Fishing during March (Quarter 1) over an allocated area (with random-stratified design) covering the ICES Division VII e-h (including Western English Channel) using two 4m beam trawls (with different mesh size). Station, catch, length and biological data for each of the annual surveys in support of EU data regulations and as part of an ICES funded research program. (Data 2006-2013 within English Channel: N=1037)	No (time constraints; non comparable catch data with those from BTS in Eastern English Channel (different methods and season))

Fish data	Source	Survey/data information	Used for model calibration
Cefas Young Fish Surveys in South Coast areas	Cefas	Survey series carried out between 1981 and 2006 by Cefas. Fishing inshore with 2m scientific beam trawl (with 4mm mesh liner) in September each year. Surveys aim to provide indices of abundance of small demersal fish, in particular juvenile 0-group and 1-group plaice and sole, prior to their recruitment to the fishery. The data is in support of the EU Data Collection Regulation. Station, catch, length data for each of the annual surveys. (Data 2000-2006 within English Channel: N=496)	No (time constraints; non comparable catch data with those from BTS in Eastern English Channel (different methods and season))
Cefas Small Pelagic Fish Western Channel and Celtic Sea plankton survey (PELTIC11)	Cefas	Cefas surveys in the Western Channel and the Celtic Sea targeting small pelagic fish. Surveys in May/June 2011, using multiple methods (sandeel trawl, otter trawl, rosette sampler, drop nets, high speed manta trawl, sounders). Station, catch, length and biological data, as well as associated oceanographic data. (Data 2011 within English Channel: N=56)	No (time constraints)

4.2. Environmental data

Requirements identified for the collation of environmental data layers:

- Data availability for the main environmental variables considered relevant to fish species (including depth, sediment type, water temperature, salinity, hydrodynamic conditions, or proxies for these variables).
- Full spatial coverage of the South Inshore and Offshore Marine Plan areas, and, if possible, of the wider area where fish survey stations are located.
- Data layers at a spatial resolution equal or higher than the spatial resolution used in the project (5 x 5 km).
- For variables showing a marked seasonal and inter-annual variability (e.g. oceanographic data, like water temperature), data layers available for different seasons and years, covering the temporal extent/resolution of the specific fish survey dataset.

The following tables summarise:
A) The environmental data layers that have been collated by the project and used to obtain predictor variables in the analyses.
B) The environmental variables obtained as potential predictors of essential fish habitat distribution.
Table A).

Data theme	Data layer (Source)	Description
Elevation and bathymetry	Bathymetry (EMODnet)	For each maritime region bathymetric survey data and aggregated bathymetry data sets have been collated from public and private organizations. These have been processed

Data theme	Data layer (Source)	Description
		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 for EUSeaMap)	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 km2).
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 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 Oceanography Centre It can be displayed with "UK Not Reefs v1 2011", which shows area that are not reef in UK waters.

Data theme	Data layer (Source)	Description
Habitats and Biotopes - water column	Marine Water Column Features (JNCC)	This dataset describes aspects of the water column over the UKCS. 4 shapefiles, one for each season (Autumn, Winter, Spring, and Summer) are given. It describes stratification and mixing of water types.
Habitats and Biotopes - water column	Global Ocean OSTIA Sea Surface Temperature and Sea Ice analysis REPROCESSED (1985-2007) (EU project My Ocean)	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.
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 BBP, ADG, APH, KD (490)) that are computed by using QAA algorithm (Lee *et al.*, 2002). 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).

