ICES WGDEC REPORT 2018

ICES ADVISORY COMMITTEE

ICES CM 2018/ACOM:26

Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC)

5-9 March 2018

Dartmouth, Nova Scotia, Canada

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CIEM Conseil International pour l'Exploration de la Mer

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Contents

Executive summary

On 5th March 2018, the joint ICES/NAFO Working Group on Deep-water Ecology (WGDEC), chaired by Neil Golding (UK) and attended by sixteen members (eleven in person, three via WebEx video conferencing and two via correspondence), met at the Northwest Atlantic Fisheries Organisation (NAFO) HQ in Dartmouth, Nova Scotia, to consider the Terms of Reference listed in Section 2.

WGDEC was requested to provide all new information on the distribution of vulnerable marine ecosystems (VMEs) in the North Atlantic. A total of 14 417 new records were submitted through the ICES VME data call in 2017/2018 (a combination of VME indicator and VME habitat records) and included within the ICES VME database; 113 for the NEAFC Regulatory Area (RA), 14 298 for the Exclusive Economic Zones (EEZs) of ICES Member Countries and six for the NAFO RA. A substantial contribution of new information on VMEs was made by Canada with 13 745 VME habitat and indicator records submitted. All records from the VME database were also presented as outputs from the VME weighting system, showing the likelihood of VMEs being encountered on the seabed along with an associated confidence assessment.

This year, WGDEC was also requested to provide a list of areas and spatial layers, where VMEs occur, or are likely to occur, with respect to implementation of the EU deep-sea access regulation. To identify areas where VME occur, a data review was undertaken initially from the ICES VME database. However, in some EU waters the VME database is impoverished with respect to data on VME occurrence, and as such in these areas, data from the VME database was supplemented with data from peer reviewed literature and the OSPAR 2015 database. To identify areas where VME are likely to occur, WGDEC used the outputs of the VME weighting algorithm. The group focused on those c-squares which have been identified as having a 'high' VME index with an associated 'high' or 'medium' confidence. Data relevant to this ToR was identified from seven ICES reporting areas: IV, V, VI, VII, VIII, IX and X. Results were presented as maps within the report as well as the provision of spatial layers to ICES and on the VME data portal.

To follow on from work undertaken in 2015, WGDEC continued to investigate the latest scientific literature on the ecosystem functioning of VMEs, and of deep-sea benthic ecosystems more widely. This review is not exhaustive, but represents an overview of the key insights from new investigations on ecosystem functionality in the deep sea.

To ensure consistency in how WGDEC interpret new evidence of VME submitted to the VME database, and to identify if/when we can consider groups of VME indicator records as *bona fide* VME, WGDEC 2018 undertook a review of how to better define VMEs under NEAFC using existing approaches. The review considered approaches used by other RFMOs including NAFO and the South Pacific Regional Fisheries Management Organization (SPRFMO). It also provided recommendations on potential approaches for the VME habitat types; hydrothermal vents, cold seeps, coral gardens, cold-water coral reefs and seamounts. WGDEC identified aspects of the VME weighting algorithm that could be modified in future in light of new research on the vulnerability of deep-sea communities.

Finally, WGDEC identified the need to improve links with the General Fisheries Commission for the Mediterranean (GFCM) Working Group on Vulnerable Marine Ecosystems, which was established in 2017, potentially through WGDEC participation at the GFCM WGVME and vice versa, and sharing of information and tools of relevance.

1 Opening of the meeting

The Working Group on Deep-water Ecology (WGDEC) commenced in plenary at 09:00 on Monday 5th March 2018 at the Northwest Atlantic Fisheries Organisation (NAFO), Nova Scotia. The leads for each Terms of Reference (ToR) were appointed, and are outlined below:

- ToR [a] lead: James Albrecht
- ToR [b] lead: James Albrecht
- ToR [c] lead: Steinunn Ólafsdóttir
- ToR [d] lead: Ellen Kenchington
- ToR [e] lead: Laura Robson

Following the review and adoption of the agenda, the WGDEC began working through the Terms of Reference. Each ToR lead outlined how they intended to tackle the ToR, and led the discussion. Dedicated plenary sessions were held every morning and afternoon; these were via WebEx allowing remote participants to participate. During these plenary sessions, ToR leads updated the group with progress and issues were discussed. Remote participants could comment on working documents via the WGDEC SharePoint site. At the end of the week, the Working Group was formally closed at midday on Friday 9th March 2018 by the Chair.

2 Adoption of the agenda

2017/2/ACOM: 26 The **Working Group on Deep-water Ecology** (WGDEC), chaired by Neil Golding, UK, will meet 5–9 March 2018 in Dartmouth, Nova Scotia, Canada to:

a) Collate new information on the distribution of vulnerable habitats as well as important benthic species and communities in the North Atlantic and adjacent waters, archive appropriately using the ICES VME Database, and disseminate via the Working Group report and ICES VME Data Portal. In addition, prepare spatial layers and a list of areas where VMEs are likely to occur in the Northeast Atlantic, in particular in areas deeper than 800 m.

b) Provide all available new information on the distribution of vulnerable habitats (VMEs) in the NEAFC Convention Area. In addition, provide new information on location of habitats sensitive to particular fishing activities (i.e. vulnerable marine ecosystems, VMEs) within EU waters;

c) Summarize existing knowledge of ecosystem functioning of deep-sea benthic communities and habitats and the ecosystem roles of chemical/physical structures such as vents, seeps, seamounts, canyons, etc.;

d) Review how vulnerable marine ecosystems (VMEs) have been defined previously (e.g. from other RFMOs or States) and through the use of case studies for specific VMEs (e.g. seapen fields and cold-water coral reefs), suggest a procedure and consider approaches relevant to the available data and species of the NE Atlantic for developing a biological basis for defining how VMEs are identified, which will allow us in future to have an ecological basis for determining when a VME indicator record (or group of) transitions into a VME;

e) Propose parameters for use within the VME database that would serve to remove the effect of the passage of time in the evaluation of confidence in the weighting system, associated with each data entry. In addition, consider anthropogenic impacts that might be used to reintroduce uncertainty in such records.

WGDEC will report by 28th May 2018 to the attention of the ACOM Committee.

Supporting Information

Priority	The current activities of this Group will enable ICES to respond to advice requests from a number of clients (NEAFC/EC). Consequently, these activities are considered to have a high priority.
Scientific justification	ToR [a] The Joint ICES/NAFO Working Group on Deep-water Ecology undertake a range of Terms of Reference each year; the scope of these cover the entire North Atlantic, and include aspects such as ocean basin processes. Therefore, collating information on vulnerable habitats (including important benthic species and communities) preparation of spatial layers and lists of areas where VMEs are likely to occur across this wide geographic area (and adjacent waters) is essential. This ToR will address a special request from the EC to advice on a list of areas where VMEs are likely to occur and should be closed off from bottom fishing, in particular in areas deeper than 800 m. To this end, a VME data call will be run from November 2017 to February 2018, facilitated by the ICES Data Centre. Data will be quality checked/prepared one month in advance of WGDEC 2018. New data will be incorporated into the ICES VME Database and ICES VME Data Portal. This ToR includes any development work on the ICES VME Database and Data Portal, as identified by WGDEC, with support from the ICES Data Centre. ToR [b] This information and associated maps are required to meet the NEAFC recurring advice "to continue to provide all available new information on distribution of vulnerable habitats in the NEAFC Convention Area and fisheries activities in and in the vicinity of such habitats, and provide advice relevant to the Regulatory Area…" as well as part of the European Commission MoU request to "provide any new information regarding the impact of fisheries on. sensitive habitats". The location of newly discovered/mapped sensitive habitats is critical to these requests. ToR [c] In the past five years there have been new insights into the role of benthic species in deep-sea ecosystems. Examples include the filtration capacity of deep-sea sponges, the draw-down of surface production by *Lophelia* reefs and the microbial loop associated with deep-sea sponges. Collating this information will provide greater insight into functioning of these ecosystems, identify knowledge gaps and inspire research to fill those gaps. This information can be used to describe ecosystem services and assess anthropogenic impacts on these areas. ToR [d] With WGDEC now considering records of *bona fide* VME from Remotely Operated Vehicle (ROV) or towed video observations, there is a need to better define VMEs using quantitative approaches linked to the biology. This is needed to ensure we are consistent in how we interpret new evidence of VME brought to the group, as well as to identify if/when we can consider groups of VME indicator records as VME, and can be done through reviewing existing definitions and quantitative approaches used by existing RFMOs and States. ToR [e] When the VME Database was first developed there was a need to give a lower confidence in the weighting system to some of the historical data for which there was no expert available to validate the records. As data has been collected more recently, WGDEC feel the data are robust, yet they still reduce in confidence with the passage of time, due to criteria in the VME weighting algorithm. This ToR will allow those records to stand equal with newer records, which is appropriate given the biology of the VME species, unless certain anthropogenic events intervene to change the value of the record. New data will be incorporated into the ICES VME Database and ICES VME

	Data Portal. This ToR includes any development work on the ICES VME Database and Data Portal, as identified by WGDEC, with support from the ICES Data Centre.
Resource requirements	Some support will be required from the ICES Secretariat
Participants	The Group is normally attended by some 15–20 members and guests.
Secretariat facilities	None, apart from WebEx provision and SharePoint site
Financial	No financial implications.
Linkages to advisory committees	ACOM is the parent committee. Links to work undertaken by WGSFD and to WGDEEP (although no explicit overlap with the latter this year).
Linkages to other committees or groups	No direct linkages, but better links in 2018 to WGMHM and BEWG will be explored
Linkages to other organizations	As a Joint ICES/NAFO group, the work of this group links to work being undertaken by Working Groups under the NAFO Scientific Council, such as WGESA

3 Collate new information on the distribution of vulnerable habitats as well as important benthic species and communities in the North Atlantic and adjacent waters, archive appropriately using the ICES VME Database, and disseminate via the Working Group report and ICES VME Data Portal – ToR [a]. Provide all available new information on the distribution of vulnerable habitats (VMEs) in the NEAFC Convention Area. In addition, provide new information on location of habitats sensitive to particular fishing activities (i.e. vulnerable marine ecosystems, VMEs) within EU waters – ToR [b]

3.1 A note on Vulnerable Marine Ecosystem (VME) terminology used by WGDEC

WGDEC considers information relating to Vulnerable Marine Ecosystems (VMEs) in three ways;

1) 'VME habitat' records are those from visual survey data (e.g. remotely operated vehicle (ROV) or towed/drop-down camera systems) that demonstrates the presence and location of a VME with a high degree of confidence and spatial accuracy. VME habitats = VME (ICES, 2016a).

2) 'VME indicator' refers to records of VME indicator species from data sources for which there is a degree of uncertainty that a VME is, or was, present. Typical examples are records trawl survey or static longline bycatch (ICES, 2016a).

3) 'VME element' refers to seabed topographic features, readily identified using high resolution multibeam data, and with which VMEs are often associated. Examples include seamounts, ridges, canyons (ICES, 2013a).

3.2 Background

A total of 14 417 new records of Vulnerable Marine Ecosystem (VME) indicator species and VME habitats were submitted, via the ICES VME Data Call, to WGDEC since the 2017 meeting, and these were incorporated into the ICES VME database. Of these, 113 records were located within the NEAFC Regulatory Area, 14 298 records were located within the Exclusive Economic Zones (EEZs) of ICES Member States and six records originated from within the NAFO Regulatory Area.

Consistent with last year, existing VME data are not presented alongside newly submitted VME data on the maps within this section, primarily to improve clarity. However, maps of existing VME data for each area considered are shown as outputs from the VME weighting algorithm (VME Index and VME Confidence – see Section 7.2) as a separate series of maps.

3.3 Data providers for ToR (a) and (b)

New records of VME indicators/habitats were submitted via the ICES VME Data Call to WGDEC by the following ICES Member Countries (organisations/affiliations in brackets).

3.3.1 United Kingdom (Marine Scotland)

Marine Scotland submitted information relating to VMEs from two fisheries research trawl surveys (1217S and 1317S) utilising BT 137 and Jackson BT 184 bottom trawls respectively, with groundgear bag nets, for several areas in Scottish offshore waters. From the fisheries research trawl surveys, 173 VME indicator records were submitted to ICES (Table 3.1).

Table 3.1. Summary of VME indicator records submitted by Marine Scotland.

Vme indicator	Number of records
Black coral	5
Gorgonian	13
Cup coral	35
Seapen	40
Sponge	62
Soft coral	9
Stony coral	9
Total	173

3.3.2 United Kingdom (JNCC)

The Joint Nature Conservation Committee (JNCC) undertook an exercise to review seabed video imagery originating in older surveys to identify VME habitat records. In total, 99 VME habitat records (Table 3.2) were submitted from five separate surveys as follows (note the survey ID in brackets);

- RSS James Cook 060 2011 (JC060)
- MV Franklin 2009/03-JNCC (2009/03-JNCC)
- RV Celtic Explorer 2007 (CE0705)
- MV Franklin SEA/SAC 2006 (SEA/SAC 2006)
- SV Kommandor Jack SEA7 2005 (SEA7 2005)

RSS James Cook 060 2011 (JC060)

The National Oceanography Centre's JC060 survey in 2011 undertook Remotely Operated Vehicle (ROV) dives in Scottish waters within the UK EEZ (Huvenne *et al.*, 2011).

28 records of VME habitat (cold-water coral reefs and deep-sea sponge aggregations) were identified from this survey, from the Rockall Bank and Darwin Mounds area.

MV Franklin 2009/03 (2009/03–JNCC)

The 2009/03-JNCC cruise was conducted on behalf of the JNCC and visited East Rockall Bank and Anton Dohrn Seamount (JNCC, 2009). The research cruise included a drop camera survey at both sites and video data collected has been used to identify 34 records of VME habitat (cold-water coral reef and coral gardens) at East Rockall and Anton Dohrn Seamount. At Anton Dohrn, VME indicator data from the 2009/03-JNCC cruise had previously been submitted in 2011 (with updates in 2014). These existing VME indicator records have been complimented with additional VME habitat records, which have been identified from the seabed imagery for the first time.

RV Celtic Explorer 2007 (CE0705)

The CE0705 cruise was conducted on behalf of the Mapping European Seabed Habitats (MESH) project in 2007 and visited deep-sea canyons in the South West Approaches to the British Isles (Stewart and Davies, 2007). The research cruise undertook a drop camera survey of the Explorer Canyon, where one record of cold-water coral reef has been identified.

MV Franklin SEA/SAC 2006 (SEA/SAC 2006)

The SEA/SAC 2006 survey was conducted on behalf of UK government and visited a range of sites within Scottish offshore waters including George Bligh Bank, Hatton Bank, Rosemary Bank Seamount and the Faroe Shetland Channel. Drop camera seabed video imagery collected during the SEA/SAC 2006 survey was used to identify 31 new records of VME habitat from Hatton Bank and the Faroe Shetland Channel.

SV Kommandor Jack SEA7 2005 (SEA7 2005)

The SEA7 2005 SV Kommandor Jack research cruise was conducted on behalf of UK government and visited the Strategic Environmental Survey area 7 (SEA7). A drop camera was used to collect seabed imagery. Five new VME habitat records were identified from the still images from Hatton Bank and George Bligh Bank.

Table 3.2. Summary of VME records submitted by JNCC.

