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Review and compilation of habitat models in European Seas

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Contents

1 Introduction

1.1 Habitat as a concept

The term "habitat" has a broad meaning but generally refers to a place where species and communities thrive in abiotic conditions, described by substrate and physio-chemical parameters. More broadly speaking, species themselves can form habitats, especially when densely occurring and creating physical structure that would not otherwise exist. Such habitat-forming species may be called ecosystem engineers as they structure habitats such as kelp forests, seagrass meadows, coral reefs or sponge aggregations, on which a variety of species depend.

Various habitat classification schemes have been developed for covering habitat descriptions at regional scales. The European Nature Information System (EUNIS) is a comprehensive harmonized habitat classification scheme that uses substrate type, hydrodynamic exposure, biological zone and salinity criteria to classify habitats. EUNIS is hierarchical, and covers terrestrial, marine and freshwater environments. It has been gradually extending geographically and is currently being revised to become more representative of all European seas (EMODnet 2016). For instance, the Baltic Sea differs in some of the abiotic drivers compared with other European seas, and therefore Baltic marine habitats are not fully compatible with the EUNIS classification. To address this, HELCOM underwater biotope and habitat classification system HELCOM HUB was established. It provides a framework for categorizing biotopes and habitats across the Baltics Sea. HELCOM HUB retains the basic hierarchical structure of EUNIS, but classifies the substrates into finer scales (HELCOM 2013).

1.2 Usage of habitat maps

Habitat maps, once created, can be used for locating marine areas of high ecological or biological value. The United Nations Convention on Biological Diversity (CBD), in particular, has resulted in a system of Ecologically or Biologically Significant Marine Areas (ESBAs - https://www.cbd.int/ebsa/) which are chosen and described by using seven criteria that include: uniqueness or rarity, importance for threatened or endangered species or habitats, vulnerability, fragility, sensitivity or slow recovery. In many cases the units that determine the level of significance are based on the status of the habitats that a given marine area harbours.

Habitat maps can also be used for improving the state of the marine environment, including to help to prevent the flow of harmful substances and excess nutrients from entering the sea and to help to limit the direct impact of humans on the environment and organisms living in it. The latter requires are area-based management measures and knowledge of the location and abundance of valuable ecosystems.

Many environmental policies and conventions require countries to report on the status of important features marine environment, including spatial extent, distributional range and pattern, which can be informed by habitat maps. Such conventions include CBD which aims at halting the global loss of biodiversity, also in the oceans, and EU directives, such as the Habitats Directive, Water Framework Directive, and Marine Strategy Framework Directive, which all call for a holistic approach to management of the sea areas and aim at keeping the marine and coastal ecosystems in a Good Environmental State.

Information on the status, rarity and vulnerability of habitats can be used for various area-based measures, in particular for choosing areas for conservation. By assessing the status of the habitats using mapping products, it is also possible to determine more specific management measures that aim to improve or restore the condition of a given habitat and organisms living in it. Furthermore, by identifying the type, size and location of habitats, the potential flow of propagules of different species between habitats can be determined. This information can be used for developing a coherent network of Marine Protected Areas (MPAs).

Furthermore, information on the location of habitats with lower resilience to anthropogenic stresses can be used to mitigate degradation, i.e. to determine where usage of a certain area can be allowed. This information can be fed into national and regional marine spatial plans, and used to guide various environmental impact assessments. By balancing conservation and sustainable use of the sea, the UN Sustainable Development Goal 14, which aims at sustainably managing the marine and coastal ecosystems, stopping overfishing, and conserving at least 10 % of coastal and marine areas, can be reached.

As well as being important features worthy of protection, some habitat types supply significant ecological services to humans such as food resources, carbon sequestration or recreation opportunities. Habitat maps therefore offer us a chance to quantify the natural capital available in the marine environment.

1.3 Habitat modelling

Although habitat maps are needed for various purposes, it is neither cost-efficient nor possible to sample data from every inch of the seafloor. Given the difficulty in conducting full-coverage surveys, we do not typically have as detailed information on the habitats on marine environments as we do from terrestrial areas. Modelling gives us tools to estimate the spatial distribution of potential habitat areas and, where conditions in the past or in the future can be estimated, to extrapolate ecological distributions to different times. Modelling has therefore been commonly used as a way to get an overview of the distribution of habitats.

The use of predictive modelling as a quantitative approach to study species distribution started in the 1980s with methods that applied a set of "rules" to produce maps of potential distributions. In the 1990s modelling was increasingly used as a tool as GIS software and digital maps of environmental conditions became more available.

Species distribution modelling (SDMs), or habitat suitability modelling, relies on the concept of an environmental niche for species (Fig. 1). In deterministic and/or probabilistic forms, such models capture the environmental envelopes that correspond to the occurrence of a particular species/habitat. The spatial projection of these conditions forms one of the cornerstones of modern biogeography and spatial macroecology. The realism of such models depends on a number of factors, for instance: the availability of sufficient environmental data, reliable biological data, and on the accuracy and performance of the models. Factors beyond the abiotic ones, like biotic interactions or dispersal abilities, affect the realization of the niche but are less frequently used in models.

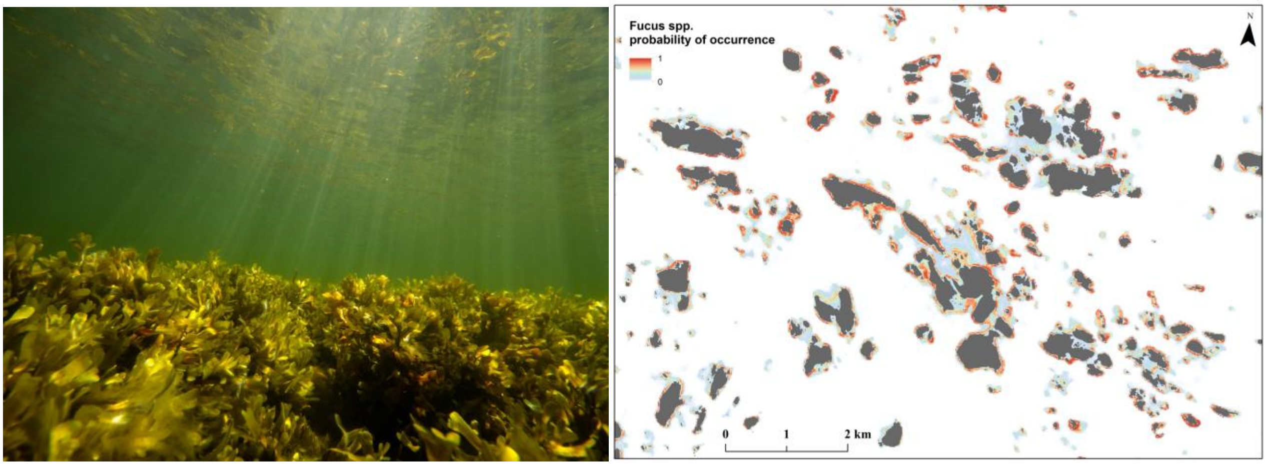

Figure 1: Fucus spp., a habitat-forming brown algae photographed in the southern coast of Finland and its potential range in an example area in the Archipelago Sea of Finland (modified from Virtanen et al. 2018). Islands are shown with dark grey. Photo: Juuso Haapaniemi, Parks and Wildlife Finland, 2015.

Various reviews have addressed the use of terrestrial SDMs, but only a few have analysed marine SDMs specifically. For instance Robinson *et al.* 2011 highlighted the practical and conceptual problems when applying SDMs to marine organisms. Robinson *et al.* 2017 performed a systematic, broad literature review for marine SDMs, generated overall trends in the application of SDMs, and gave recommendations for best practices.

1.4 Aims

The aim of this study was to present the current state of play regarding modelling studies done in the European Seas that have focused on seabed habitat types, communities or habitat-forming species. This was achieved through two objectives:

1. Literature review followed by a summary and comparison of the range of studies conducted to date, so that the reader may understand the typical approaches, parameters and variables used.
2. Collation of habitat modelling outputs and publication via an online interactive mapping portal, so that a user may visualize the model predictions and quickly understand the range of models that exist in a particular area.

2 Method

2.1 Literature review

This review was approached through a thorough literature review of peer-reviewed original research papers. Grey literature (reports), books, or book chapters were not included.