Table B)

Variable	Theme	Type	description	Source	Predictor for fish data
WDepth	bathymetry	continuous	**Water depth**_mean depth (m below surface) calculated 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; EMODnet-derived maps have been used for model prediction instead)	Fish survey data	BTS, IHLS
DomMix	water column, mixing type	categorical	**Type of mixing of the water column**_dominant type of mixing calculated 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**, C degrees_average value of mean seasonal temperature calculated within 2.5km from the fish survey station (mean location), for model	EU project MyOcean (derived)	BTS, IHLS, WGEGGS

Variable	Theme	Type	description	Source	Predictor for fish data
			calibration, or within 5km grid cell for model implementation		
APH	water column, APH	continuous	**APH_** monthly mean absorption coefficient due to phytoplankton at 443 nm (expressed in m^{-1}) _mean value of max APH calculated within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation	EU project MyOcean (derived)	IHLS, WGEGGS
TidE	substratum, energy	continuous	**Tidal energy**_Mean tidal energy (N/m2) calculated within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation	EUSeaMap (derived)	BTS, IHLS, WGEGGS
WavE	substratum, energy	continuous	**Wave energy**_Mean wave energy (N/m2) calculated within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation	EUSeaMap (derived)	BTS, IHLS, WGEGGS
M-sM	substratum, type	continuous	**Mud to sandy mud**_Proportion of area (0-1) within 2.5km from the station (mean location)	EMODnet for EUSeaMap (derived)	BTS, IHLS, WGEGGS
S-mS	substratum, type	continuous	**Sand to muddy sand**_Proportion of area (0-1) calculated within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation	EMODnet for EUSeaMap (derived)	BTS, IHLS, WGEGGS
Cs	substratum, type	continuous	**Coarse sediment**_Proportion of area (0-1) calculated within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation	EMODnet for EUSeaMap (derived)	BTS, IHLS, WGEGGS
Mx	substratum, type	continuous	**Mixed sediment**_Proportion of area (0-1) calculated within 2.5km from the fish	EMODnet for EUSeaMap (derived)	BTS, IHLS, WGEGGS

Variable	Theme	Type	description	Source	Predictor for fish data
			survey station (mean location), for model calibration, or within 5km grid cell for model implementation		
R	substratum, type	continuous	**Rock or other hard substrata**_Proportion of area (0-1) calculated within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation	EMODnet for EUSeaMap (derived)	BTS, IHLS, WGEGGS
DomSubst	substratum, type	categorical	**Dominant substratum type** calculated within 2.5km from the fish survey station (mean location), for model calibration, or within 5km grid cell for model implementation: 1=M-sM, 2=S-mS, 3=Cs, 4=Mx, 5=R (substratum type codes as per variables above)	EMODnet for EUSeaMap (derived)	BTS, IHLS, WGEGGS
Reef	substratum, type	categorical	**Presence-absence of reef** calculated 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

5. Limitations and gaps

A number of gaps and limitations in the data, leading to limitations in the obtained results, were identified and they are reported below.

5.1. Species

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 (e.g. cod, haddock, hake, monkfish, mackerel). Due to this limitation in the range of species considered, it is likely that the overall 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 in MMO (2013) 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).

5.2. Spatial coverage of fish survey data

Although the fish datasets selected for the modelling were those with the widest coverage of the South marine plan areas, there was poor spatial coverage of shallower inshore areas and western areas of the English Channel (EC) and this limited the ability to characterise and predict EFH for the species. A gap in the model predictions often occurred also in the area offshore of the Isle of Wight, due to high tidal energy levels which were outside the variability range related to the data available for model calibration (as areas with these specific conditions were not covered by fish survey stations). As a result, the ecological importance of these areas is might be underestimated. It is of note that data for the western EC were available but could not integrate (due to issues on data comparability) with those used for the eastern EC for the model calibration of the whole South Marine Plan Areas. The option of undertaking separate modelling of eastern and western EC could be considered (as undertaken for example in the CHARM project).

5.3. 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 inshore areas.

5.4. 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 only 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), nor 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, or alternative data sources bearing similar information, the confidence assessment of the obtained outputs could be improved.

5.5. Temporal reference

The outputs obtained in the MMO (2013) 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.

Annex 2: Methods for model statistical validation

The validation of the existing essential fish habitat maps undertaken using the expert judgement provided during the stakeholder consultation was integrated with a statistical approach. This aimed to assess the quality of the models developed within MMO (2013) to predict the presence of fish life stages based on the environmental conditions. Accuracy was assessed by comparing the model predictions with independent data and by computing measurements of the prediction error (Fielding and Bell, 1997).