Vme	Number of records
Deep-sea Sponge Aggregations	24
Coral Garden	25
Cold-water Coral Reef	50
Total	99

3.3.3 Canada (DFO Canada)

For the 2017/2018 data call, Canada contributed 13 745 records of corals, seapens, and sponges to the ICES VME database. These records are from five different biogeographic zones in Eastern Canada (DFO, 2009), from the US border to the eastern Canadian Arctic. The data were drawn from annual trawl surveys, which used a depth-stratified random design and were conducted from 1995 to 2015 collectively (Table 3.3).

Data were submitted by functional group (sponges, N=9387; seapens, N=2972; large gorgonian corals, N=751; small gorgonian corals, N=575; and the glass sponge *Vazella pourtalesi*, N=60) as analysed in Kenchington *et al*. (2016), which were categorised into the relevant VME indicators (Table 3.4). The use of functional groups was due to uncertainties in at-sea identification within and among DFO administrative units. These data were used to identify significant benthic areas in Canadian waters (DFO, 2017). Of the 13 745 records submitted, 3019 have also been identified as VME habitats (Kenchington *et al.*, 2016; DFO, 2017).

Table 3.3. Time frame of data provided to the ICES VME database by Canada from multispecies trawl surveys by biogeographic region.

Biogeographic region	Data time frame
Eastern Arctic	1996–2014
Gulf of St Lawrence	2003–2015
Hudson Bay Complex	2007–2013
Newfoundland-Labrador Shelves	1995–2015
Scotian Shelf	2001–2015

Table 3.4. Summary of VME indicator records submitted by DFO Canada.

Vme indicator	Number of records
Gorgonian	1326
Seapen	2972
Sponge	9447
Total	13 745

Table 3.5. Summary of VME habitat records submitted by DFO Canada (Kenchington *et al.*, 2016; DFO, 2017).

Vme	Number of records
Deep-sea Sponge Aggregations	1806
Coral Garden	388
Seapen Field	825
Total	3019

3.3.4 Greenland

A literature review of Greenlandic invertebrate fauna revealed several records of VME indicators that were not registered in the ICES VME database. Four scientific papers from 1934 to 1992 (Burtonç 1934; Zibrowius, 1980; Tendal, 1992; Klitgaard and Tendal, 2004) had information on VME indicators with sufficient detail to warrant an entry in the database.

From this literature review, a total of 41 VME indicator records were submitted, as summarised in Table 3.6. Some of the records were of very large aggregations of sponges, and maps displaying this information are shown in Section 3.6.7.3 of this report. Many of the sponge catches did not have a weight estimate (Klitgaard and Tendal, 2004). As such, a minimum estimate based on the standard size of the plastic basket (44 litres) used for collecting the sponges was provided, with an estimated minimum of 40 kg for a full basket.

The large sponge aggregations on the east coast of Greenland, together with the information in the literature, show that the geographic distribution of the "ostur" areas follows two band-shaped arcs, defined by the East Greenland Current and the Irminger Current (Klitgaard and Tendal, 2004).

Table 3.6 Summary of VME indicator records submitted for Greenland

Vme indicator	Number of records
Gorgonian	10
Sponge	28
Stony coral	3
Total	41

3.3.5 Spain

Spain submitted a VME dataset originating from the research cruise "Mediterranean out flow water and vulnerable ecosystems" (MEDWAVES) (Orejas *et al.*, 2017) on the Research Vessel "Sarmiento de Gamboa" (CSIC). The cruise was conducted by the Spanish Institute of Oceanography (IEO) within the framework of the H2020 European project ATLAS. The data were submitted from an ROV survey at the Ormonde seamount.

Six ROV transects have been conducted covering a depth range from 674 to 1962 m. Six records of VME habitats were identified from Ormonde seamount: One coral garden and five deep-sea sponge aggregations (Table 3.7).

Table 3.7. Summary of VME indicator records submitted by MEDWAVES.

Vme	Number of records
Deep-sea Sponge Aggregations	5
Coral Garden	1
Total	6

3.3.6 Russia

VME data were collated by Russia between March 2016 and September 2017 from fishing trawl bycatch records. Data were collected by fisheries observers on the Grand Bank of Newfoundland, the Flemish Cap and Rockall Bank. VME indicators included deep-sea sponges and cold-water corals, including a catch of *Geodia* sponges of approx. 50 kg in the East Greenland area. The amount of caught VME indicator species throughout the NAFO RA and the Rockall Bank did not exceed 1 kg per haul. These data were not submitted to ICES for inclusion in the VME database in time for consideration at WGDEC 2018, but will be submitted in 2018 for further consideration at WGDEC 2019. A working paper submitted by Russia detailing the records discussed above is included in Annex 4: Catches of cold-water corals and sponges in the North Atlantic as reported in observations obtained by Russian fishing vessels in 2016–2017.

3.4 Data resubmissions

Changes were made to the VME data submission process for the 2016/2017 data call, utilising the new format developed at the WKVME workshop (ICES, 2016) and further modified for WGDEC 2017. It was recommended during the WGDEC 2017 meeting that the ICES Data Centre facilitated the resubmission of VME data, allowing records in the old VME data format to be overwritten with resubmitted data in the new format.

These changes were undertaken by the ICES Data Centre in preparation for the 2017/2018 data call.

As part of the 2017/2018 data call, seabed imagery data from certain areas that were originally submitted to the VME database as VME indicator records were reanalysed and updated to identify VME habitats, where relevant. These are noted below as 're-submissions'.

Furthermore, WGDEC has historically considered many datasets regarding the distribution of VMEs before a structured VME database was in place (for example, VME records considered at WGDEC 2007 from Hatton Bank: ICES, 2007). As such, where identified, these data have been revisited and added to the database as part of the 2017/2018 VME data call. These are noted below as 'historical' data. In some instances, this also involved reanalysis of seabed imagery to confirm presence of VME habitats.

3.5 Areas with new, historical or resubmitted VME data to the ICES VME Database in 2018

For the WGDEC 2018 data call, new and historical data were received for the following areas within the NEAFC Regulatory Area:

- Rockall Bank
- Hatton Bank
- Reykjanes Ridge

New, historical and resubmitted data were received for the following areas within the EEZs of various countries:

- Rockall Bank
- George Bligh Bank
- Anton Dohrn Seamount
- Scottish/Irish Continental Shelf
- Rosemary Bank Seamount
- Darwin Mounds
- Faroe-Shetland Channel
- Explorer Canyon
- Ormonde Seamount
- Greenland Continental Shelf
- Reykjanes Ridge

3.5.1 Rockall Bank

Rockall Bank is located off the west coast of Scotland and Ireland. The more gently sloping western side of the bank is located within the NEAFC Regulatory Area whereas the steeper, eastern side of the bank is located within the EEZ of both the UK and Ireland.

At Rockall Bank, new VME indicator data within the NEAFC Regulatory Area were submitted by the UK (Figure 3.1). These records came from a Marine Scotland Science fisheries research trawl survey (1217s) on the RV Scotia, as detailed in Section 3.3.1. Notably, 140 individuals of the VME indicator seapen species *Funiculina quadrangularis* were identified at one station (Figure 3.1).

These new data have contributed to updated outputs from the VME weighting algorithm. The updated VME index for Rockall Bank is shown in Figure 3.2. The algorithm has a gridded output layer, which shows the likelihood of encountering a VME for each grid cell; either low (yellow), medium (orange) or high (red). Those grid cells containing bona fide records of VME habitat are shown in green, and were excluded from the VME weighting algorithm and confidence layer.

The confidence layer associated with the VME weighting algorithm's VME Index layer is shown in Figure 3.3. High confidence cells are shaded white, medium confidence cells are shaded grey and low confidence cells are shaded black.

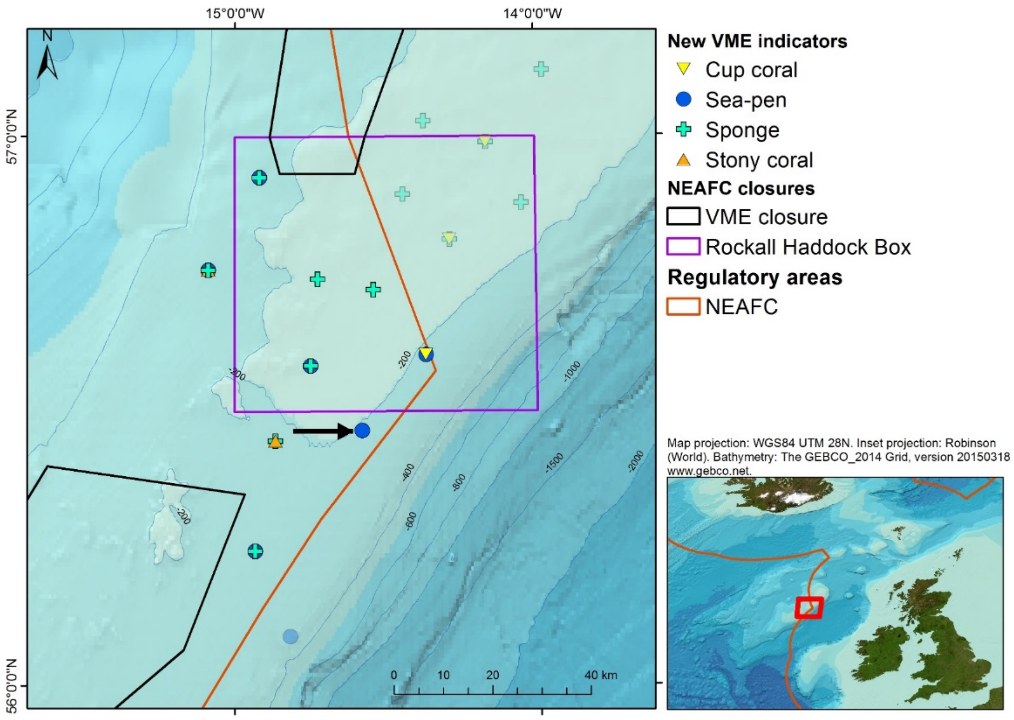

Figure 3.1. New VME indicator records submitted for WGDEC 2018 on Rockall Bank within the NEAFC Regulatory Area (new records outside the NEAFC Regulatory Area are displayed as transparent). A research trawl survey station which collected 140 seapens is indicated with an arrow.

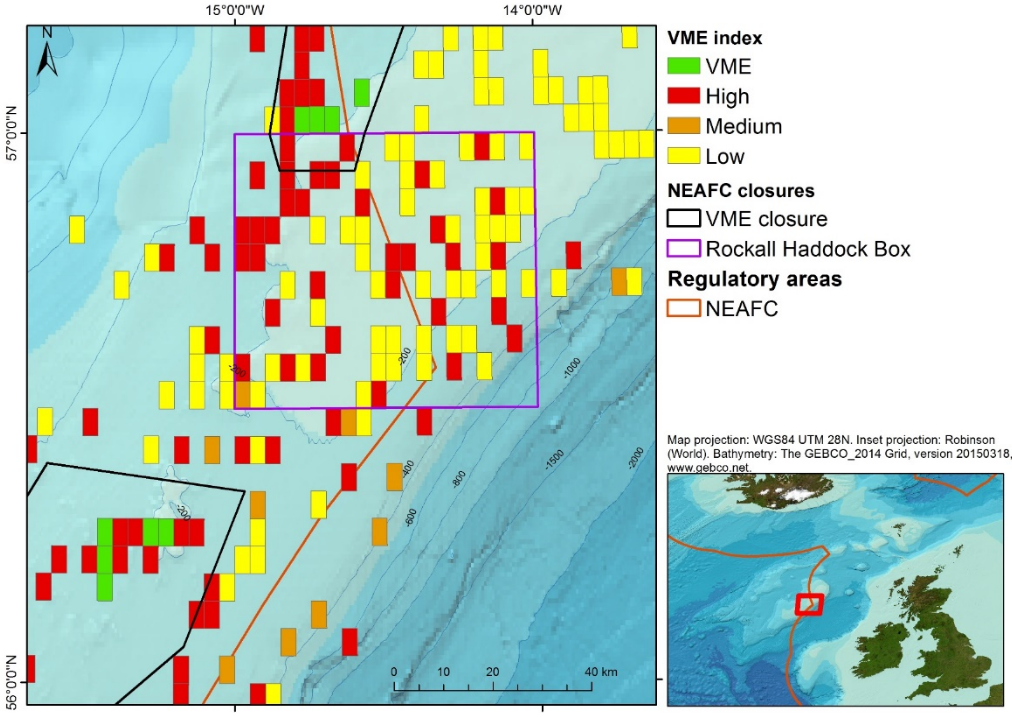

Figure 3.2. Output of the VME weighting algorithm for the area shown in Figure 3.1., showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high); and presence of actual VME. Note this includes all (not only 2018) records from the ICES VME database.

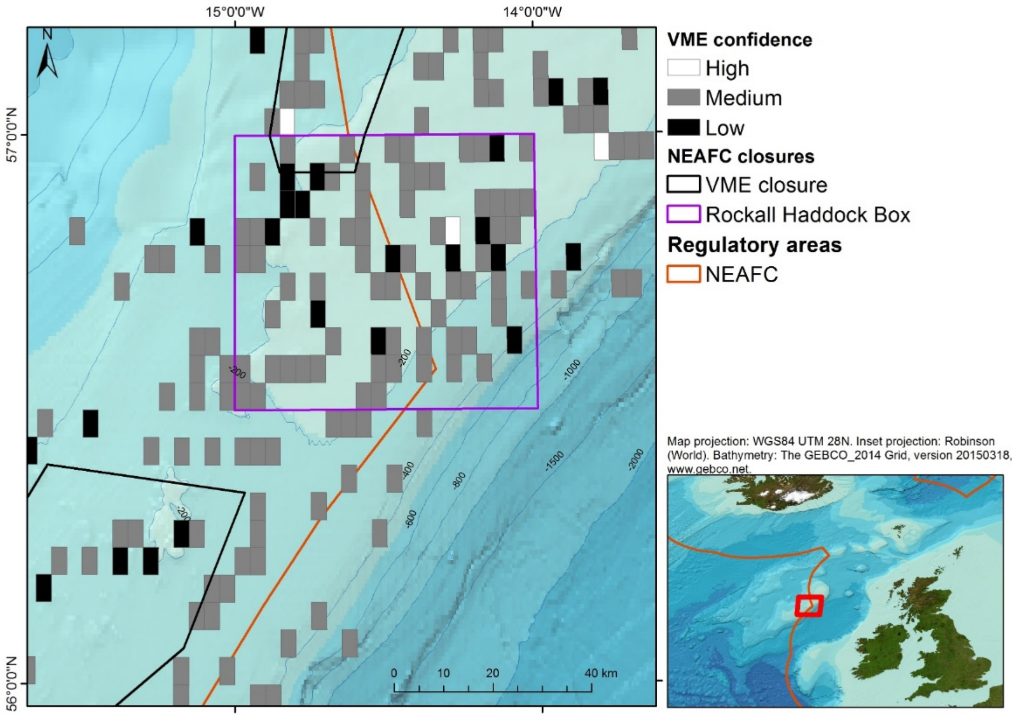

Figure 3.3. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.2). Note this includes all (not only 2018) records from the ICES VME database.