Our goal was to review all major studies that we identified as seabed habitat modelling works. Therefore species modelling studies were included only if they concerned habitat-forming species. Studies that only dealt with mapping efforts (surveys, samplings) were excluded from the analyses.

Using Web of Science (accessed 15.1.2018), we identified 4,364 articles citing "marine habitat modelling", and when narrowing the time span to covering only years 2007–2017, search terms "habitat" & "marine" & "model" resulted in 3,377 articles. These articles were reviewed based on title and area, resulting in 289 articles that dealt with marine habitat mapping and modelling in the European Seas. Based on abstracts and content, we identified 54 papers dealing with habitat modelling.

We conducted the qualitative data analysis using the NVivo software (NVivo 2018).

2.2 Collation and publication of model outputs

We define habitat modelling outputs as spatial layers showing either habitat suitability/likelihood on a scale from 0-1, or a categorised output showing predicted presence or absence of a habitat or habitat-forming species. For this objective, we included modelling outputs from studies that were not necessarily from peer-reviewed published studies.

For the collation, we first looked at the model outputs identified in the literature review, as well as other model outputs identified by the 12 EMODnet Seabed Habitat project partners[1] in their own institutions, in their own country, or that they knew of otherwise from any source.

All the information was collected into an Excel spreadsheet, and in total 147 individual model outputs were identified and listed. Based on the Excel list, we sent 104 separate requests regarding relevant model outputs that were going to be collated to the EMODnet Seabed Habitat portal. Most requests were sent to institutions within the 12 partner countries of the EMODnet Seabed Habitats project but requests were also sent to third party countries (Estonia, Lithuania and Russia).

The collated model outputs were uploaded as map layers to the EMODnet Seabed Habitats interactive map, with an associated metadata record on a linked metadata catalogue hosted by the International Council for the Exploration of the Seas (ICES). Where licences allowed, they were also made available to download.

[1] EMODnet Seabed Habitats partners: https://www.emodnet-seabedhabitats.eu/about/partnership/

3 Results

3.1 Literature review

With the scope and restrictions outlined in section 2, the review of habitat modelling studies included 54 scientific papers, listed in Appendix 1. Most of the studies (n=25) concentrated on modelling the habitat suitability and the potential distribution range of species, fewer addressed conservation (n=9), methodological questions in modelling (n=9), marine spatial planning (n=3), impacts of changing climate (n=1), and theoretical questions in ecology (n=1).

3.1.1 Source of habitat data for models

The most common sources of observations (independent variables) for models were underwater photos and videos (n=17), followed by online databases (n=9), diving (n=7) and sampling (n=6) (Fig. 2). In the rest of the studies, the source of observations was not reported. Lidar (n=1) and satellite images (n=1) were not commonly used.

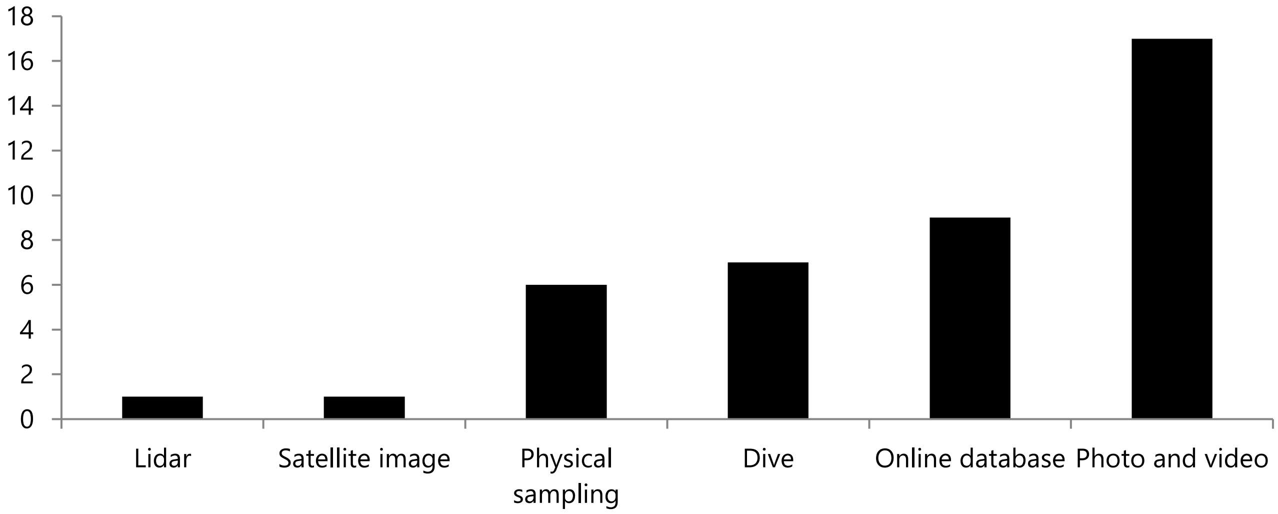

Figure 2: Sources of input data for 54 reviewed habitat modelling studies in Europe.

3.1.2 Relevant environmental data

Habitat models usually aim to project the probability of occurrence of a given habitat-forming species within a study area and use various environmental data as predictor variables. The most frequently used environmental predictor across the marine habitat models reviewed was bathymetry (depth) (n=43) followed by slope (n=28), salinity (n=26), temperature (n=23), substrate type (n=21), current speed (n=19) and wave exposure (n=14) (Fig. 3). Less utilized predictors (n=≤10) were nutrients, rugosity indices of seafloor, light and oxygen, to name a few. Some studies have used proxies for environmental degradation or condition, such as enclosedness or distance to coast, for predicting the occurrences of habitats.