Different survey datasets were used to test the model, depending on the fish species and life stage considered. The fish data characteristics, source and how they were selected for the model validation are described in detail in Table A2.1.

The model prediction (as presence or absence of a species life stage) at the survey locations of the fish data was extracted from the essential fish habitat maps and the performance of the model was summarised using an error matrix that cross-tabulates the observed and predicted presence/absence patterns (Table A2.2). Within this matrix, the prediction error made by the model is represented by:

- False positives FP, i.e. the number of cases that were erroneously predicted as presence by the model (these are also indicated as type I error).
- False negatives FN, i.e. the number of cases that were erroneously predicted as absence by the model (these are also indicated as type I error).

In turn, true positives (TP) and true negatives (TN) indicate the number of cases when the model successfully predicted the presence or absence of a species life stage respectively.

Table A2.1: Fish survey data used for the statistical validation of the predictive models developed in MMO (2013).

Fish data	Source	Survey/data information and selection	Use for model validation
Data layer used for the mapping of nursery grounds in UK waters undertaken by Ellis *et al*. (2012) (within Defra project MB5301)	Cefas website[6]	This was a points layer of presence and abundance of selected juvenile species conducted by fishery-independent research surveys in UK waters. These data were used by Ellis *et al*. (2012) to provide the evidence-base behind the identification of nursery grounds for selected highly mobile species. Juveniles for different fish species were identified using size threshold values as indicated in Ellis *et al*. (2012). Further information on the source data used in these datasets is provided in Ellis *et al*. (2012).	The data on the presence/absence of fish juveniles were selected for the survey stations within the South marine plan areas. These integrated survey data obtained during different beam trawl surveys (BTS), including: • UK Eastern English Channel BTS undertaken between 1988 and 2008 (Quarter 3) using a 4m beam trawl. • UK Western English Channel BTS undertaken between 1989 and 2008 (Quarter 4) using a 4m beam trawl deployed off a commercial fishing vessel. • UK South Western BTS undertaken between 2006 and 2008 (Quarter 1) using a twin 4m beam trawl. Within this dataset, data were available for the validation of models predicting nursery habitats of plaice, sole and thornback ray. It is noted that the dataset marginally overlapped with the data used for the calibration of the model predicting species nursery habitats in MMO (2013) (UK Eastern English Channel BTS between 2000 and 2012). However, this overlap was only minor compared to the additional data included from different regions or years within the study area and therefore the dataset was considered suitable as an independent dataset for the model validation.

6 http://www.cefas.defra.gov.uk/our-science/fisheries-information/ecologically-important-fish-habitats/distribution-of-spawning-and-nursery-grounds.aspx

Fish data	Source	Survey/data information and selection	Use for model validation
Data layer used for the mapping of spawning grounds in UK waters undertaken by Ellis *et al*. (2012) (within Defra project MB5301)	Cefas website (as above)	This was a points layer of egg and larval surveys conducted in UK waters between 1990 and 2008 used to identify the spawning grounds of selected UK fish. These data were used by Ellis *et al*. (2012) to provide the evidence-base behind the revised spawning grounds of selected UK fish. Further information on the source data used in these datasets is provided in Ellis *et al*. (2012).	The data on the presence/absence of fish eggs and larvae were selected for the survey stations within the South marine plan areas. These integrated survey data obtained during different ichthyoplankton surveys, including: • Cefas Sole Egg Survey conducted in the English Channel and Southern Bight in 1991, primarily to sample sole and bass, but including also data collected for other species. • ICES North Sea Egg Surveys undertaken by several international institutes covering a large area of the North Sea between December 2003 and early April 2004. • International Herring Larval Survey (IHLS) undertaken over the main herring spawning grounds in the North Sea in 2008 Within this dataset, data were available for the validation of models predicting spawning habitats of herring. It is noted that the dataset marginally overlapped with the data used for the calibration of the model predicting herring spawning habitats in MMO (2013) (IHLS between 2000 and 2011). However, this overlap was only minor compared to the additional data included from different regions or years within the study area and therefore the dataset was considered suitable as an independent dataset for the model validation. Although the dataset included also data on plaice eggs, these were available only from the ICES North Sea Egg Surveys. This is the dataset that was used for the calibration of the model predicting plaice spawning habitats in MMO (2013), and therefore it was not considered suitable as an independent dataset for the model validation.