3.5.2 Hatton Bank

Hatton Bank is a large volcanic bank, situated in the Atlantic Northwest Approaches, towards the western extent of the UK Continental Shelf. It is an elongate, arc-shaped bank, stretching nearly 500 km in length and rising up to 1 km above the surrounding seabed.

As noted in Section 3.4, Hatton Bank is an area where 'historical' data reviewed by WGDEC in 2007 (ICES, 2007) were revisited to confirm the presence of VME habitats. These data (Figure 3.4) were submitted by the UK for the 2017/2018 data call, from the SEA/SAC 2006 and SEA7 2005 surveys, as described in Section 3.3.2.

The weighting algorithm has been re-run to include the new VME data, and the output is shown in Figure 3.5. The confidence layer for the VME index for Hatton Bank is shown in Figure 3.6. Example images of cold-water coral reefs and coral gardens are shown in Figure 3.7 and Figure 3.8 respectively.

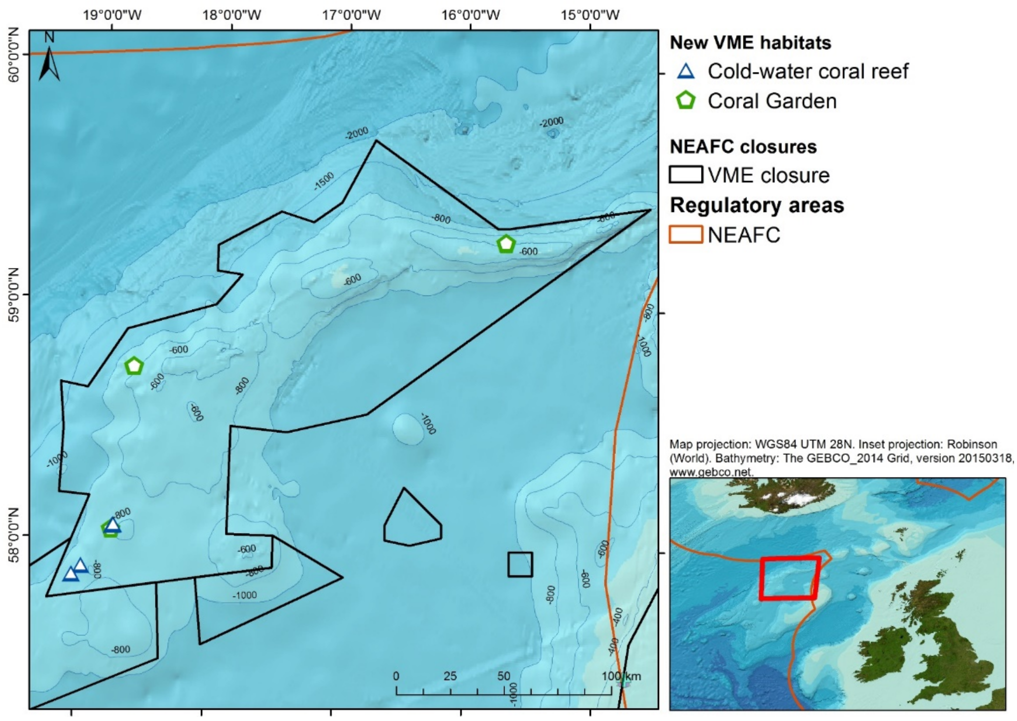

Figure 3.4. New VME records submitted to the VME database ('historical' data) for WGDEC 2018 on Hatton Bank within the NEAFC Regulatory Area.

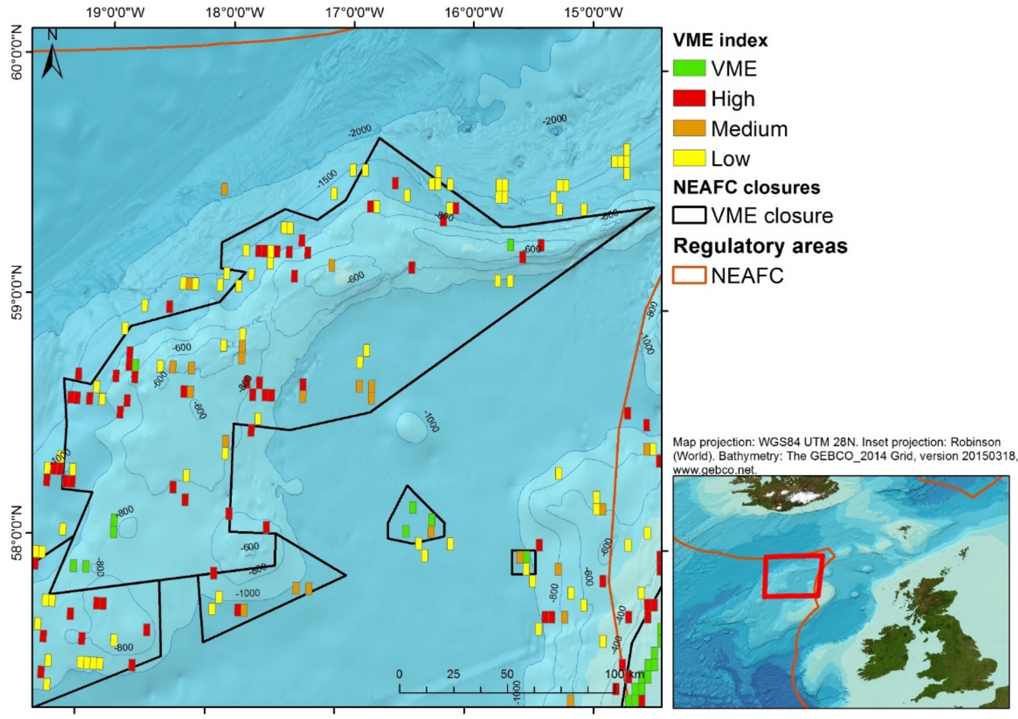

Figure 3.5. Output of the VME weighting algorithm for the area shown in Figure 3.4 showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high); and presence of actual VME. Note this includes all (not only 2018) records from the ICES VME database.

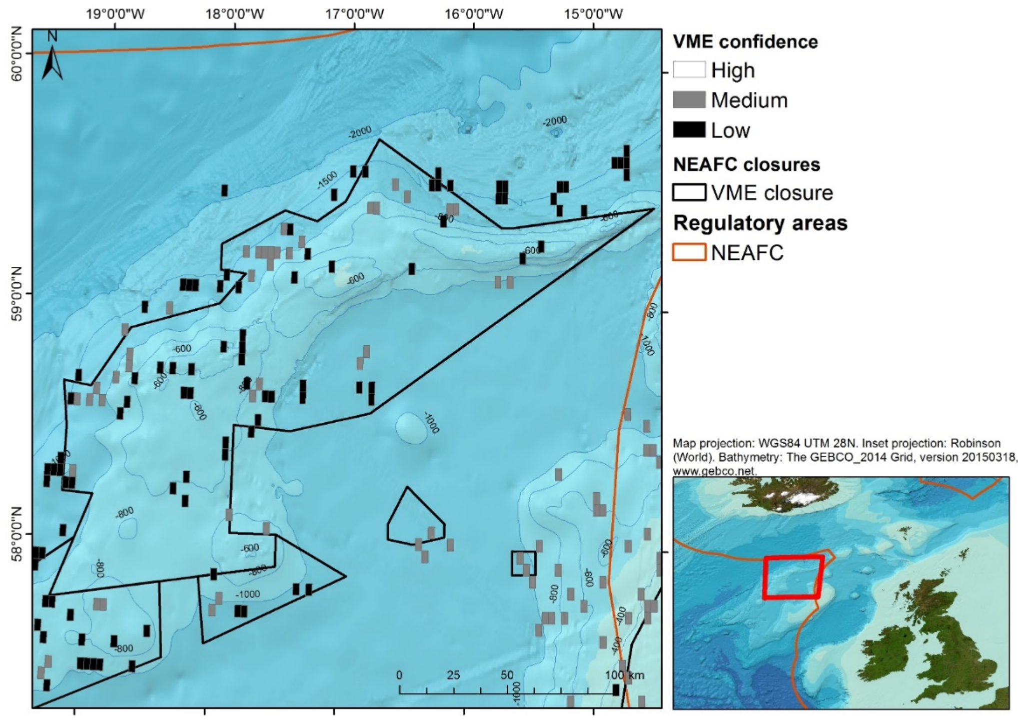

Figure 3.6. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.5). Note that actual records of VME (e.g. VME habitat) are not assigned a confidence rating. This includes all (not only 2018) records from the ICES VME database.

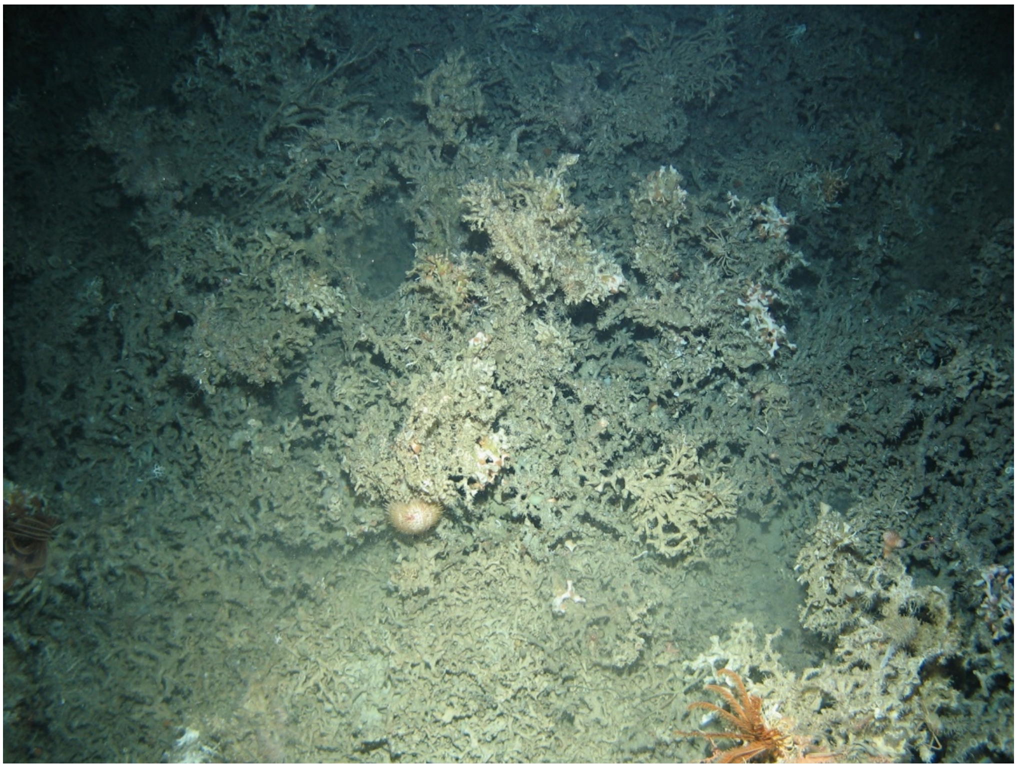

Figure 3.7. Image from Hatton Bank showing the VME habitat cold-water coral reef from SEA/SAC 2006, Station HS_3_2.

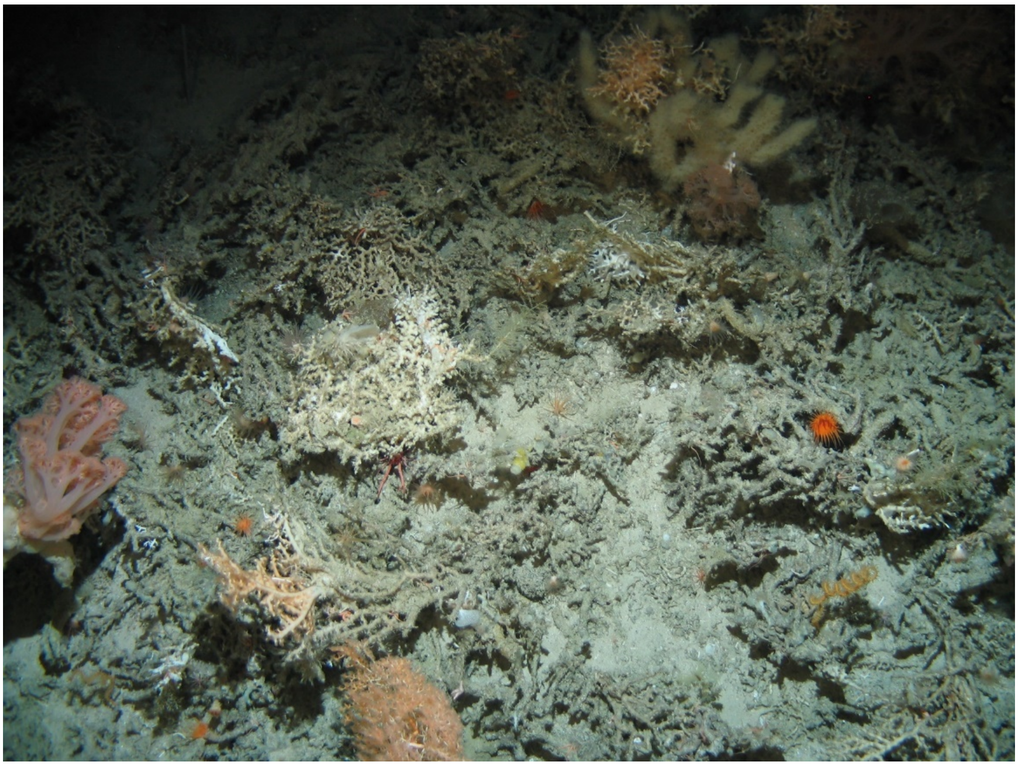

Figure 3.8. Example image of a coral garden identified from Hatton Bank from SEA7_2005, Station HB_K#1.

3.5.3 Reykjanes Ridge

A single new VME indicator record of stony coral was submitted by Greenland for the Reykjanes Ridge. The record was identified from Zibrowius, 1980 as described in Section 3.3.4. For maps of the area see Section 3.6.8.

3.6 Areas with new VME data submissions (or data resubmissions) to the ICES VME Database in 2018 for areas considered within the EEZs of various countries

3.6.1 Rockall Bank and George Bligh Bank (UK)

New VME habitat and indicator data were submitted by the UK through the ICES VME data call for the area of Rockall Bank within the UK and Ireland's EEZs, and for George Bligh Bank, which is located to the west of Scotland within the UK's EEZ (Figure 3.9).

VME indicator records for Rockall Bank came from the Marine Scotland Science 1217s fisheries research trawl survey, as described in section 3.3.1. Notably, at one station, 43 kg of *Lophelia pertusa* (VME indicator = stony coral) was collected.

New VME habitat records of cold-water coral reefs and coral gardens on Rockall Bank were provided by JNCC from the JC060 and 2009/03-JNCC research surveys. New VME habitat records of coral gardens on George Bligh Bank, also provided by JNCC, came from the SEA7 2005 research survey, as described in Section 3.3.2.

These new data have contributed to updated outputs from the VME weighting algorithm. The VME index and confidence layers for Rockall Bank and George Bligh Bank are shown in Figure 3.10 and Figure 3.11 respectively.

Example images of the cold-water coral reef and coral garden VMEs are shown in Figure 3.12 and Figure 3.13 respectively.