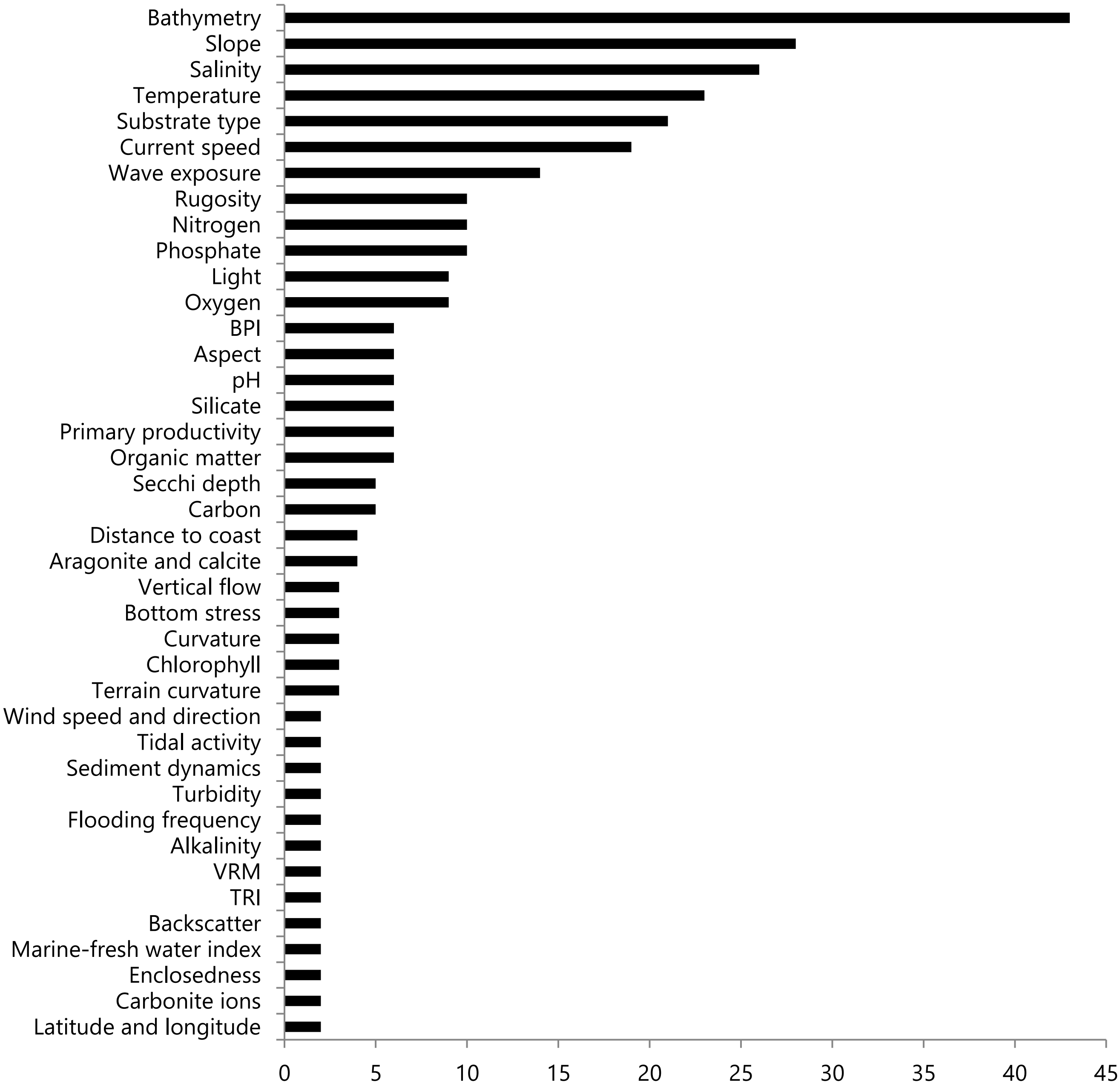

Figure 3: Environmental variables used in 54 reviewed habitat modelling studies in Europe.

3.1.3 Modelled habitats

Of the reviewed habitat modelling studies, most (n=33) concentrated only on one habitat-forming species (n=9) (Fig. 4). Similarly, habitat types and biotopes were individually modelled based on certain needs of the study.

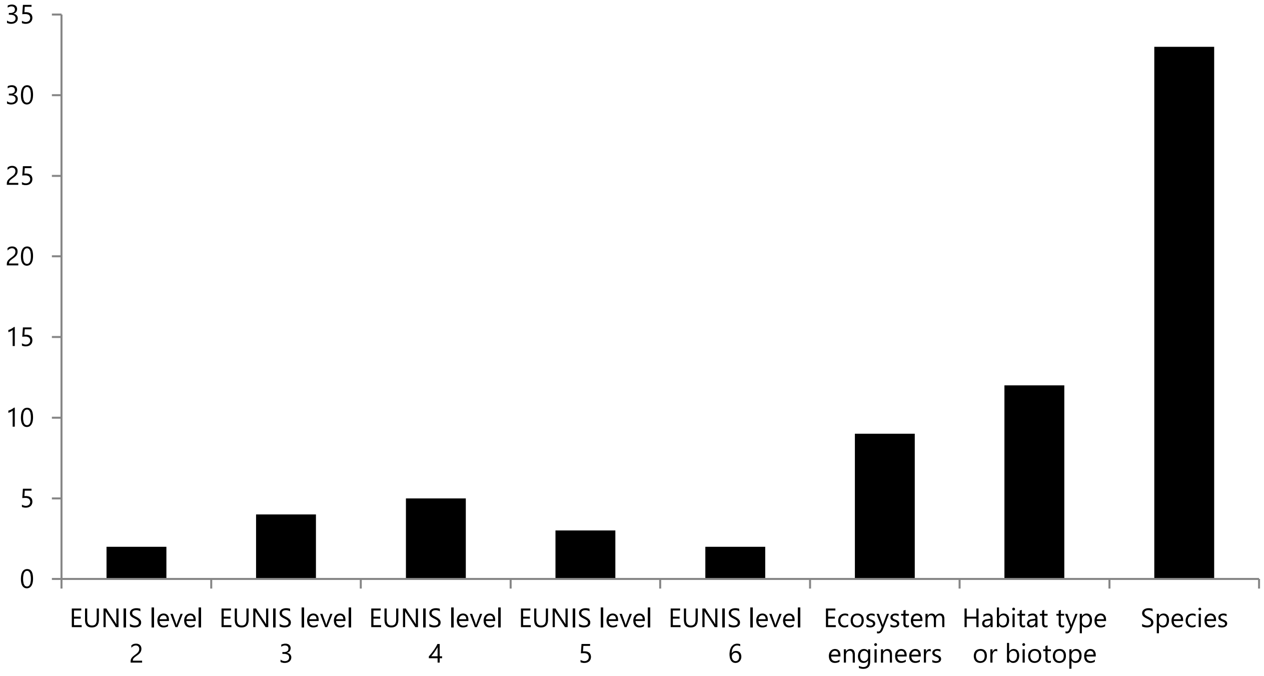

Figure 4: Habitat levels addressed in 54 reviewed habitat modelling studies in Europe.

As a whole, 76 different species and communities were addressed in the models. *Lophelia pertusa* (n=10), *Zostera marina* (n=8) and different kelp species (n=5) were the most common habitat-forming species that were modelled (Appendix 2). There were also studies concerning *Macoma balthica* (n=3) and *Fucus spp.* (n=4).

3.1.4 Modelling methods

Maximum Entropy Modelling (MaxEnt; Phillips et al. 2006) was the most popular (n=17) modelling algorithm across the studies (Fig. 5). MaxEnt uses presence-only data and has been shown to out-perform other algorithms when applied to small datasets (Elith et al. 2006, Hernandez et al. 2006, Aguirre-Gutiérrez et al. 2013). Small sample sizes and an absence of absence data is a common feature of seabed sampling; so this is to be expected.

Non-parametric regression models, Generalized Additive (GAM) (n=10) and Generalized Linear Models (GLM) (n=7), were also quite numerous, potentially due to their easy interpretation and model parametrization. Boosting and ensemble models (e.g. Random Forests; RF, n=6, Gradient Boosting Machine; GBM, n=1, and its extension, Boosted Regression Trees; BRT, n=3) (Fig. 5), were less common, although these machine learning algorithms usually outperform other modelling methods (Pittman *et al.* 2007; Elith & Graham 2009). Some studies did not specify the model used or had used their own developed model (n=6) (labelled as 'unnamed modelling method' in Fig. 5).

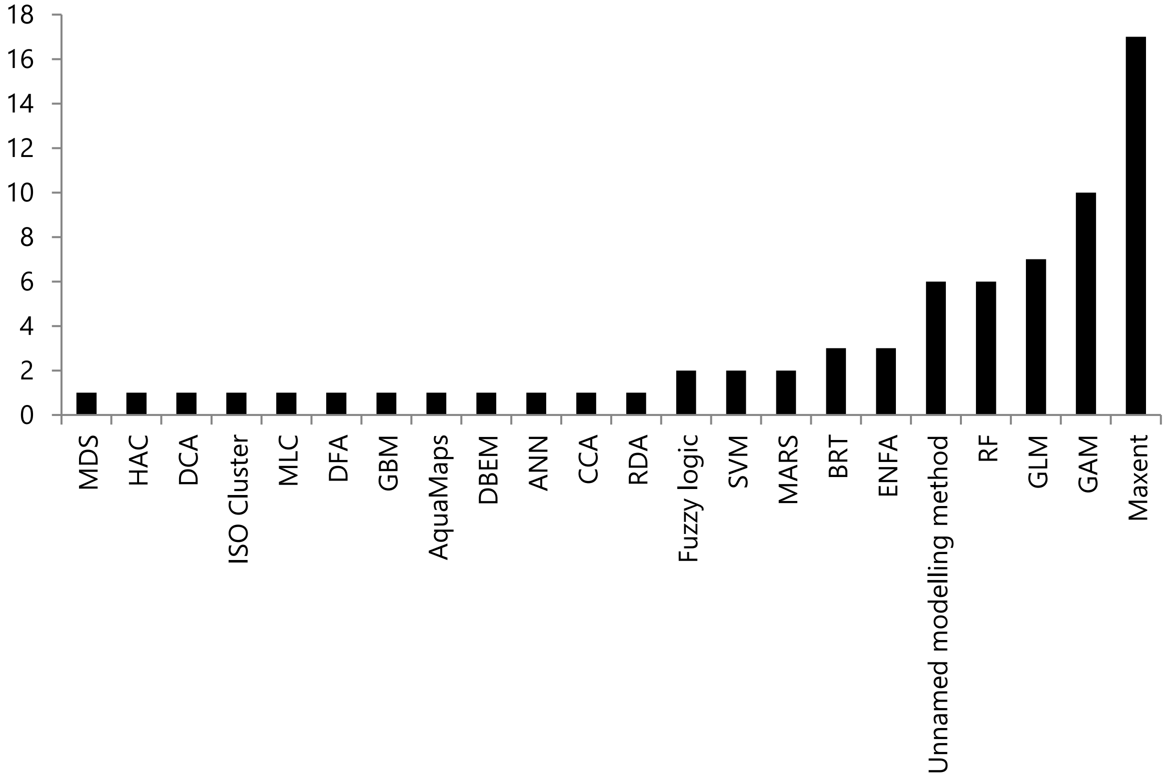

Figure 5: Modelling methods used across 54 reviewed habitat modelling studies in Europe.