Fish data	Source	Survey/data information and selection	Use for model validation
UK South Western BTS	Cefas	Survey series starting in 2006 and ongoing, carried out by Cefas (data between 2006 and 2013 were available in the explored dataset). Fishing during March (Quarter 1) over an allocated area (with random-stratified design) covering the ICES Division VII e-h (including Western English Channel) using twin 4m beam trawls (with different mesh size). Station, catch, length and biological data for each of the annual surveys in support of EU data regulations and as part of an ICES funded research program.	The data on the presence/absence of fish juveniles and adults fish were selected for the survey stations within the South marine plan areas. Body size threshold values as used in MMO (2013) were applied to distinguish juveniles and adults. Within this dataset, data were available for the validation of models predicting adult and juvenile distribution of all selected species. The dataset was spatially distinct from the data used for the calibration of the model predicting adult foraging and nursery habitats in MMO (2013) (UK Eastern English Channel BTS between 2000 and 2012) and therefore it was considered suitable as an independent dataset for the model validation.

Table A2.2: An error matrix.

<table>
<tr><td colspan="2"></td><td colspan="2">Actual
(from fish surveys)</td></tr>
<tr><td colspan="2"></td><td>Presence</td><td>Absence</td></tr>
<tr><td rowspan="2">Predicted (from model)</td><td>Presence</td><td>True Positives (TP)</td><td>False Positives (FP)</td></tr>
<tr><td>Absence</td><td>False Negatives (FN)</td><td>True Negatives (TN)</td></tr>
</table>

As a measure of the model accuracy, the following indices (Fielding and Bell, 1997) were derived from the error matrix obtained for each tested model:

Misclassification rate, MR = (FP+FN) / N

False positive rate, FPR = FP / (FP+TN)

False negative rate, FNR = FN / (FN+TP)

With N being the total number of cases tested (i.e. TP+FP+FN+TN).

The misclassification rate measures the overall error made by the model in classifying both presence and absence of a species life stage (the complementary of MR, i.e. 1-MR, measures the predictive ability of the model). This parameter was used to re-evaluate the confidence in the model predictive ability, by rating the MR (as a %) using the criterion applied in MMO (2013) (Table 2; MMO, 2013). The amended rating for the model predictive ability was used to re-calculate the total confidence associated with the essential fish habitat map obtained from the model prediction, using the methodology developed in MMO (2013) (MMO, 2013). As a result, an amended overall confidence rating (ranging between Low and High) was allocated to the associated validated map. Confidence classifications are described in Table A2.3.

Table A2.3: Confidence in the classification tree model predictive ability.

Confidence	Definition
Low (rating 1)	Low confidence in the model predictive ability. Total model predictive ability ≤ 0.5, equivalent to Total misclassification rate ≥ 0.5 (i.e., less than 50% of the data in the validation dataset is correctly classified by the model)
Moderate (rating 2)	Moderate confidence in the model predictive ability. Total model predictive ability ≤ 0.75 and > 0.5, equivalent to Total misclassification rate ≥ 0.25 and < 0.5 (i.e., between 50 and 75% of the data in the validation dataset is correctly classified by the model)
High (rating 3)	High confidence in the model predictive ability. Total model predictive ability > 0.75, equivalent to Total misclassification rate < 0.25 (i.e., more than 75% of the data in the validation dataset is correctly classified by the model)

In addition to MR, also FPR and FNR were estimated as they provide respectively a measure of the proportion of absence cases erroneously predicted as presence and a measure of the proportion of presence cases erroneously predicted as absence. Therefore, these two measures were used to obtain an indication of the tendency of the model to overestimate or underestimate the presence of a species life stage, respectively.