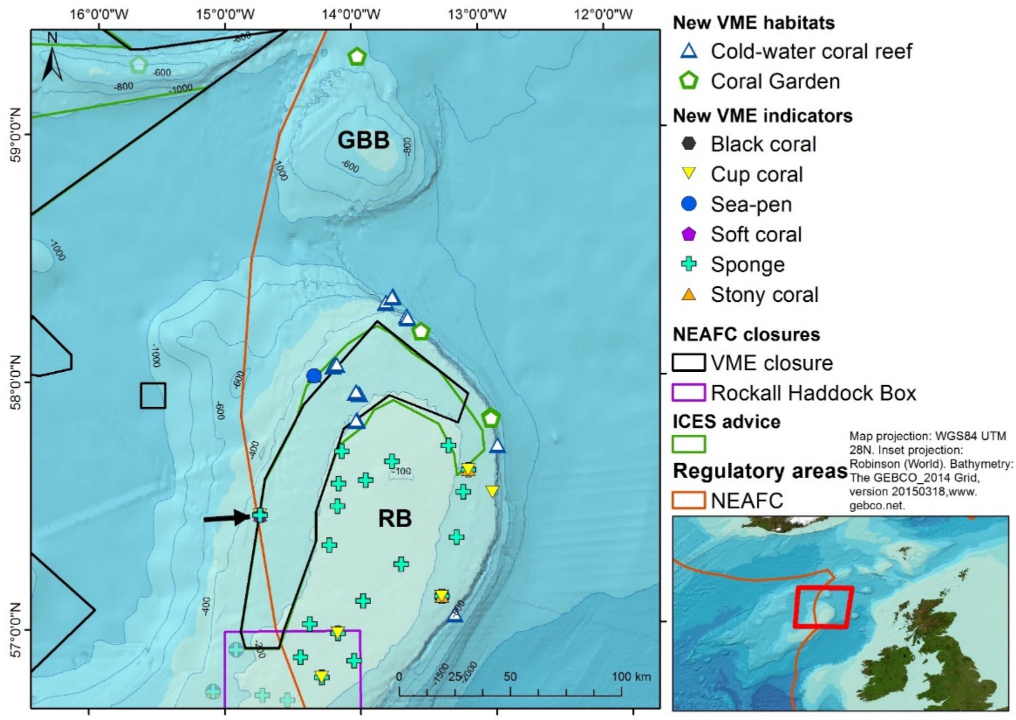

Figure 3.9. New VME indicator and habitat records submitted for WGDEC 2018 on Rockall Bank (RB) and George Bligh Bank (GBB) within EU waters (new records outside EU waters are displayed as transparent). A research trawl survey station which collected 43 kg of stony coral is indicated with an arrow.

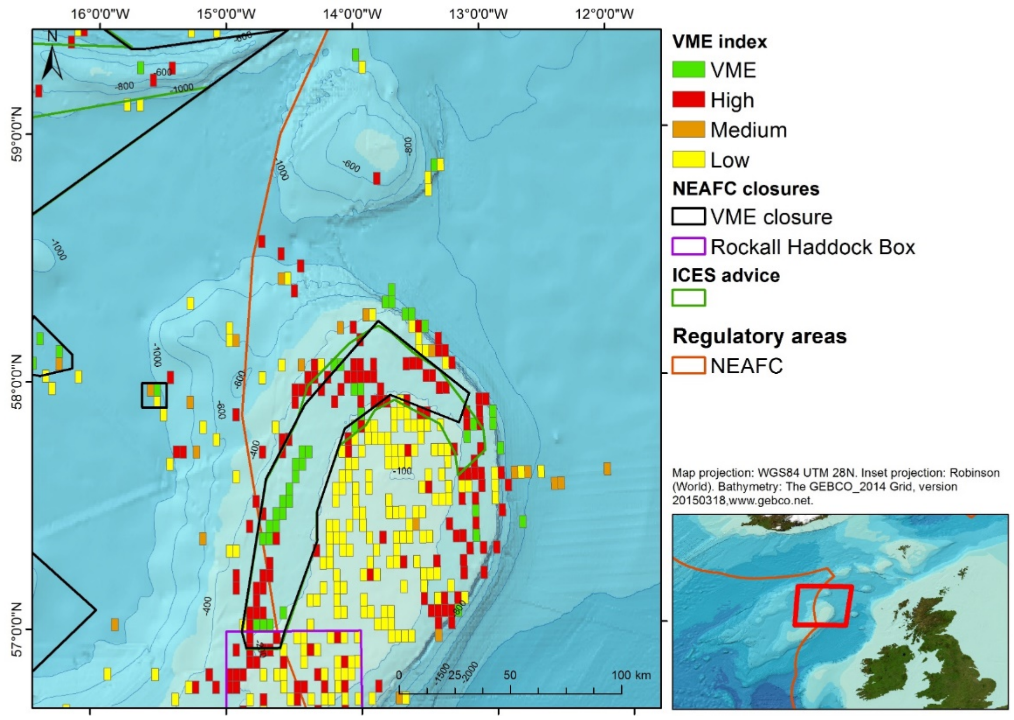

Figure 3.10. Output of the VME weighting algorithm for the area shown in Figure 3.9, showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high); and presence of actual VME. Note this includes all (not only 2018) records from the ICES VME database.

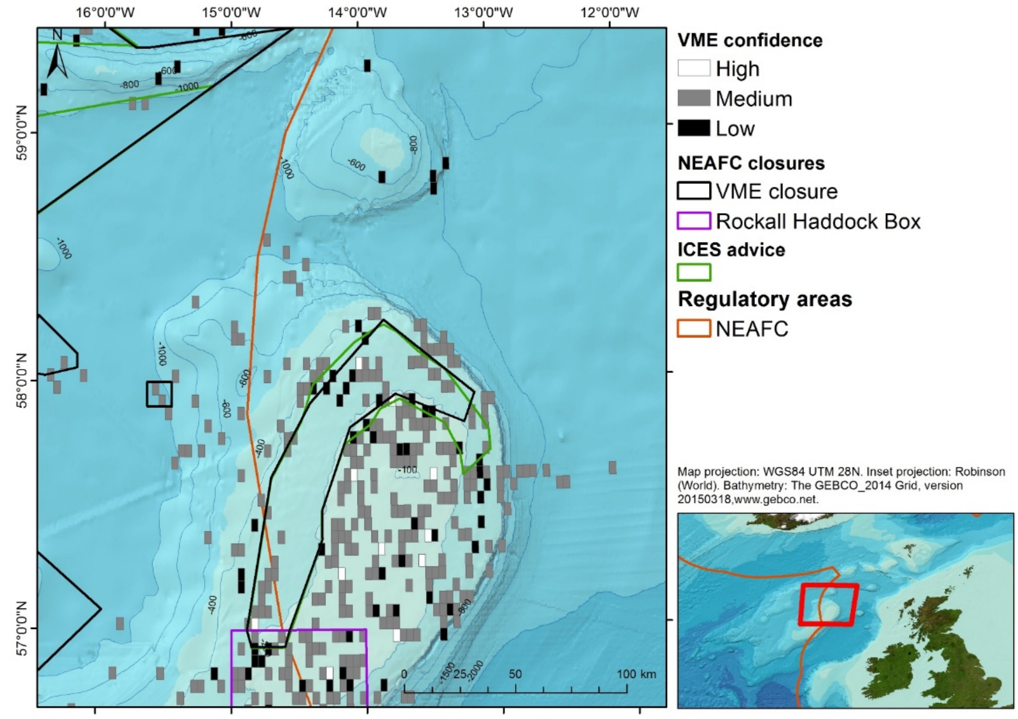

Figure 3.11. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.10). Actual records of VME (e.g. VME habitat) are not assigned a confidence rating. Note this includes all (not only 2018) records from the ICES VME database.

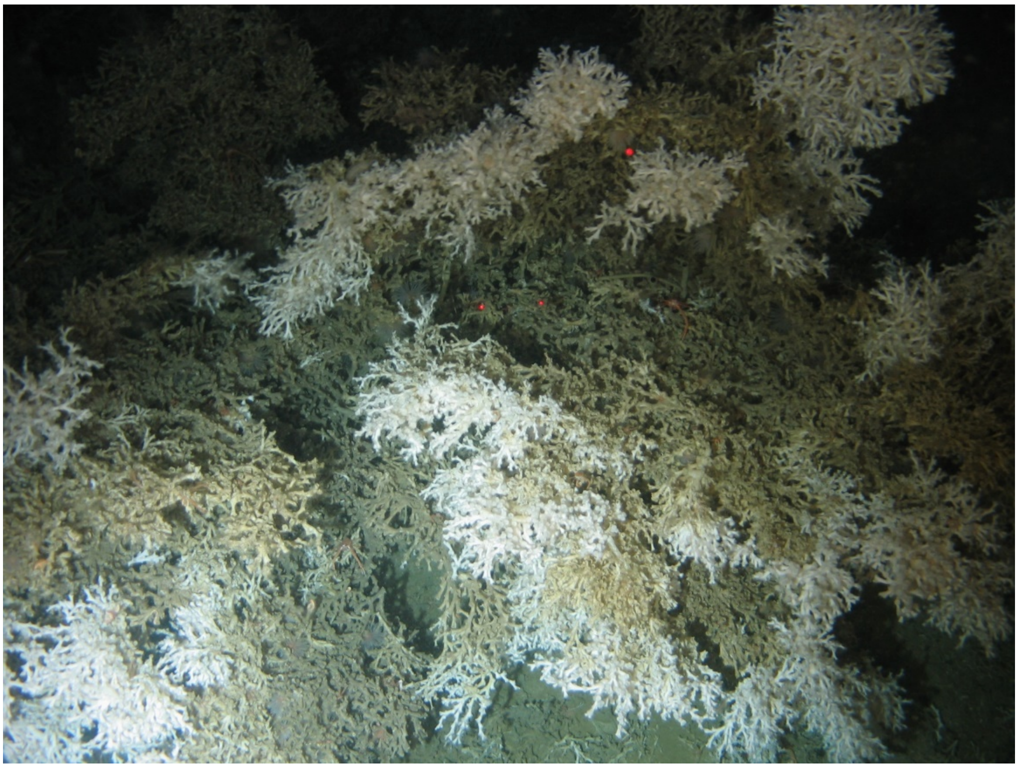

Figure 3.12. Example image of cold-water coral reef identified from Northwest Rockall from JC060, Station JC060_91. Image © NOC, NERC – 2011.

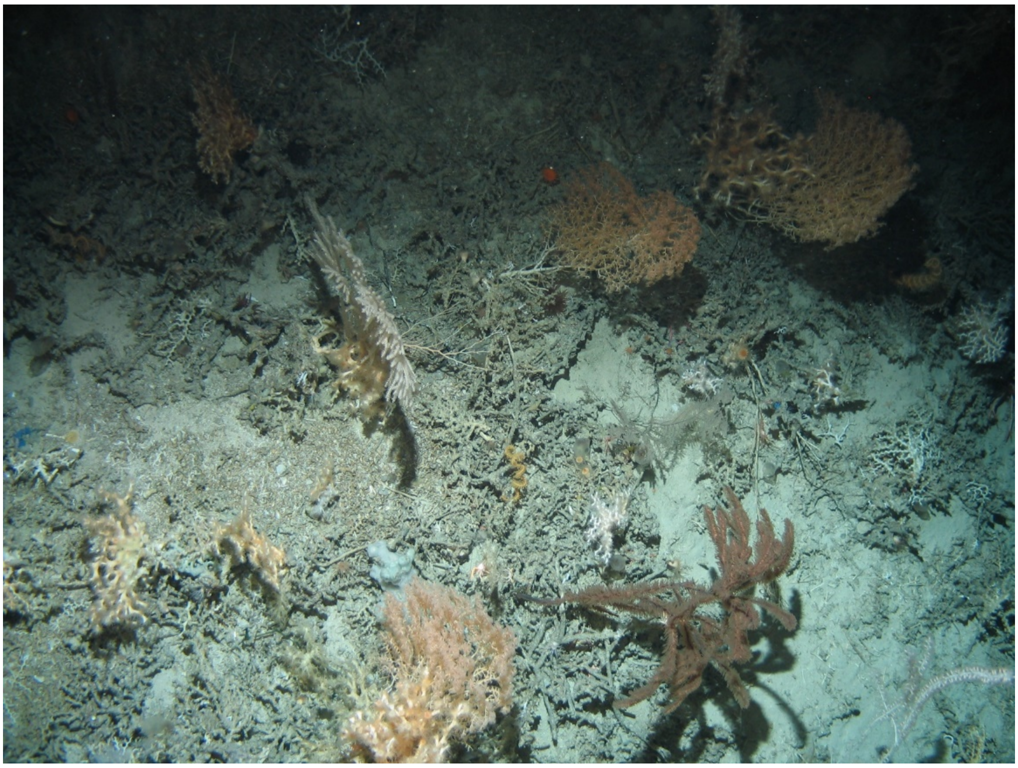

Figure 3.13. Example image of coral garden identified from George Bligh Bank from SEA7_2005, Station GB_A#7.

3.6.2 Anton Dohrn Seamount and Scottish/Irish continental shelf (UK and Ireland)

New VME habitat and indicator data were submitted by the UK for Anton Dohrn Seamount, which is located west of Scotland within the UK's EEZ, and for the Scottish/Irish continental shelf, within the UK and Ireland's EEZs (Figure 3.14).

VME indicator data came from the Marine Scotland Science 1317s fisheries research trawl survey, as described in Section 3.3.1. VME habitat records on Anton Dohrn Seamount were submitted by JNCC from the 2009/03-JNCC survey, as described in Section 3.3.2.

These new data have contributed to updated outputs from the VME weighting algorithm. The VME index and confidence layers for Anton Dohrn Seamount and the Scottish/Irish continental shelf are shown in Figure 3.15 and Figure 3.16 respectively.

Example images of the cold-water coral reef and coral garden VMEs from Anton Dohrn Seamount are shown in Figure 3.17 and Figure 3.18 respectively.

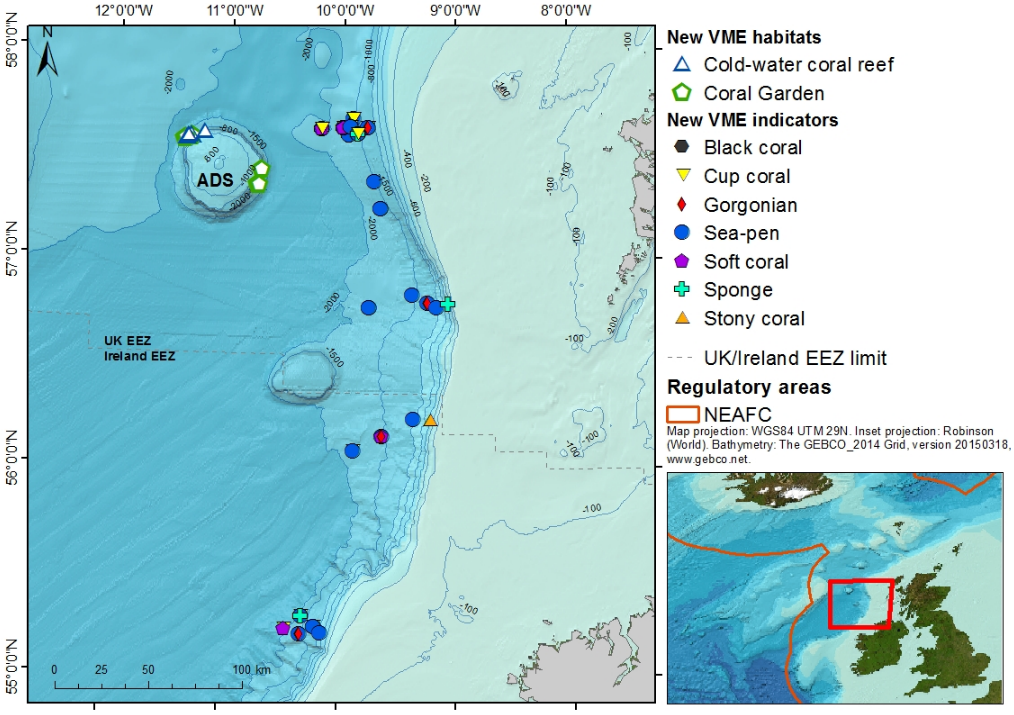

Figure 3.14. New VME indicator and habitat records submitted for WGDEC 2018 on Anton Dohrn Seamount (ADS) and along the Scottish/Irish continental shelf within EU waters.