The various types of modelling methods are reflected in the types of response data (Fig. 6); 13 of the reviewed studies produced presence-absence habitat models; the others concentrated on modelling categorical class or continuous response variables (Fig. 6).

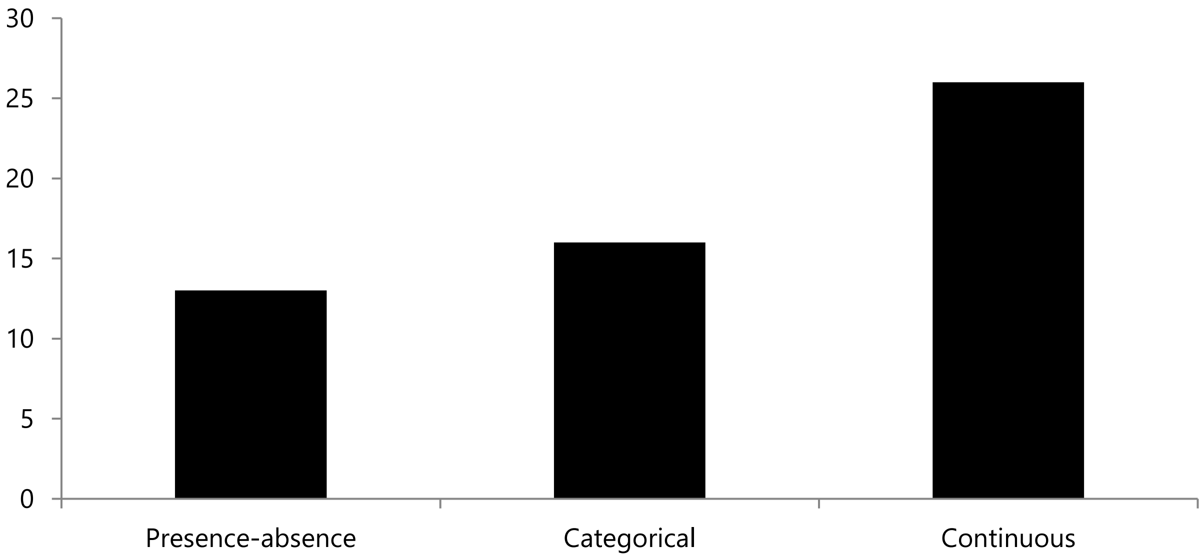

Figure 6: Modelled response variables in 54 reviewed habitat modelling studies in Europe.

3.1.5 Modelling resolution and extent

Modelling resolution ranged from meso-scale (5 – 500 m) models to macro-scale (1 – 100 km) (Fig. 7). The majority of models in the reviewed studies were produced at meso-scale (n= 31) whereas macro-scale models were less frequent (n =13). Some (n=8) of the studies did not report the resolution of the habitat models produced. When considering the extent covered by the models, we observed that they are produced to cover a variety of areas, and only a fraction (n=7) addressed whole regional sea areas (Fig. 8). This suggests that habitat data representation or the environmental data availability is still inadequate for producing reliable habitat models for large sea areas or whole sea basins.

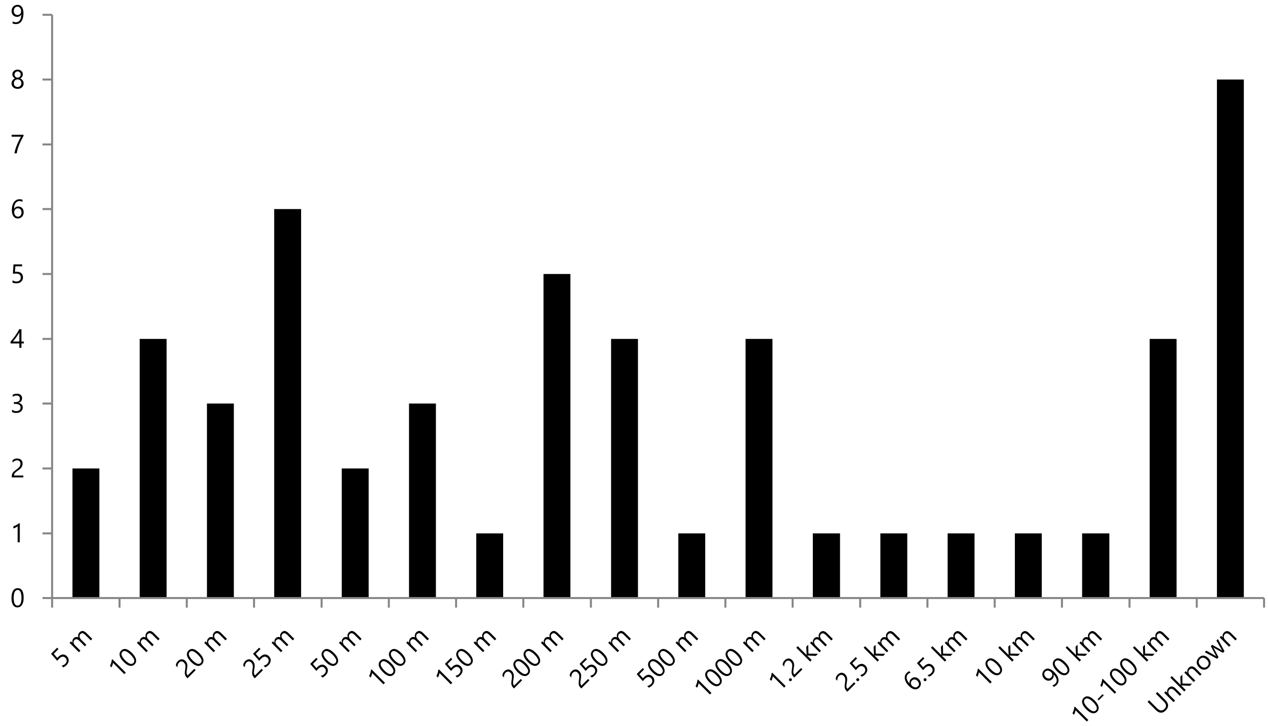

Figure 7: Spatial resolution of input data for 54 reviewed habitat modelling studies in Europe.

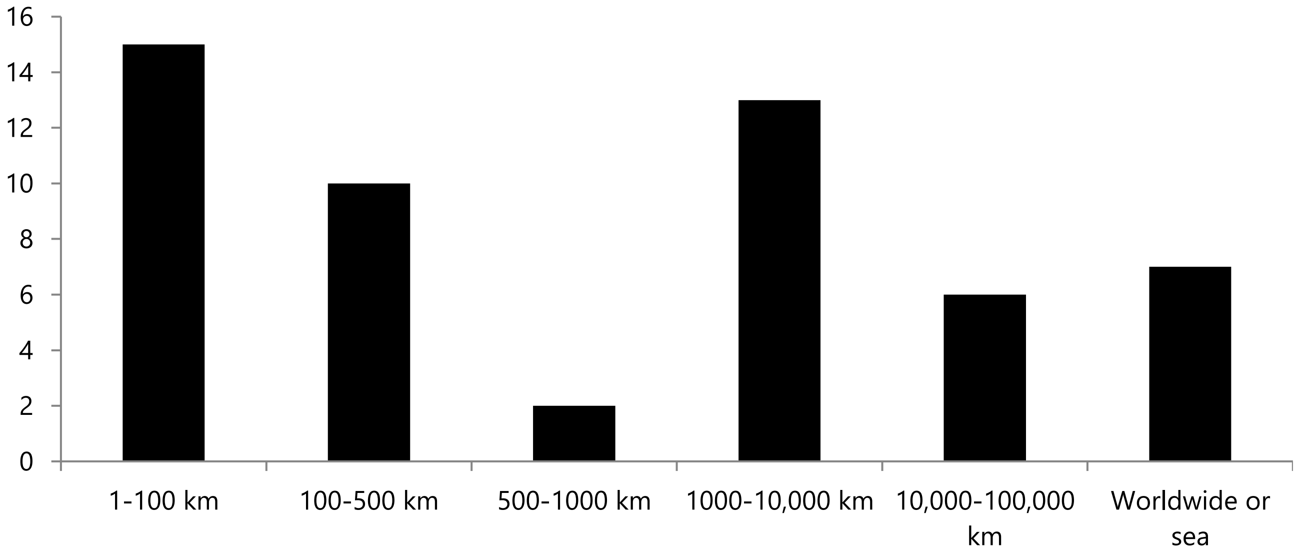

Figure 8: Spatial extent of 54 reviewed habitat modelling studies in Europe.