Annex 3: Thickback sole nursery grounds (amended)

An error was found in the cut-off size used to identify juveniles of the species (210mm total length was used but this includes both juveniles and adults). This was amended to 120mm (Amara *et al*., 1998). The fish survey data were re-selected based on this amendment and a new model was calibrated. The procedures and environmental data layers used were exactly as in MMO (2013).

The resulting predictive model identified suitable habitat conditions for thickback sole juveniles based on the distribution of mixed sediment substrata (Figure A3.1)). Suitable conditions for the presence of these nursery habitats in particular were identified in areas with a relatively high coverage of mixed sediments (proportion coverage ≥0.88) and with mean tidal energy on the seabed lower than 537.8N/m^2. In these conditions, the model predicted a probability of presence of the species juveniles of 74%. A high confidence was associated with the model predictive ability, the overall misclassification error (based on calibration dataset) being 12%.

The procedure applied in MMO (2013) was applied to the amended results to predict the spatial distribution of the species nursery grounds in the area based on the above environmental conditions (and associated data layers, as used in MMO (2013)) and to calculate the associated overall confidence and confidence map (MMO, 2013). The resulting spatial output is reported in Figure A3.2.

The overall confidence ascribed to the spatial output for thickback sole nursery habitats was classified as low, notwithstanding the high confidence associated to the predictive model. This result was mostly ascribed to the input environmental data layers for seabed substratum (EMODnet) and tidal currents (JNCC EUSeaMap), which had a low confidence associated (mostly due to an inability to assess it using the available information).

Figure A3.1: Classification tree model for the probability of occurrence of Thickback sole nursery habitats (0-group) (proportion coverage of mixed sediment (Mx) and tidal currents (TidE).