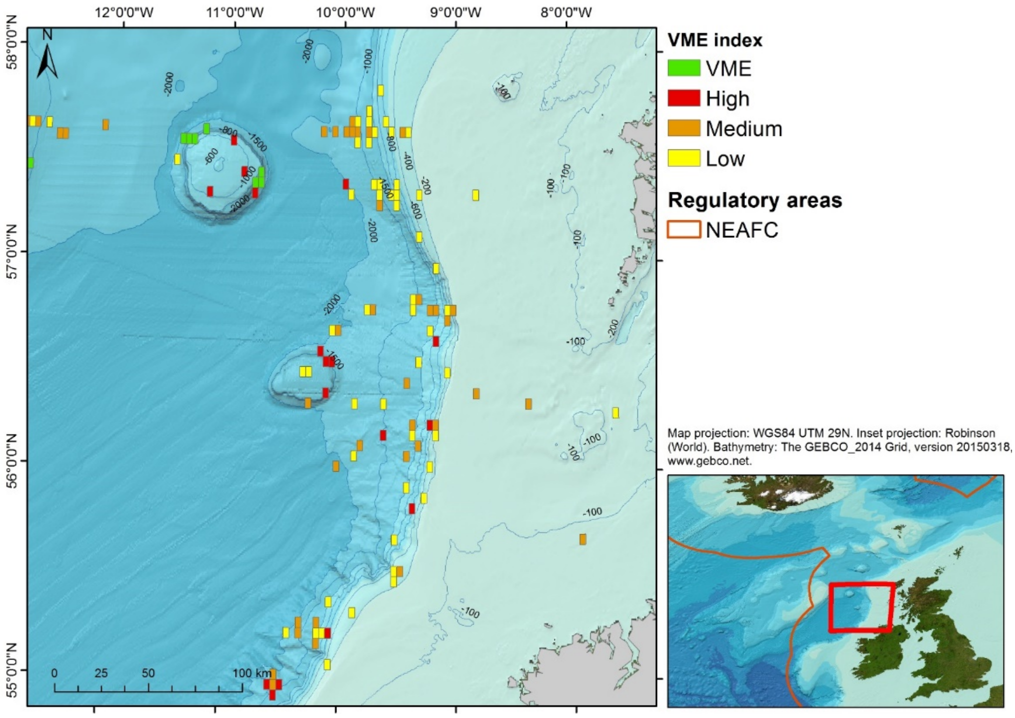

Figure 3.15. Output of the VME weighting algorithm for the area shown in Figure 3.14, showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high); and presence of actual VME. Note this includes all (not only 2018) records from the ICES VME database.

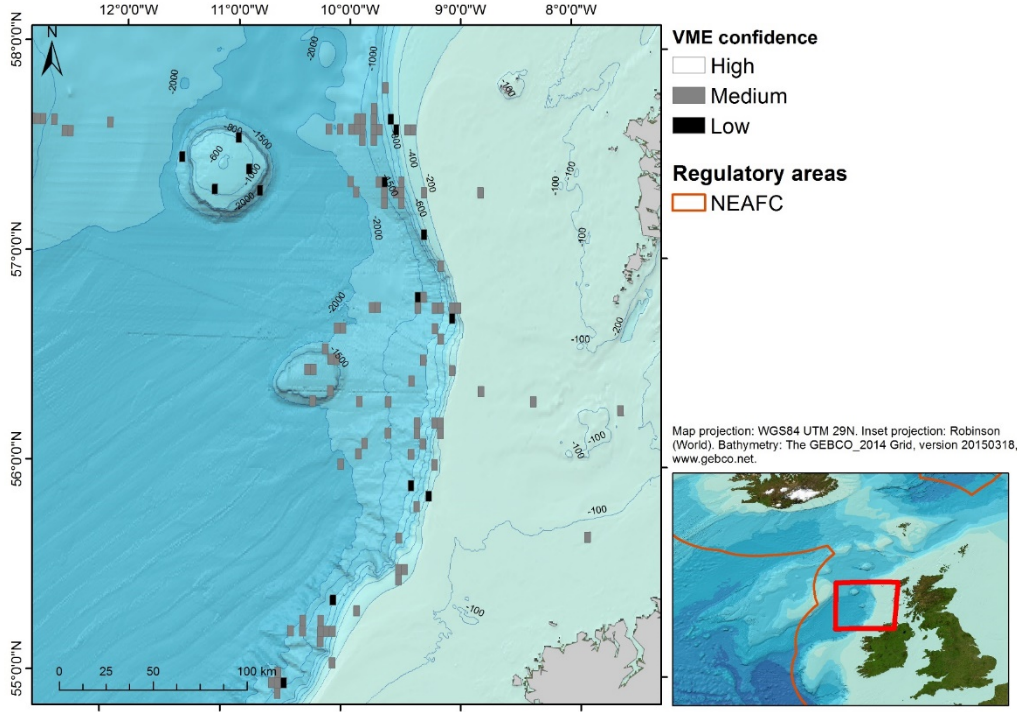

Figure 3.16. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.15). Actual records of VME (e.g. VME habitat) are not assigned a confidence rating. Note this includes all (not only 2018) records from the ICES VME database.

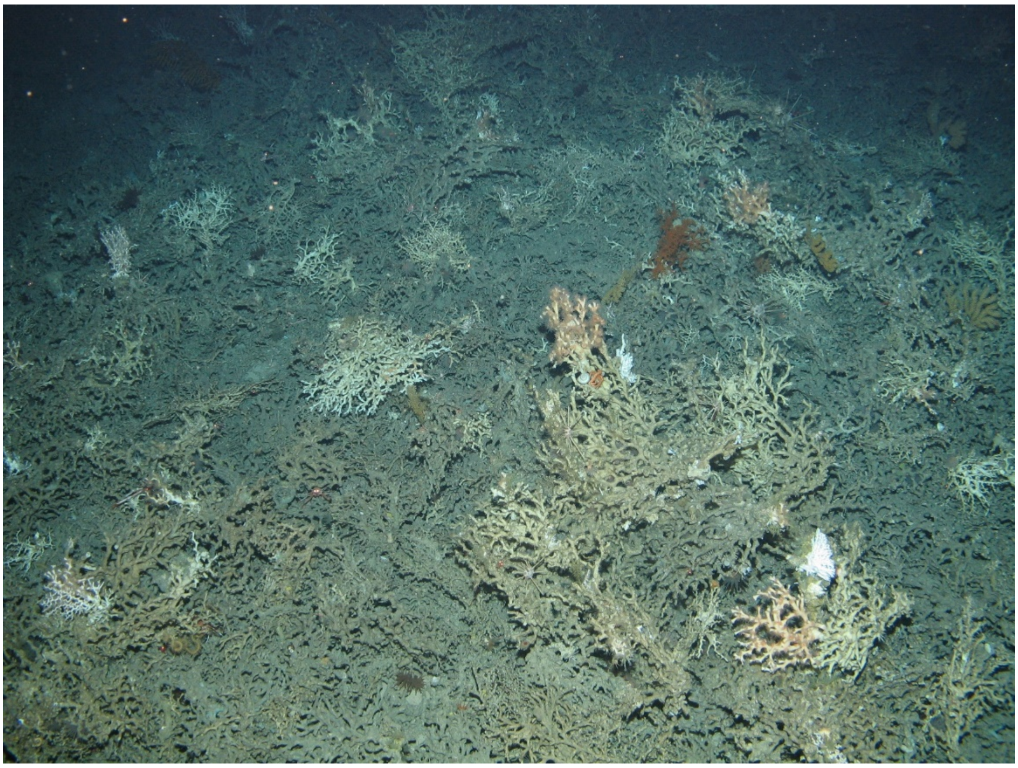

Figure 3.17. Example image of cold-water coral reef identified from Anton Dohrn Seamount from 2009/03-JNCC, Station AD_DC_09.

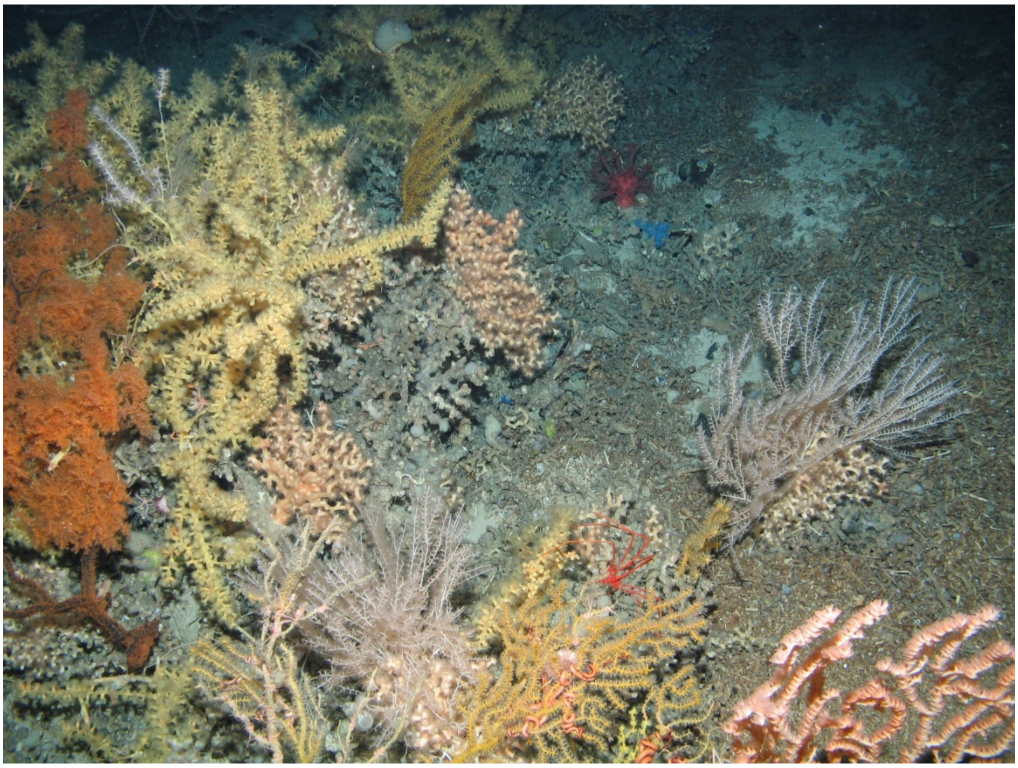

Figure 3.18. Example image of a coral garden identified from Anton Dohrn Seamount from the 2009/03-JNCC survey, Station AD_DC_13.

3.6.3 Rosemary Bank and Darwin Mounds (UK)

New VME indicator and habitat data were submitted by the UK for Rosemary Bank Seamount, which is located off western Scotland within the UK's EEZ, and for Darwin Mounds, an extensive area of sandy mounds capped with multiple thickets of *Lophelia pertusa,* located to the northwest of Scotland in the UK's EEZ (Figure 3.19).

New VME indicator records at Rosemary Bank Seamount came from the 1317s fisheries research trawl survey conducted by Marine Scotland Science, as described in Section 3.3.1. New VME habitat records at Darwin Mounds were provided by JNCC from the JC060 survey, as described in Section 3.3.2.

These new data have contributed to updated outputs from the VME weighting algorithm. The VME index and confidence layers for both Rosemary Bank and Darwin Mounds are shown in Figure 3.20 and Figure 3.21 respectively.

An example image of the cold-water coral reef from the Darwin Mounds is shown in Figure 3.22.

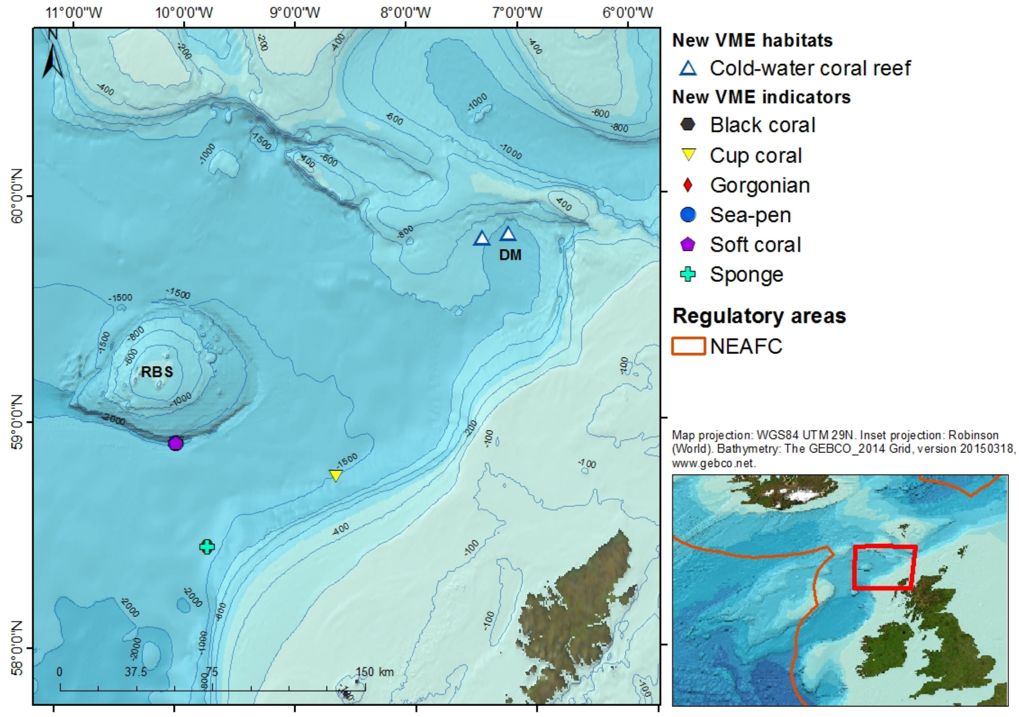

Figure 3.19. New VME indicator and habitat records submitted for WGDEC 2018 on Rosemary Bank Seamount (RBS) and Darwin Mounds (DM) within EU waters.