3.1.6 Summaries by European marine regions

Habitat models were mostly produced in the North-east Atlantic Ocean (n=31), followed by the Arctic (n=11), Baltic Sea and Mediterranean Sea (n=9) (Fig. 9). Some of the models (n=6) were global, but included parts of the European marine regions. This review did not find any marine habitat modelling studies from the Black Sea.

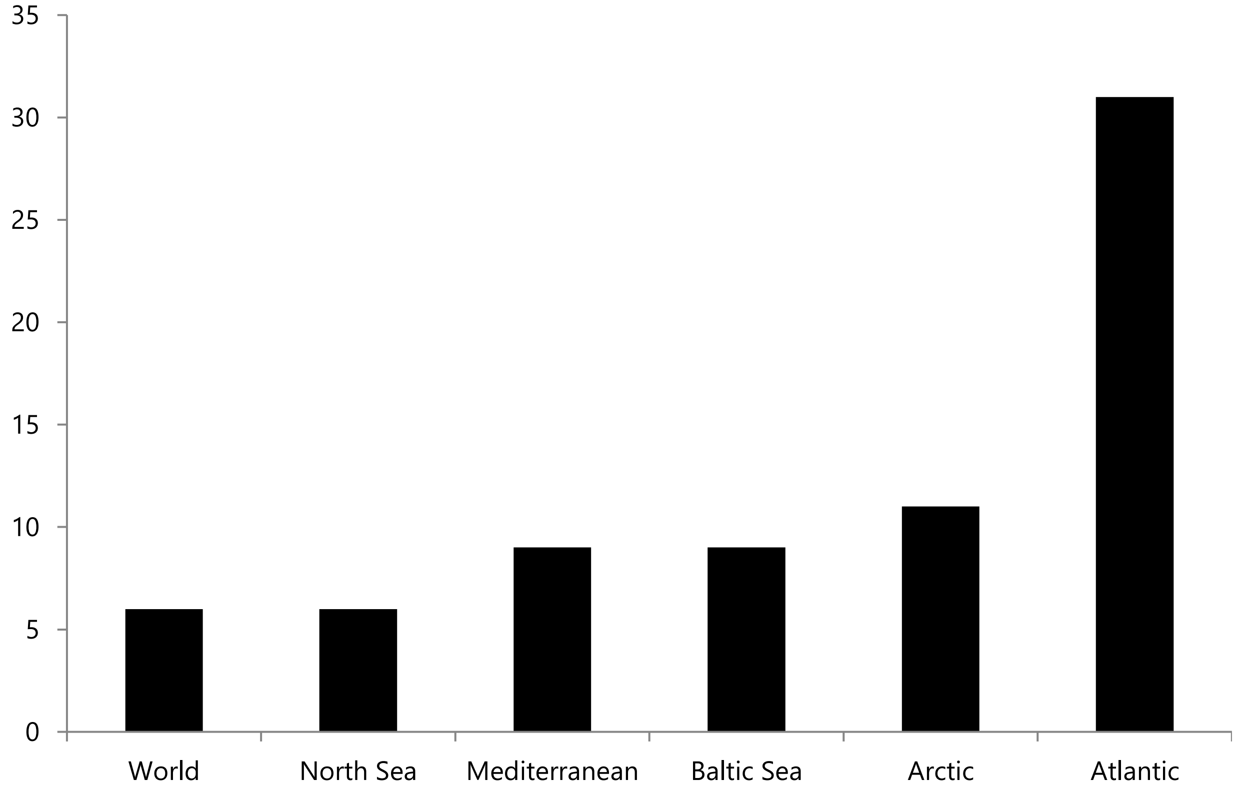

Figure 9: Number of habitat models produced in different European Seas for 54 reviewed habitat modelling studies. No studies were found for the Black Sea.

3.2 Collation and publication of model outputs

After successful and failed requests, 54 model outputs were received and uploaded to the portal[2]. We received model outputs from Ireland, the United Kingdom, Finland, France, Germany, Greenland and Norway. Moreover, global, Atlantic-wide and Baltic Sea-wide habitat model outputs were collated as well. Some of the collated model outputs were not identified in the listing as some individual researchers submitted their own models and studies spontaneously. Also, some of the identified model outputs were already published on portal and were not collated again.

The map layers are freely-available to view on the EMODnet Seabed Habitats interactive map, grouped together under the layer group 'Modelled maps of specific habitats'. They are further grouped according to region or sub-region, as defined by the Marine Strategy Framework Directive regions. Note that some layers are replicated in more than one group if the model output spans more than one region, for example models that cover the whole British Isles are included in both 'Celtic Seas' and 'Greater North Sea' groups. Additionally, models vary in resolution including: broad-scale (Fig. 10), medium-scale (Fig. 11) and fine-scale (Fig. 12).

As well as viewing via the interactive map, the 54 model outputs can be accessed via web mapping services[3].

Only 3 of the model outputs are available to download or to access via web coverage services.

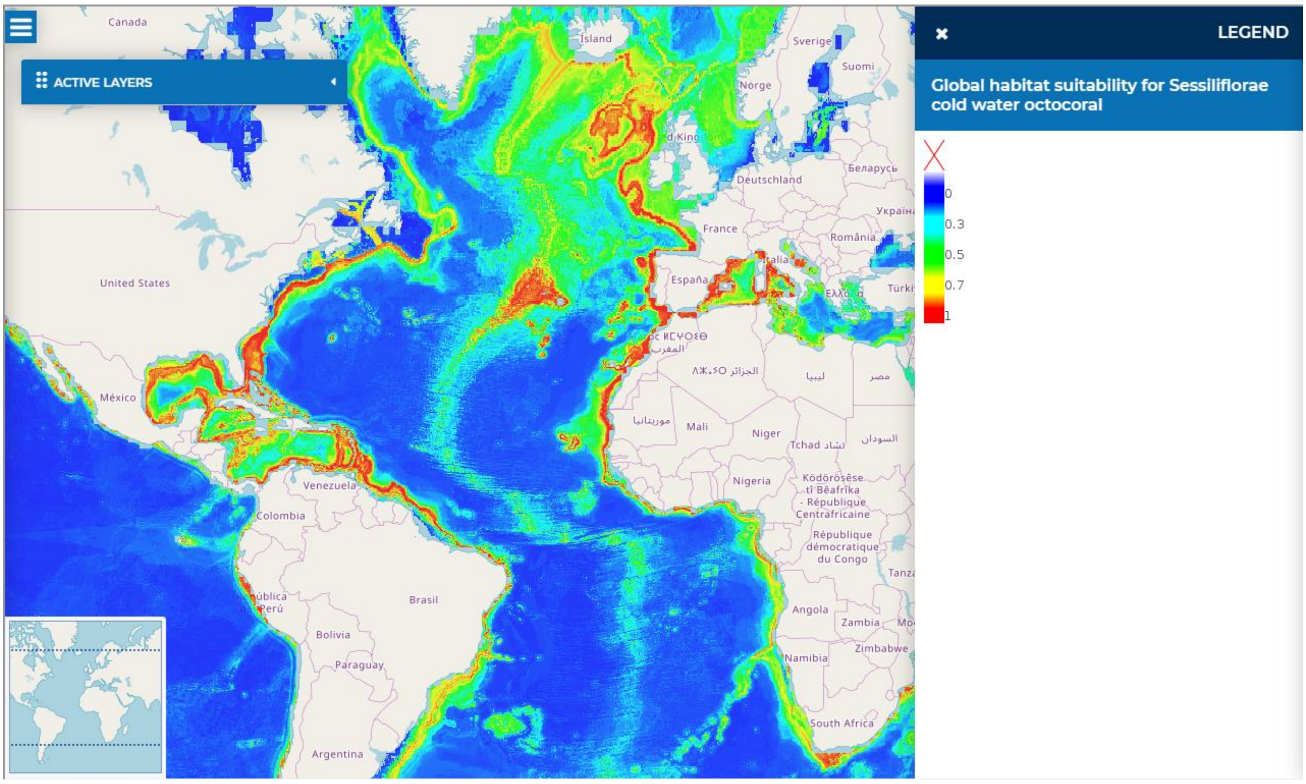

Figure 10: Example of a broad-scale resolution model on the EMODnet Seabed Habitat map viewer - displaying the global habitat suitability for the cold water octocoral species Sessiiliflorae.