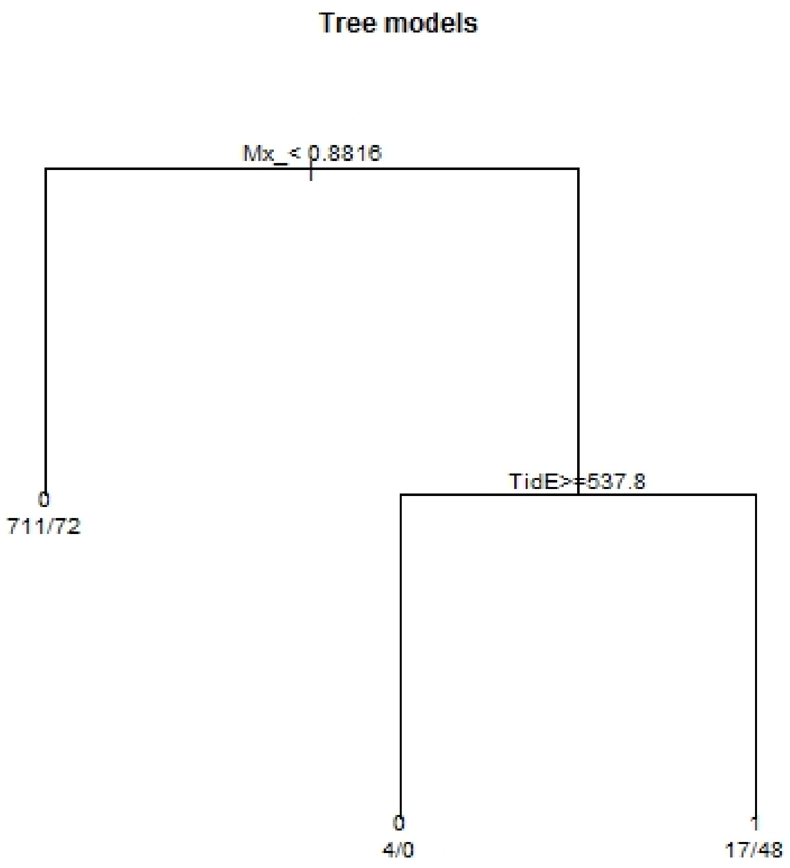
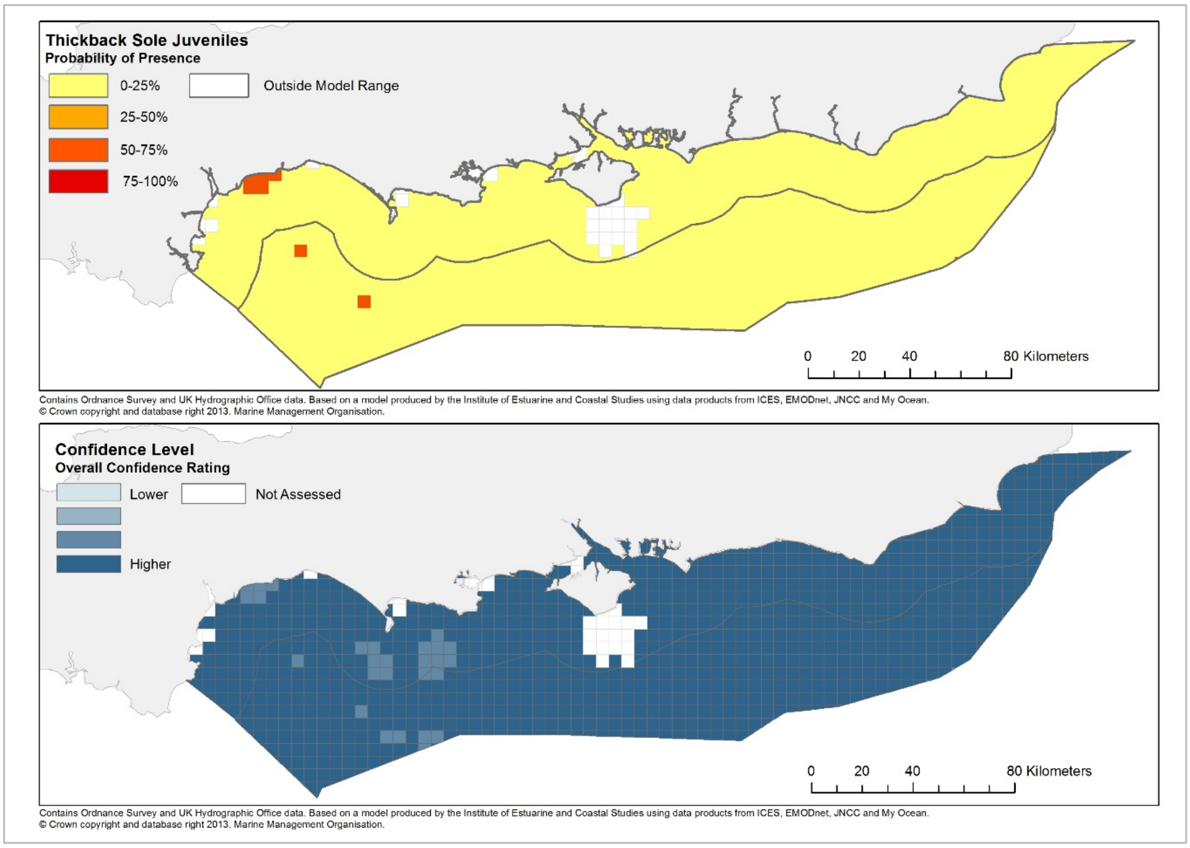


Figure A3.2: Thickback sole – predicted nursery habitat distribution and associated relative spatial confidence.



Contains Ordnance Survey and UK Hydrographic Office data. Based on a model produced by the Institute of Estuarine and Coastal Studies using data products from ICES, EMODnet, JNCC and My Ocean. © Crown copyright and database right 2013. Marine Management Organisation. Projected to British National Grid.