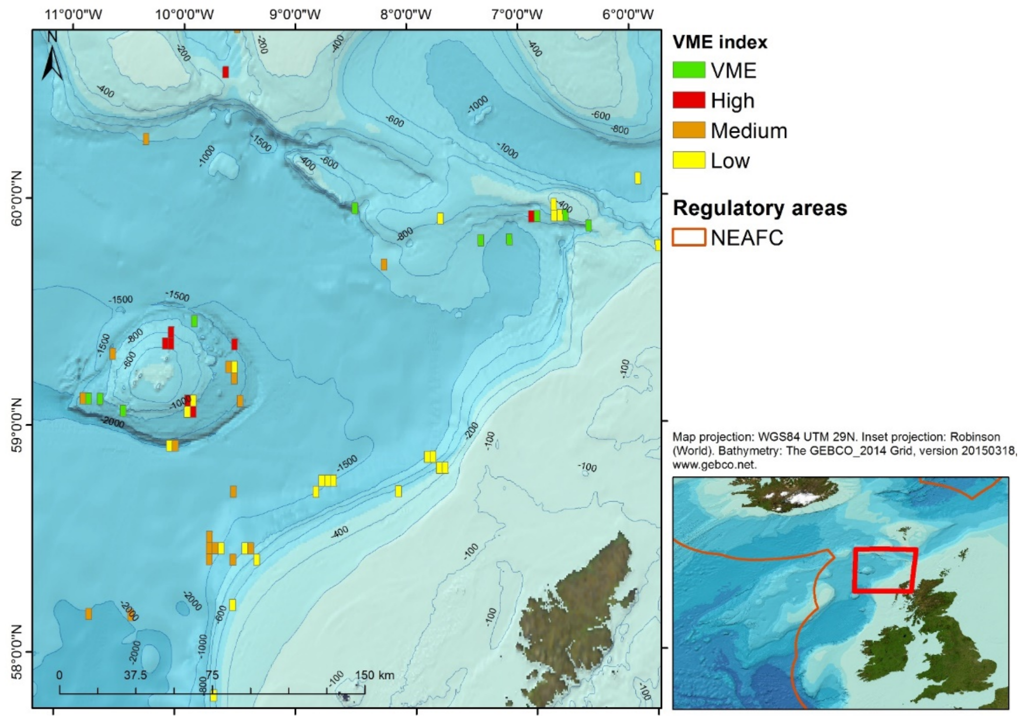

Figure 3.20. Output of the VME weighting algorithm for the area shown in Figure 3.19 showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high); and presence of actual VME. Note this includes all (not only 2018) records from the ICES VME database.

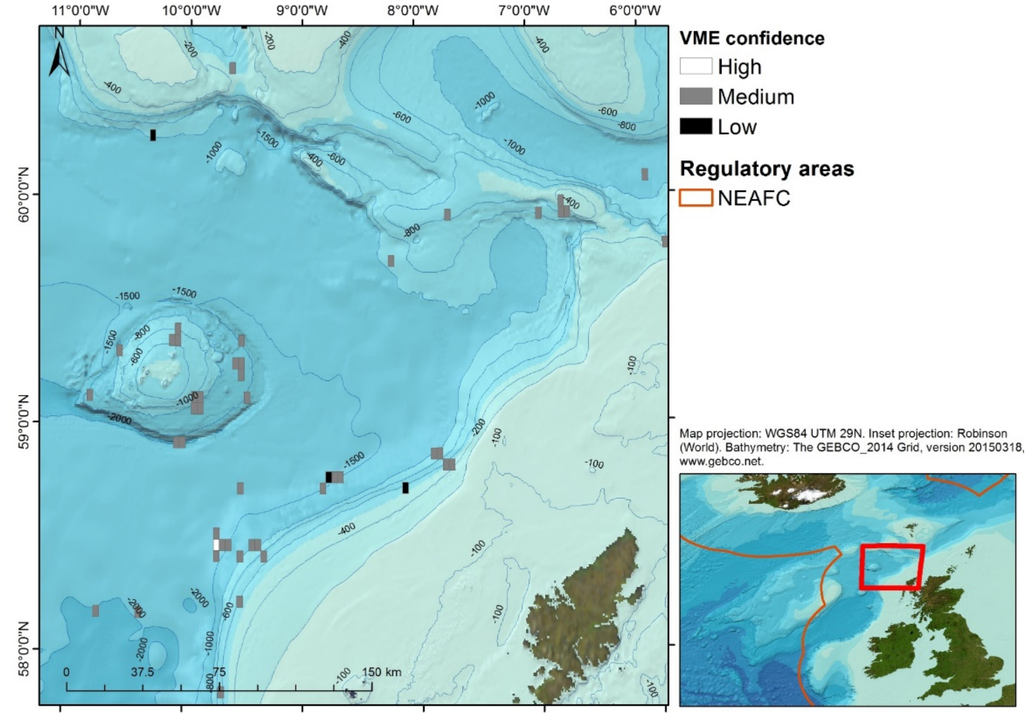

Figure 3.21. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.20). Actual records of VME (e.g. VME habitat) are not assigned a confidence rating. Note this includes all (not only 2018) records from the ICES VME database.

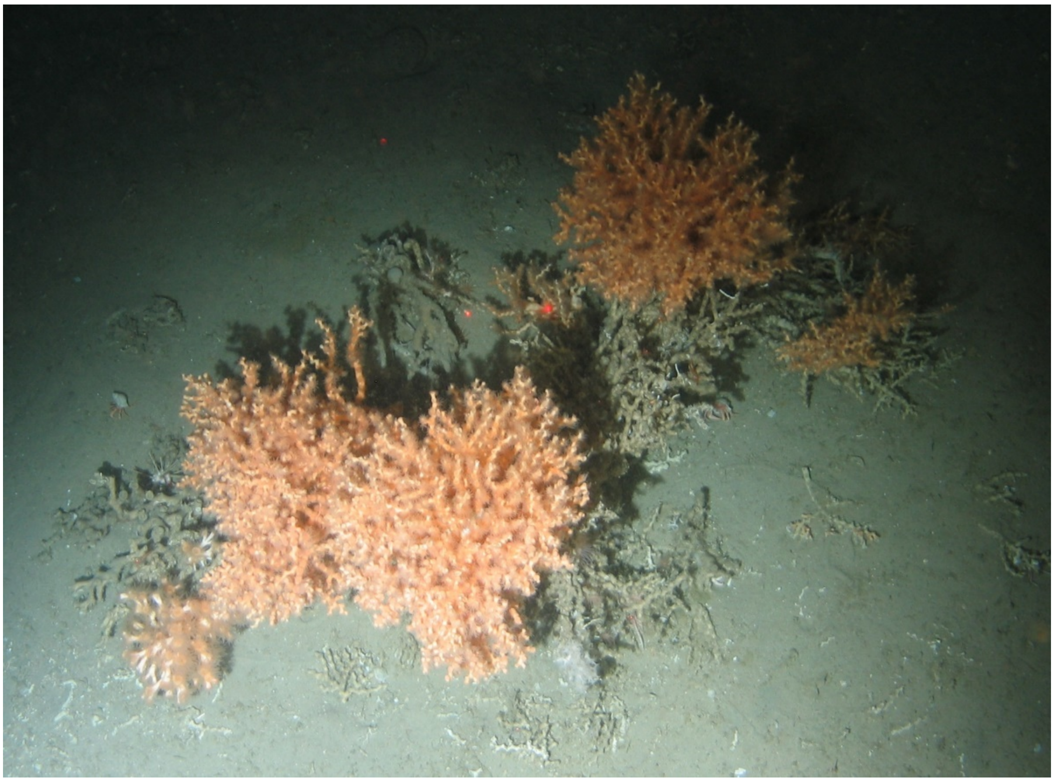

Figure 3.22. A small thicket of *Madrepora oculata* within a patchy cold-water coral reef on the Darwin Mounds, taken from the JC060 survey, Station JC060_033. Image © NOC, NERC – 2011.

3.6.4 Faroe-Shetland Channel (UK)

The Faroe-Shetland Channel is a deep channel located north of Scotland within the EEZ of the UK and the Faroe Islands (Denmark).

New VME habitat data were submitted by the UK (Figure 3.23) from the SEA SAC 2006 survey, as described in Section 3.3.2.

The weighting algorithm has been re-run to include the new VME data, and the output is shown in Figure 3.24. The confidence layer for the VME index for Faroe-Shetland Channel is shown in Figure 3.25. An example image of deep-sea sponge aggregations found at the Faroe-Shetland Channel is shown in Figure 3.26.

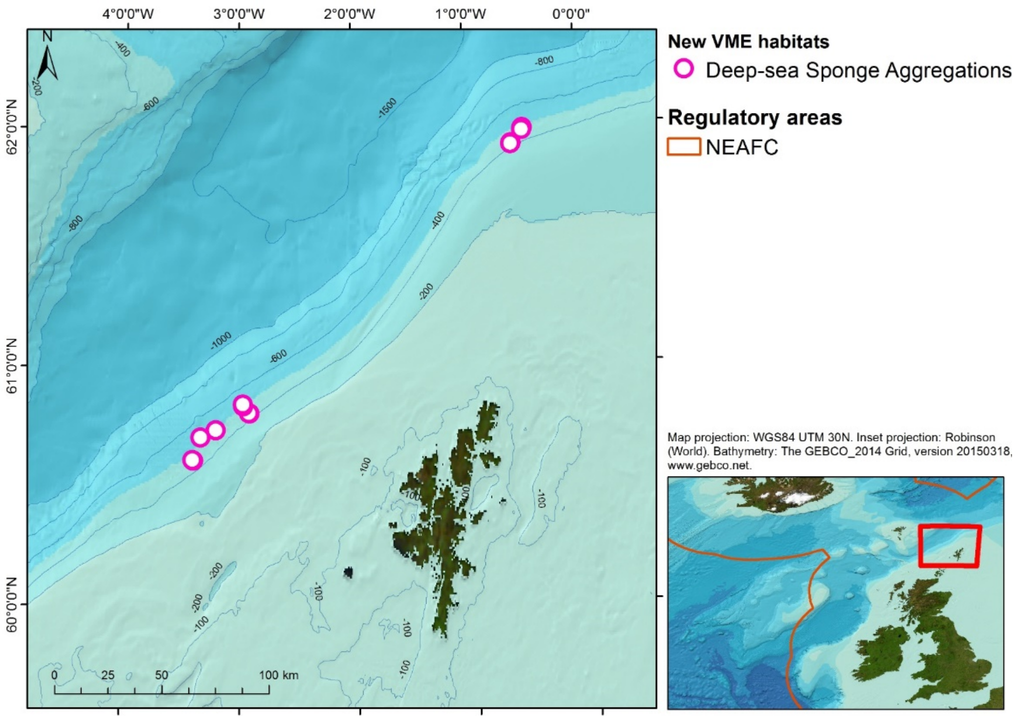

Figure 3.23. New VME habitat records submitted for WGDEC 2018 on the Faroe Shetland Channel within EU waters.

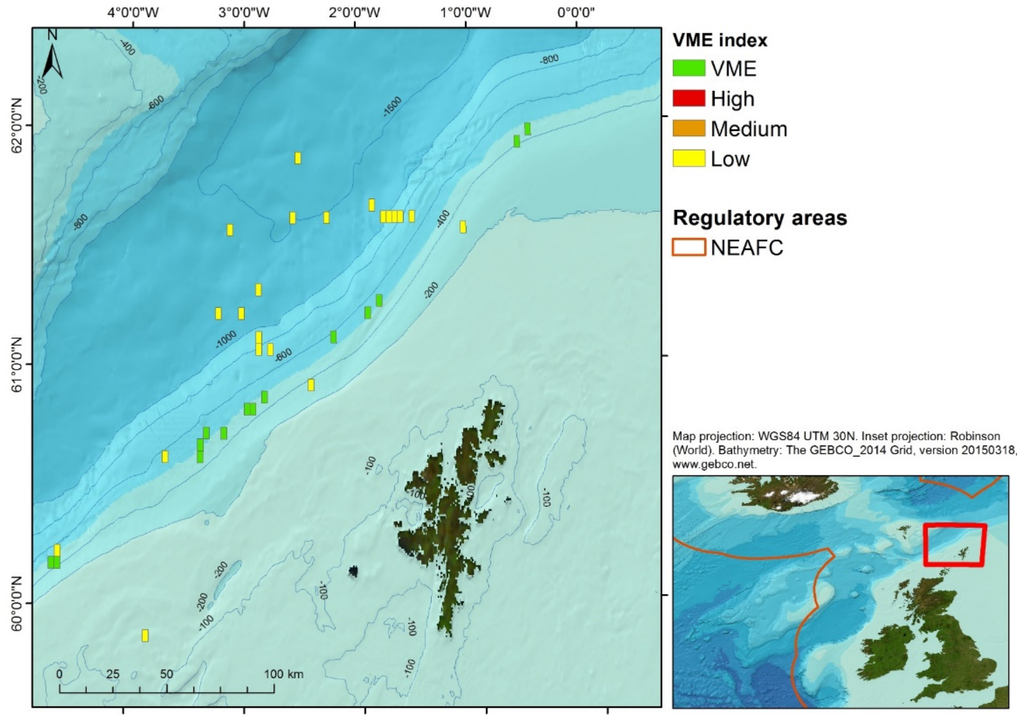

Figure 3.24. Output of the VME weighting algorithm for the area shown in Figure 3.23, showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high); and presence of actual VME. Note this includes all (not only 2018) records from the ICES VME database.

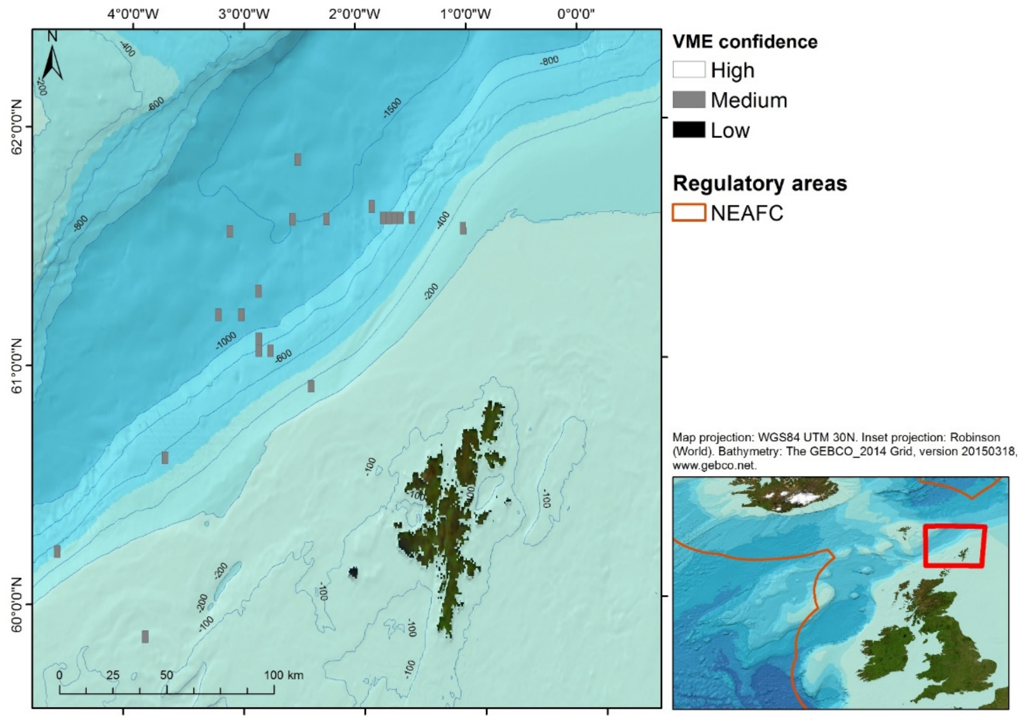

Figure 3.25. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.24). Actual records of VME (e.g. VME habitat) are not assigned a confidence rating. Note this includes all (not only 2018) records from the ICES VME database.