[2] View all collated models on the interactive map: https://www.emodnet-seabedhabitats.eu/access-data/launch-map-viewer/?zoom=4&center=-3.508,52.305&layerIds=950,951,952,953,954,955,956,957,958,959,960,961,962,963,964,965,966,967,968,969,970,971,972,973,974,975,976,977,978,979,980,981,982,983,984,985,986,987,988,989,990,991,992,993,994,995,996,997,998,999,1000,1001,1002,1003,1010,1011,1012,1013,1014,1015,1016,1017,1018,1019,1020,1021,1022,1023,1024,1025,1026,1027&baseLayerId=-3

[3] Instructions for accessing EMODnet Seabed Habitats web services: https://www.emodnet-seabedhabitats.eu/access-data/web-services/

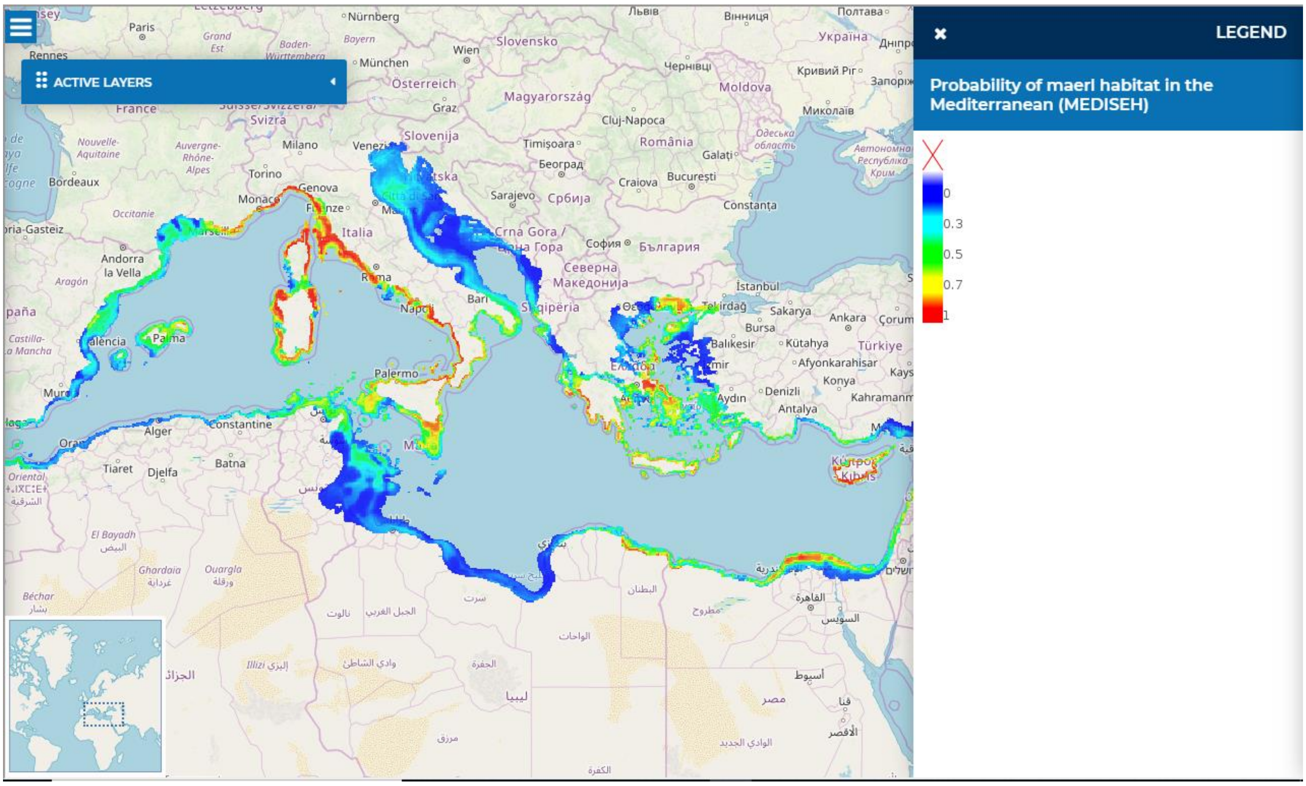

Figure 11: Example of a medium-scale resolution model on the EMODnet Seabed Habitat map viewer - displaying the probability in occurrence of maerl habitats in the Mediterranean.

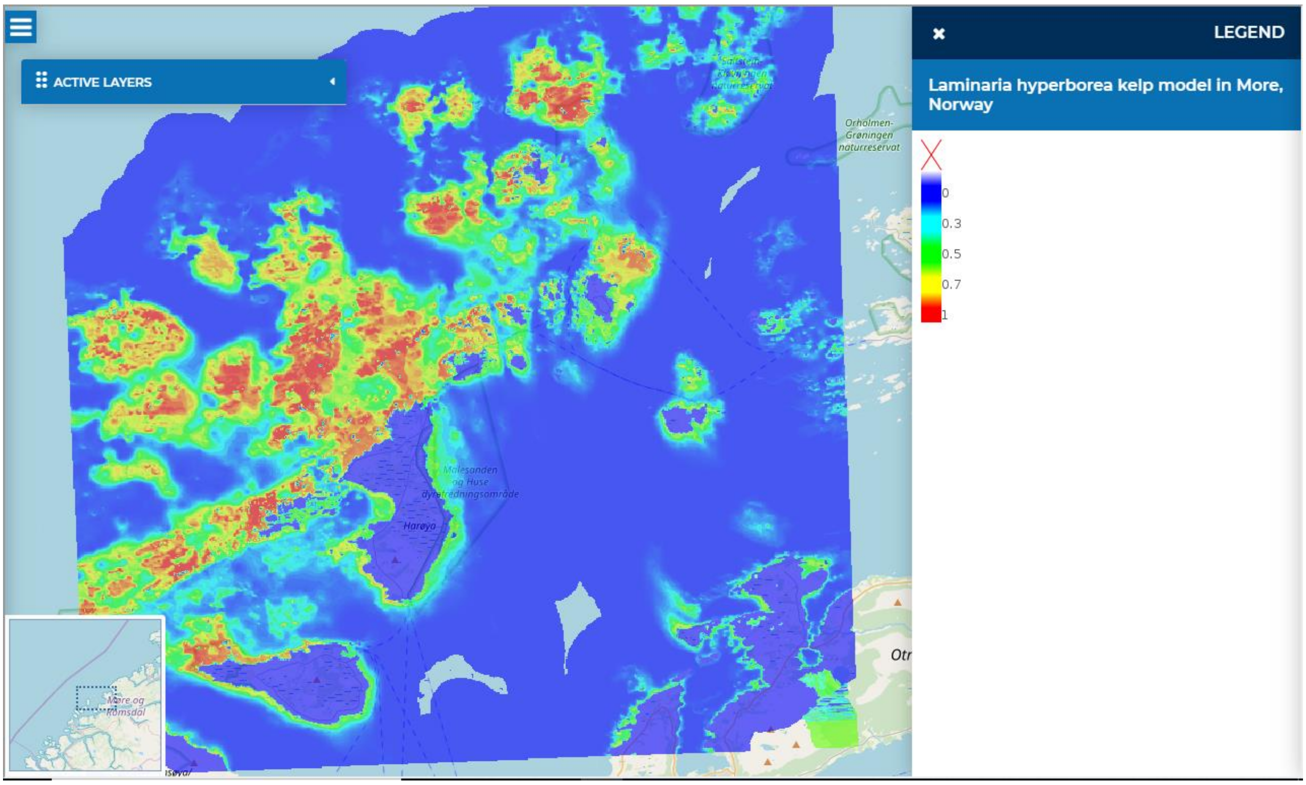

Figure 12: Example of a fine-scale resolution model on the EMODnet Seabed Habitats map viewer - displaying probability in occurrence of Laminaria hyperborea, a dense kelp species, off the South East coast of Norway.

4 Discussion

4.1 Literature review

In this report we reviewed the current trends and status of marine habitat modelling, concentrating on the European Seas. Most commonly, habitat modelling aimed at acquiring an overview of a certain habitat and its potential distribution ranges (e.g. Bekkby *et al.* 2009; Schubert *et al.* 2015). Questions regarding conservation science and management of protected areas were also answered with the help of modelling (e.g. Amorim *et al.* 2015).

Only 16 studies dealt with modelling EUNIS classes, maybe because EUNIS habitat maps in many areas are derived directly from full-coverage survey data, such as multi-beam bathymetry, and do not specifically require modelling. Another reason could be that habitat maps are often used for management purposes and, as such, are not intended for scientific publishing. For instance, marine spatial planning requires information on seafloor habitats, but the data needs are resolved regionally and locally, not being associated to published scientific analyses.

Only one paper reviewed dealt with the potential impacts of changing climate on marine environments (Gormley *et al.* 2013). Hydrodynamic 3D models and scenarios for the future ocean are advancing quickly at global scales, but are lacking at scales relevant to address niche delimitations at regional and local level. Scenarios for regional sea areas are currently available at a mediocre spatial resolution, such as NEMO Nordic in the Baltic Sea, with the operational horizontal resolution of 1 nautical mile (Hordoir *et al.* 2019). There exists a vast understanding of the drastic changes of the marine environments in the future. Rising sea temperatures, declining salinity levels, and increasing storms are acknowledged. However, more information on the impacts of changing climate on marine habitats is needed to ensure, for instance, that protected areas are maintained for the future. With correct oceanographic and environmental scenarios, habitat and species distribution models can be used to answer such questions by projecting the spatio-temporal distribution of habitats and habitat-forming species.

One of the key challenges of species distribution models is that they require a large volume of data. Not only do models need meaningful environmental predictors, but also adequate occurrence information on the habitat/species modelled. Acquiring such information in situ (e.g. by SCUBA diving, remotely-operated vehicles or remote cameras) is expensive and time-consuming. Lack of sufficient observations seems to be the main reason preventing a wider application of models in marine environments at regional to local scales. Also, sufficient data on relevant environmental predictors, i.e. ecological understanding, should be available to relate the species to their abiotic environment. As 3D marine modelling is developing quickly, projections of physical and chemical properties of the water column are becoming more accurate. The same applies to satellite sensor data. On the other hand, while data on the abiotic environment becomes more readily available and usable for modelling, much more information on biotic interactions, for instance trophic relations, would be needed for more realistic modelling of habitats and species (Robinson *et al.* 2011).

The use of satellite imagery as source for marine habitats is low, potentially due to the high cost of acquiring LiDAR data and satellite images at an adequate resolution. For example, WorldView 2, MODIS Aqua, Sentinel 2, Landsat 3 or Pleiades satellite sensors provide suitable bands for producing information on marine habitats and environments. However, prices for satellite images from commercial sensors can soar high quickly, if covering long stretches of coast. Fortunately, non-commercial optical imagery at a high spatial resolution is nowadays freely available, such as Sentinel-2 from the EU Copernicus Programme. Online databases, e.g. the Ocean Biogeographic Information System (OBIS; http://iobis.org), or the Global Biodiversity Information Facility (GBIF; http://gbif.org), which provide species distribution data freely, are also popular in marine habitat modelling studies, which is not surprising as such data is accumulating fast.

The potential for crowd-sourcing information in marine areas is still in its infancy, if compared to achievements in terrestrial environments. In shallow, clear marine areas, water binoculars, snorkelling and diving are potential methods for the general public to identify specific, easily-identifiable habitats. Another example for crowd-sourcing ecological data gathering is a mobile application that has been developed in Finland to harvest information on the extent of reed belts in marine areas. Moreover, information from social media data could be used to mine information for habitat modelling, as it has been used successfully in conservation science and in identifying peoples behaviours on land (Toivonen *et al.* 2019).

Modelling studies varied geographically, somewhat concentrating on the North-Atlantic. This was also noted in other reviews. Countries such as UK, Ireland, Norway, and France have invested in mapping and modelling their underwater habitats, which was somewhat emphasized in this review. Other regional seas were in the minority, highlighting either the differences in countries' economic abilities to channel efforts to habitat mapping and modelling, or due to short tradition of spatial studies. There are, however, a lot of underwater surveys carried out in European seas. Although the data may have not been collected specifically for spatial analyses, they may be useful for habitat modelling, once issues regarding spatial and temporal resolution, and data quality, have been taken into account.

Recent advances in machine learning algorithms and ensemble modelling platforms (e.g. R package caret) provide a promising environment for producing models. Most of the studies reviewed here concentrated on only one or more traditional modelling algorithms, such as GAMs or GLMs, which straightforwardly provide statistical relationships that can be audited vis-à-vis ecological niche theories. This may be due to an illusion of machine learning approaches being "black-boxes", and usually the difficult part is the way the machine learning algorithm actual learns from the data. However, there are numerous reasons why machine learning algorithms should be preferred in modelling marine environments; the most important one being the complexity of interactions inherent in 3D marine environment. While the studies reviewed here used mostly single approaches for building the models, marine habitat models could benefit from the implementation of multiple modelling algorithms that account for the similarity/variance between models outputs.

Our literature review is not exhaustive, as it only addressed a most recent time span of 10 years. Potentially many studies addressing marine habitat modelling might have slipped through our search criteria ("marine", "habitat", "model"). Applied technical studies as well as scientific literature dealing more extensively with ecological questions than with the model fitting approach and results are likely underrepresented in this review. In terms of marine spatial planning and conservation management effort, there are clear knowledge gaps in most of the European Sea areas towards which a wider use of habitat modelling would be beneficial.

4.2 Collation and publication of model outputs

For the first time, the results of European seabed habitat modelling studies have been compiled and published online. Using the EMODnet Seabed Habitats interactive map, users can now quickly see the coverage of models in their region of interest. More work is needed, however, to make these more useful:

- As yet, most of the model owners stipulated that their outputs may not be made available to download. This presents a barrier to use, whereby a potential user must contact the originator/point of contact to request access, which is not guaranteed.
- The map layers are currently presented independently of further information on model quality, performance or accuracy. A potential user would have to consult the associated paper for this information, which presents another barrier to use.

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Appendix 1: List of reviewed habitat modelling studies

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Appendix 2: Modelled marine habitats, biotopes, communities and habitat-forming species