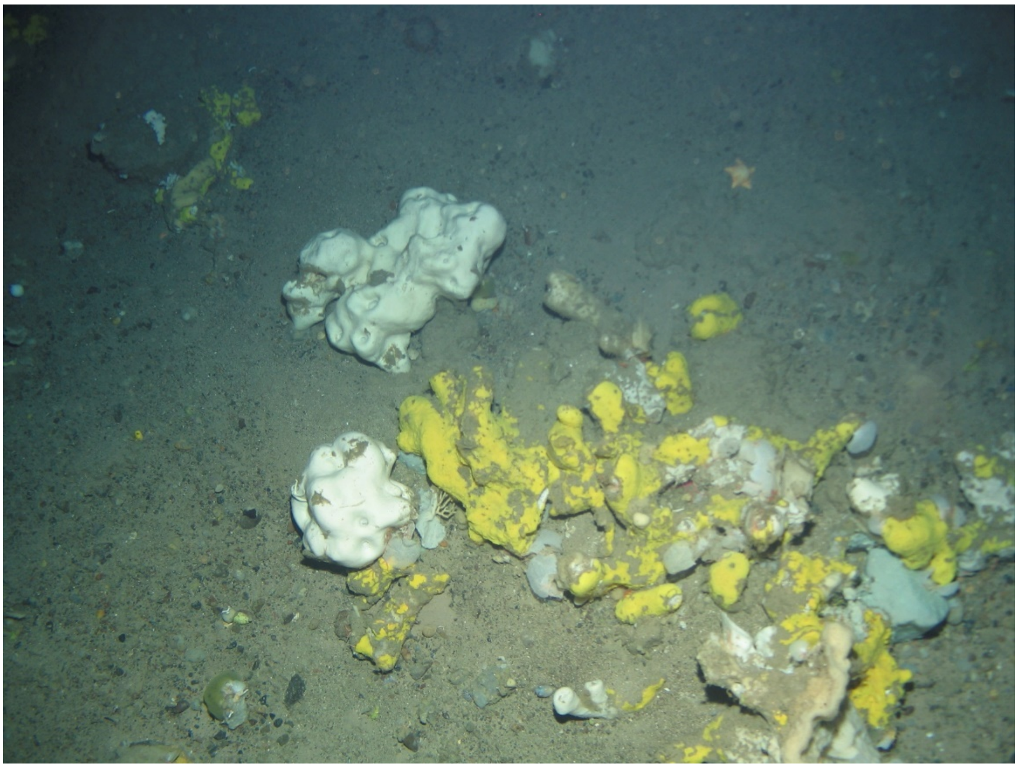

Figure 3.26. Example image of deep-sea sponge aggregation identified at the Faroe-Shetland Channel from the SEA/SAC 2006 survey, Station WSC_16.

3.6.5 Explorer Canyon (UK)

The Explorer Canyon is located in the far southwest corner of the UK continental shelf. There are two Canyons in the area; the Explorer Canyon to the north and the Dangaard Canyon below it.

A new VME habitat data record for the Explorer Canyon within the UK's EEZ was submitted by the UK (Figure 3.27). The single cold-water coral reef record is from the 2007 CE0705 survey on the RV Celtic Explorer, as described in Section 3.3.2.

The weighting algorithm has been re-run to include the new VME data, and the output is shown in Figure 3.28. The confidence layer for the VME index for the Explorer Canyon is shown in Figure 3.29. An example image of the cold-water coral reef is shown in Figure 3.30.

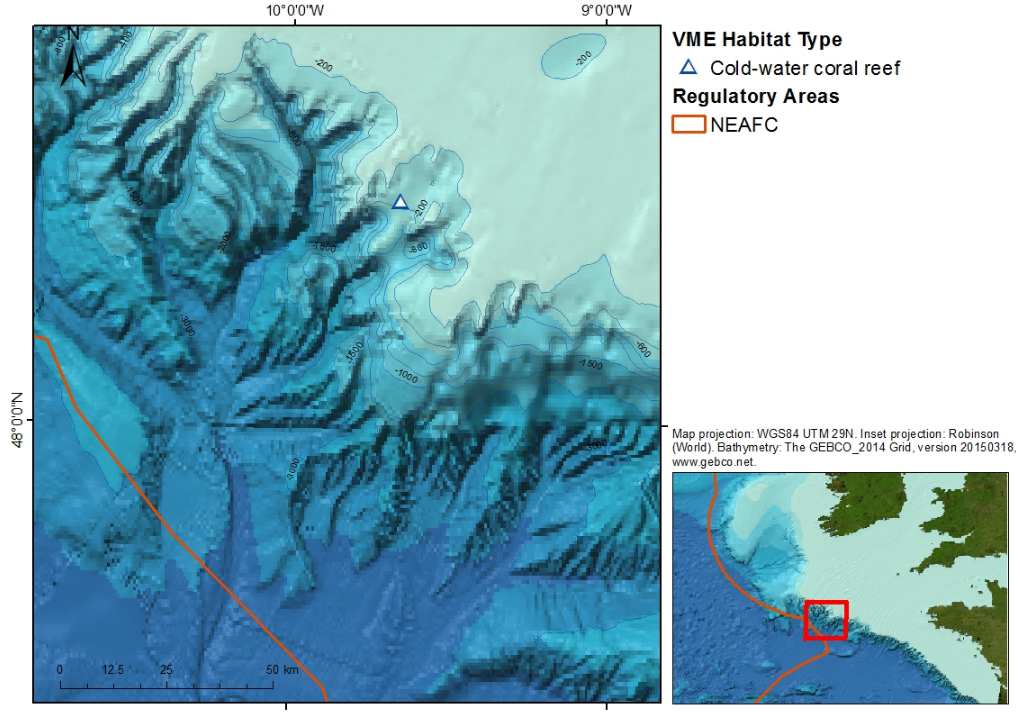

Figure 3.27. New VME habitat records submitted from the Explorer Canyon within EU waters.

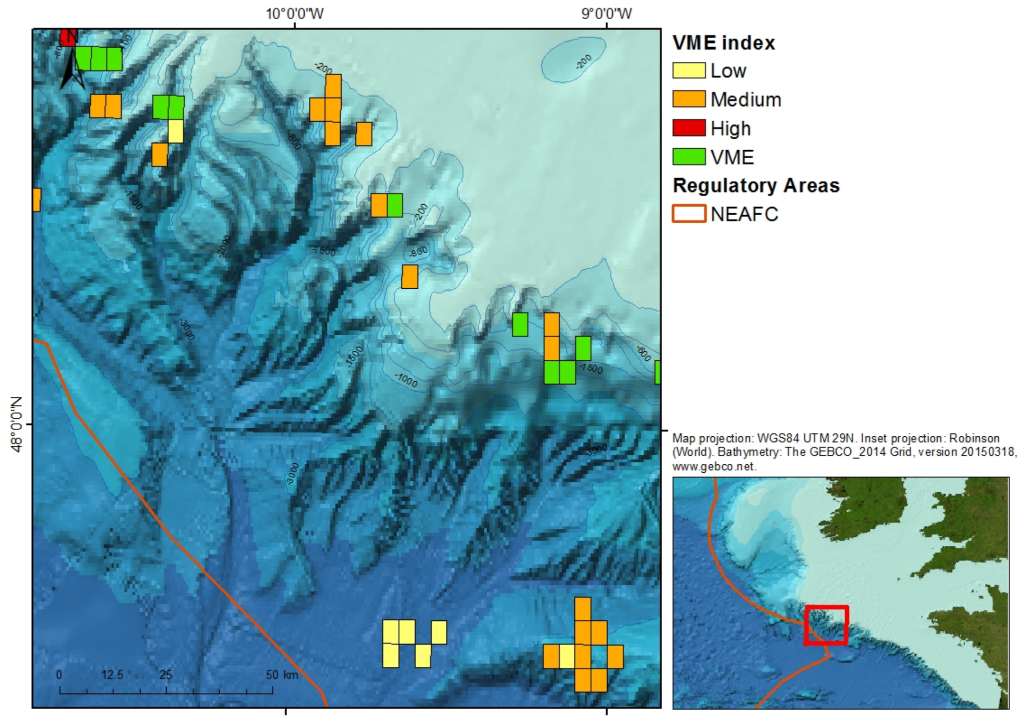

Figure 3.28. Output of the VME weighting algorithm for the area shown in Figure 3.27, showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high); and presence of actual VME. Note this includes all (not only 2018) records from the ICES VME database

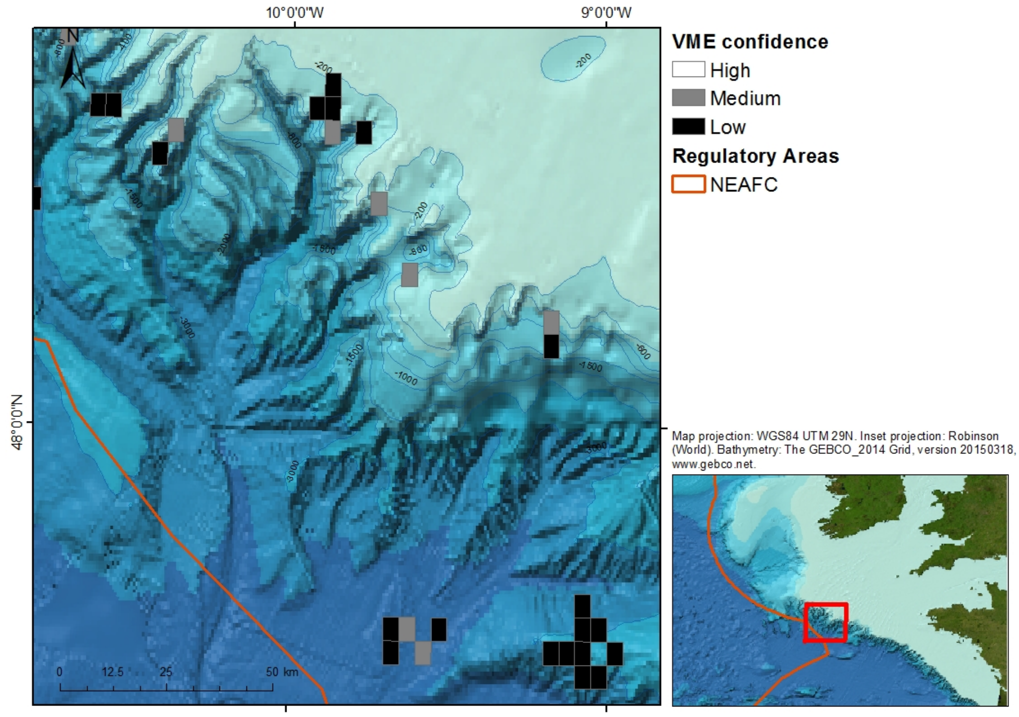

Figure 3.29. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.28). Actual records of VME (e.g. VME habitat) are not assigned a confidence rating. Note this includes all (not only 2018) records from the ICES VME database.

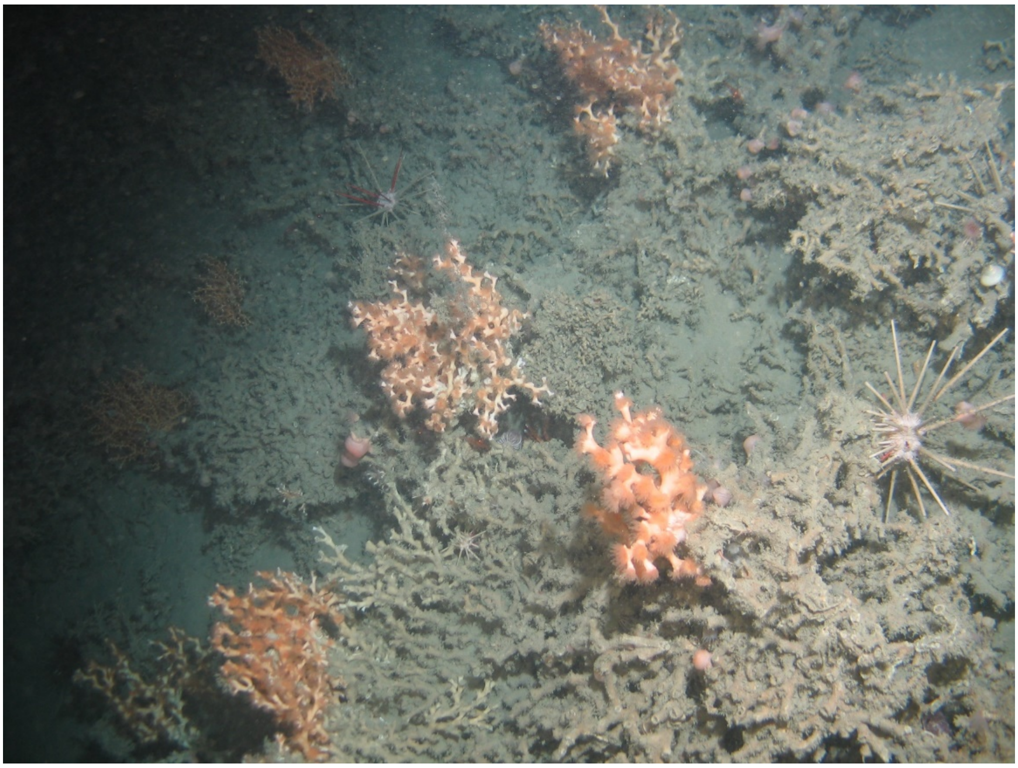

Figure 3.30. Example image of cold-water coral reef identified from the Explorer Canyon from survey CE0705, Station C_2_14. Image © MESH 2007.

3.6.6 Ormonde Seamount (Portugal)

Ormonde Seamount is located on the Portuguese continental shelf ~120–150 miles from the coast and is part of the Gorringe Ridge. The bases of the seamounts are more than 5000 m deep and the summits are less than 50 m below the sea surface.

New VME habitat data from the Ormonde Seamount were submitted by Spain (Figure 3.31). Records are from the MEDWAVES survey, as described in Section 3.3.5.

The weighting algorithm has been re-run to include the new VME data, and the output is shown in Figure 3.32. The confidence layer for the VME index for Ormonde Seamount is shown in Figure 3.33Figure 3.3. An example image of the deep-sea sponge aggregations is show in Figure 3.34.