Modelled habitat, biotope, community or habitat-forming species	Count
Biotopes	
Fine-grained mud in shelf basin	1
Sandy sediments in level areas	1
Gravelly sand on gently sloping seabed	1
Sandy gravel with cobble in areas with iceberg ploughmarks	1
Sandy gravel with cobble and boulder on morainic ridges	1
Reefs	1
Polychaete-rich deep Venus community in offshore mixed sediments	1
Flustra foliacea and Hydrallmania falcata on tide-swept circalittoral mixed sediment	1
Halidrys siliquosa and mixed kelps on tide-swept infralittoral rock with coarse sediment	1
Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles	1
EUNIS	
A3 Infralittoral rock and other hard substata	1
A3.1 Atlantic and Mediterranean high-energy infralittoral rock	1
A3.2 Atlantic and Mediterranean moderate energy infralittoral rock	1
A3.3 Atlantic and Mediterranean low-energy infralittoral rock	1
A4 Circalittoral rock and other hard substrata	1
A4.1 Atlantic and Mediterranean high-energy circalittoral rock	1
A4.12 Sponge communities on deep circalittoral rock	1
A4.12 Mixed faunal turf communities on circalittoral rock	1
A4.2 Atlantic and Mediterranean moderate energy circalittoral rock	1
A4.3 Atlantic and Mediterranean low-energy circalittoral rock	1
A5 Sublittoral sediment	1
A5.1 Sublittoral coarse sediment	1
A5.12 Infralittoral coarse sediment	1
A5.15 Deep circalittoral coarse sediment	1
A5.2 Sublittoral sand	1
A5.23 Infralittoral fine sand	1
A5.24 Infralittoral muddy sand	1
A5.25 Circalittoral fine sand	1
A5.27 Deep circalittoral sand	1
A5.3 Sublittoral mud	1
A5.33 Infralittoral sandy mud	1
A5.34 Infralittoral fine mud	1
A5.35 Circalittoral sandy mud	1
A5.37 Deep circalittoral mud	1
A5.4 Sublittoral mixed sediments	1
A5.43 Infralittoral mixed sediments	1
A5.45 Deep mixed sediments	1
A5.6 Sublittoral biogenic reefs	1
AA.J3L9 Photic or aphotic sand dominated by multiple infaunal bivalve species including C. glaucum M. balthica M. arenaria	1
AB.H3L1 Aphotic muddy sediment dominated by Macoma balthica	1
AA.H3L3 Photic or aphotic muddy sediment dominated by Arctica islandica	1
AA.J3L3 Photic or aphotic sand dominated by Arctica islandica	1
AA.J3L1 Photic or aphotic sand dominated by Macoma balthica	1
AA.J3L Photic or aphotic sand dominated by infaunal bivalves	1
AA.H3L Photic or aphotic muddy sediment dominated by infaunal bivalves	1
AA.M1C Photic mixed substrate dominated by algae	1
AA.J1E1 Photic or aphotic sand dominated by unattached Mytilidae	1
AA.J3 Photic or aphotic sand dominated by infauna	1
AA.Mx1 Photic or aphotic mixed substrate dominated by epibenthic community	1
AA.J3L11 Photic or aphotic sand dominated by multiple infaunal polychaete species including Ophelia *spp*. and Travisia forbesii	1
AA.M1E1 Photic or aphotic mixed substrate dominated by Mytilidae	1
AB.M1 Aphotic mixed substrate dominated by epibenthic community	1

The European Marine Observation and Data Network (EMODnet) is financed by the European Union under Regulation (EU) No 508/2014 of the European Parliament and of the Council of 15 May 2014 on the European Maritime and Fisheries Fund.

AA.J3L10 Photic or aphotic sand dominated by multiple infaunal bivalve species including A. borealis, A. elliptica and rare bivalves	1
AA.J3L4 Photic or aphotic sand dominated by Mya arenaria	1
AA.I1E1 Photic or aphotic coarse sediment dominated by Mytilidae	1
AA.H3L9 Photic or aphotic muddy sediment dominated by multiple infaunal bivalve species including C. glaucum M. balthica M. arenaria	1
AA.J3L5 Photic sand dominated by Astarte borealis	1
AA.I3L Photic or aphotic coarse sediment dominated by infaunal bivalves	1
AA.I3L9 Photic or aphotic coarse sediment dominated by multiple infaunal bivalve species including C. glaucum M. balthica M. arenaria	1
AA.I3L11 Photic or aphotic coarse sediment dominated by multiple infaunal polychaete species including Ophelia *spp.*	1
AA.H3 Photic or aphotic muddy sediment dominated by infauna	1
AA.I3L10 Photic or aphotic coarse sediment dominated by multiple infaunal bivalve species including A. borealis, A. elliptica and rare bivalves	1
AA.I3 Photic or aphotic coarse sediment dominated by infauna	1
AA.H3L10 Photic or aphotic muddy sediment dominated by multiple infaunal bivalve species including A. borealis, A. elliptica and rare bivalves	1
AB.B1E1 Aphotic hard clay dominated by Mytilidae	1
AA.I3L5 Photic coarse sediment dominated by Astarte borealis	1
AA.I3L3 Photic or aphotic coarse sediment dominated by Arctica islandica	1
AA.I3L1 Photic or aphotic coarse sediment dominated by Macoma balthica	1
AA.G Photic or aphotic peat bottoms	1
AA.J3M Photic sand dominated by infaunal polychaetes	1
AA.I3L4 Photic coarse sediment dominated by Mya arenaria	1
AA.B1 Photic or aphotic hard clay dominated by epibenthic community	1
AA.H1E1 Photic or aphotic muddy sediment dominated by Mytilidae	1
AA.H3L5 Photic muddy sediment dominated by Astarte borealis	1

AA.H3M Photic muddy sediment dominated by infaunal polychaetes	1
AA.H3L4 Photic muddy sediment dominated by Mya arenaria	1
AA.I3M Photic coarse sediment dominated by infaunal polychaetes	1
A4.21 Echinoderms and crustose communities on circalittoral rock	2
A5.14 Circalittoral coarse sediment	2
A5.26 Circalittoral muddy sand	2
A5.36 Circalittoral fine mud	2
A5.44 Circalittoral mixed sediments	2
Habitat-forming species	
Abra alba	2
Acanella arbuscula	1
Acanthogorgia armata	1
Amphibalanus improvisus	1
Arctica islandica	1
Ascophyllum nodosum	2
Asellus spp.	1
Bifurcaria bifurcata	1
Ceratopogonidae	1
Chironomidae	1
Cladophora aegagropila	1
Cladophora rupestris	1
Cordylophora caspia	1
Corophium volutator	1
Crassostrea gigas	1
Cymodocea nodosa	1
Dreissena polymorpha	1
Enallopsammia rostrata	1
Ephemeroptera	1
Fucus serratus	2
Fucus spiralis	1
Fucus spp.	1
Fucus vesiculosus	3
Funiculina quadeangularis	1
Furcellaria lumbricalis	2
Gammarus spp.	1
Goniocorella dumosa	1
Halicryptus spinulosus	1
Heteroconger longissimus	1
Hildenbrandia rubra	1
Himanthalia elongata	1
Hirudinae	1

Hydra spp.	1
Isidella elongata	1
Isidella lofotensis	1
Jaera spp.	1
Laminaria digitata	2
Laminaria hyperborea	1
Lobophora sp.	1
Lophelia pertusa	10
Macoma balthica	3
Madrepora oculata	2
Manayunkia aestuarina	1
Marenzelleria spp.	1
Melinna palmata	2
Modiolus modiolus	1
Monoporeia affinis	1
Munida sarsi	1
Nemertea	1
Nepthys cirrosa	1
Oligochaeta	1
Ophelia borealis-Nephtys cirrosa	1
Ophelia limacina	1
Ostracoda	1
Paragorgia arborea	1
Paramuricea clavata	1
Paramuricea placomus	1
Parastichopus tremulus	1
Pelvetia canaliculata	1
Pheronema carpenteri	2
Phyllophora pseudoceranoides	2
Polysiphonia fucoides	1
Pontoporeia affinis	1
Posidonia oceanica	1
Potamopyrgus antipodarum	1
Primnoa resedaeformis	1
Radicipes gracilis	1
Reteporella sp.	1
Rhodomeia confervoides	1
Saduria entomon	1
Solenosmillia variabilis	1
Sphacelaria arctica	1
Spio decoratus	1
Syringammina fragilissima	2
Theodoxus fluviatilis	1
Trichoptera	1

Zostera noltii	1
Communities	
A. aquamata and *A. latreilli* in mixed sediment	2
Communities characterized by L. rodriguezii	1
Barren ground	2
Black coral	2
Crepidula fornicata shoal in coarse mixed sediment	1
Coastal detritic with rhodoliths and *Osmundaria*	1
Coastal detritic with rhodoliths and *Peyssonnelia*	1
Coastal detritic without vegetation	1
Communities under variable salinity conditions	1
Coralligenous platforms	1
Deep offshore reefs dominated by calcareous macroalgae	1
Filamentous red seaweed	1
Hard bottom coral	1
Hard-bottom communities	1
Hydrozoa	1
Infralittoral coare and mixed sediment communities	1
Intertidal soft-bottom communities	1
Kelp	5
Lithothamion spp. and red algae	1
Lithothamion spp.	1
Maërl beds	2
Mixed algal	2
Mytilus beds	2
Radicipes meadows	1
Reefs dominated by Porifera	1
Reefs with opportunistic and tolerant macroalgae	1
Scleractinian cold-water coral reef	3
Seagrass meadows	2
Soft bottom demosponges	1
Stylasterids and lobose sponges	1
Xenophyophore fields	1
Zostera marina beds	8