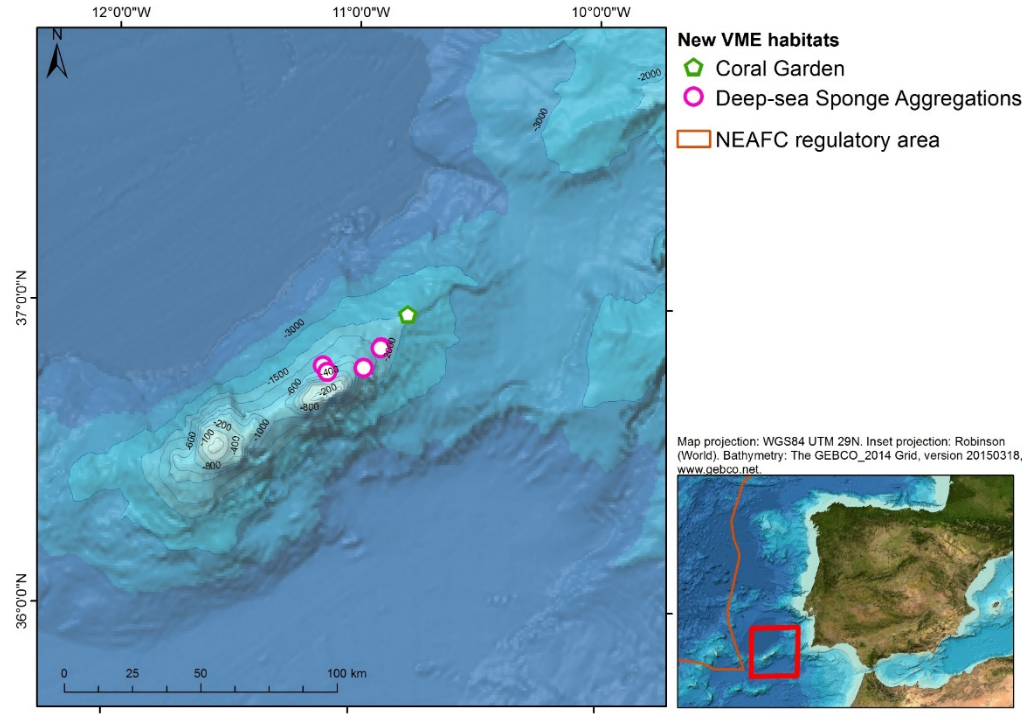

Figure 3.31. New VME habitat records submitted for WGDEC 2018 from the Ormonde Seamount within EU waters.

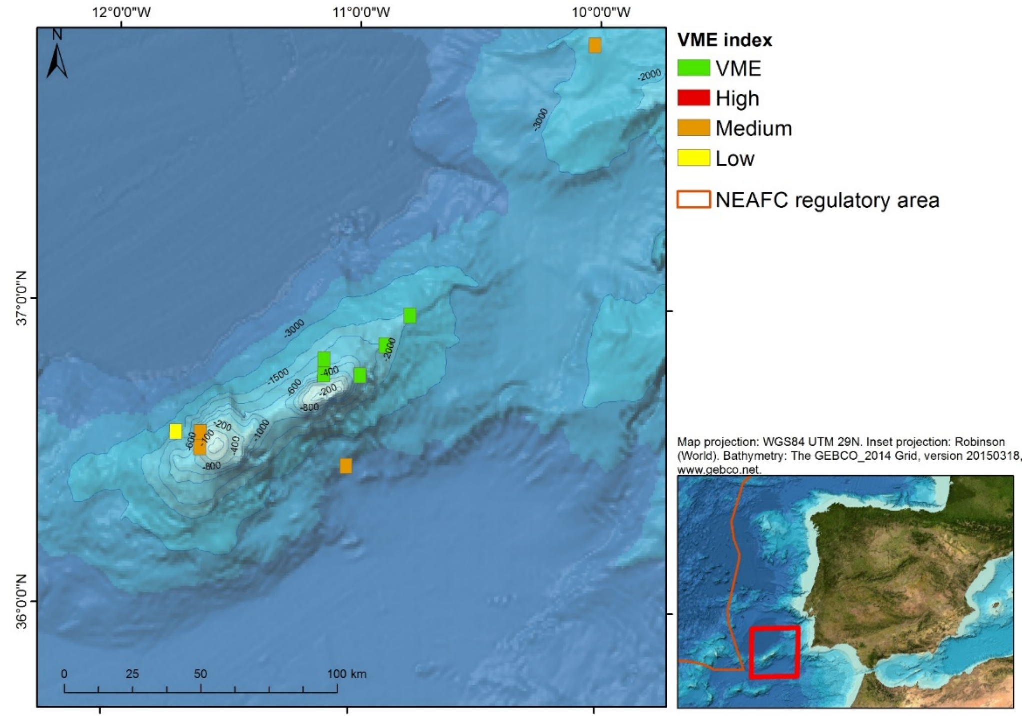

Figure 3.32. Output of the VME weighting algorithm for the area shown in Figure 3.31, showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high); and presence of actual VME. Note this includes all (not only 2018) records from the ICES VME database.

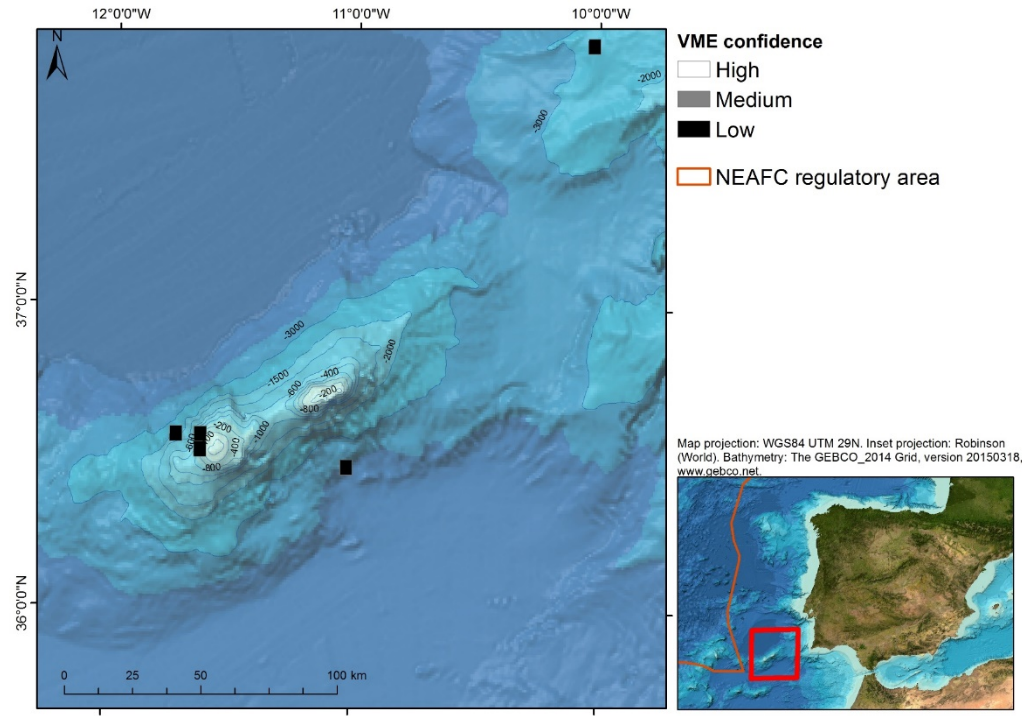

Figure 3.33. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.32). Actual records of VME (e.g. VME habitat) are not assigned a confidence rating. Note this includes all (not only 2018) records from the ICES VME database.

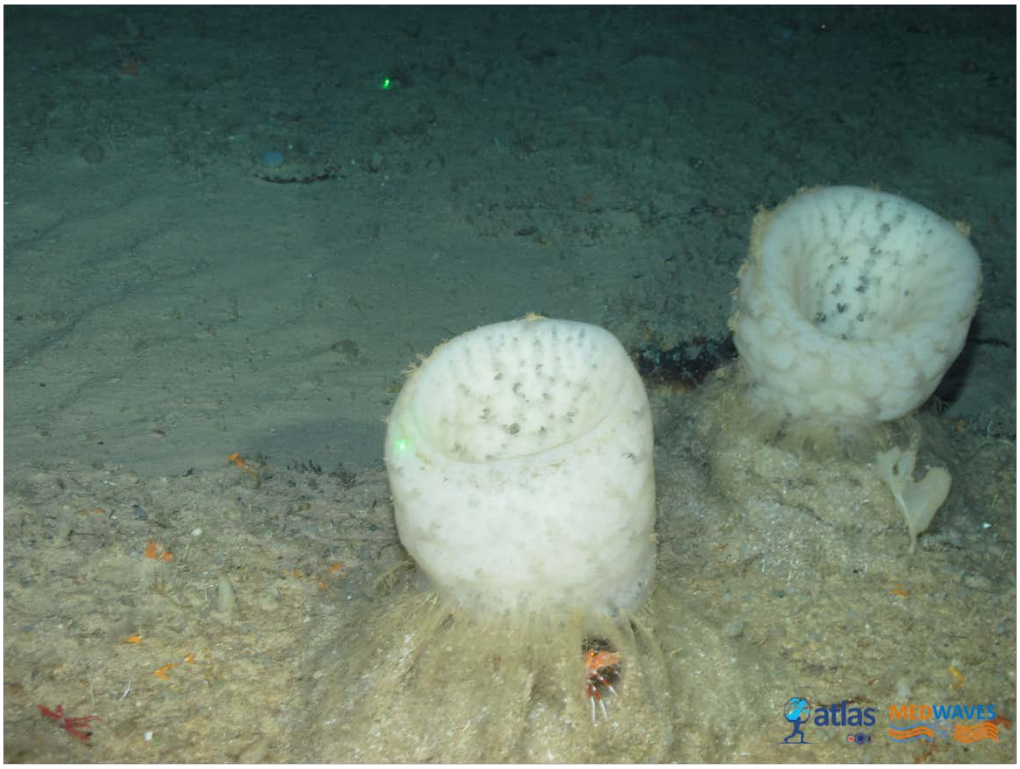

Figure 3.34. Image of the deep-sea sponge aggregations at Ormonde Seamount. Image credits: ATLAS-MEDWAVES/IEO.

3.6.7 Greenland continental shelf (Greenland)

New VME indicator data were submitted by Greenland based on a literature review, for areas within Greenland's EEZ. For the purpose of reporting on the submitted records, Greenland's EEZ was split into three areas, West, South and East.

3.6.7.1 Greenland (West)

New VME indicator data were submitted for the west of Greenland (Figure 3.35). Records are from Tendal, 1992, as described in Section 3.3.4. These newly submitted data have contributed to updated outputs from the VME weighting algorithm. The VME index and confidence layers for the west of Greenland are shown in Figure 3.36 and Figure 3.37 respectively.

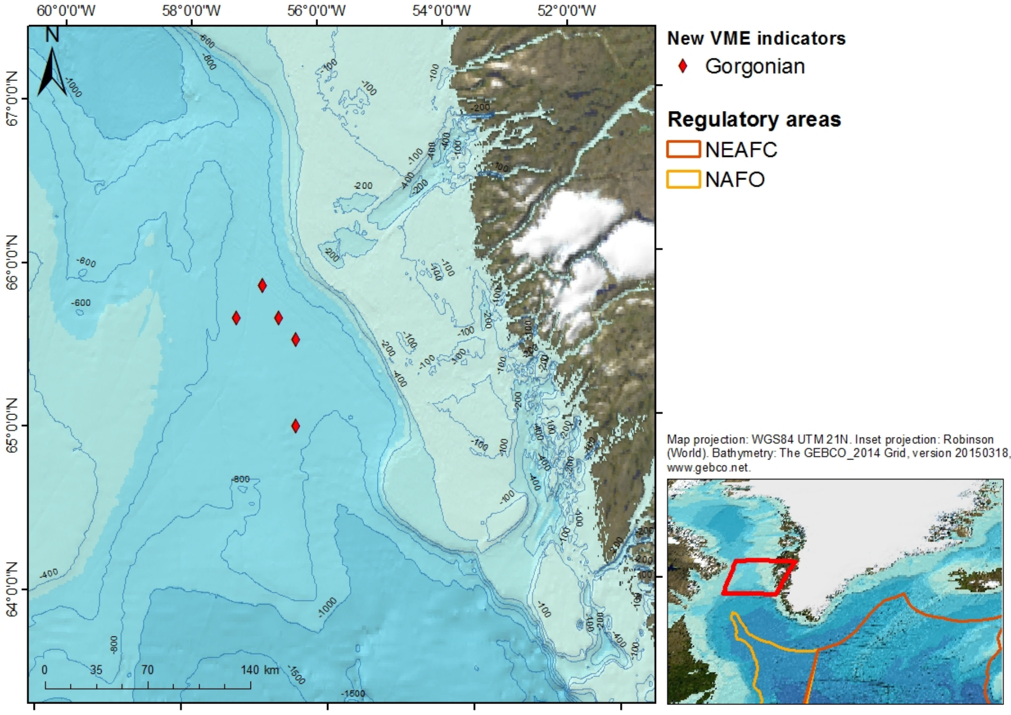

Figure 3.35. New VME indicators submitted for WGDEC 2018 off the west coast of Greenland within Greenland's EEZ.

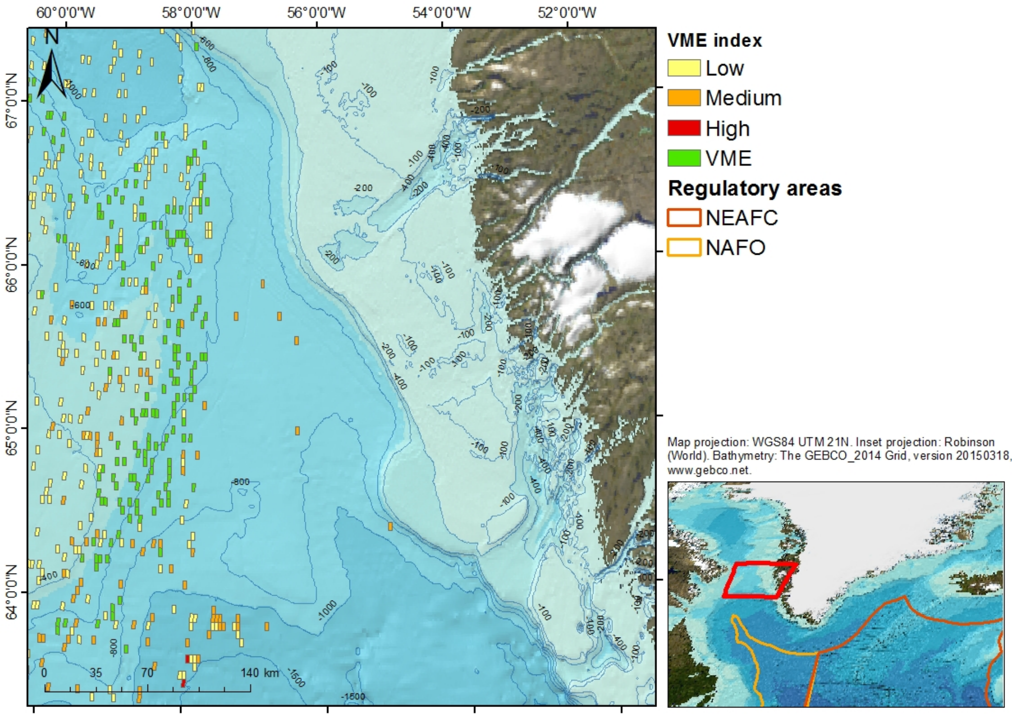

Figure 3.36. Output of the VME weighting algorithm for the area shown in Figure 3.35, showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high); and presence of actual VME. Note this includes all (not only 2018) records from the ICES VME database.

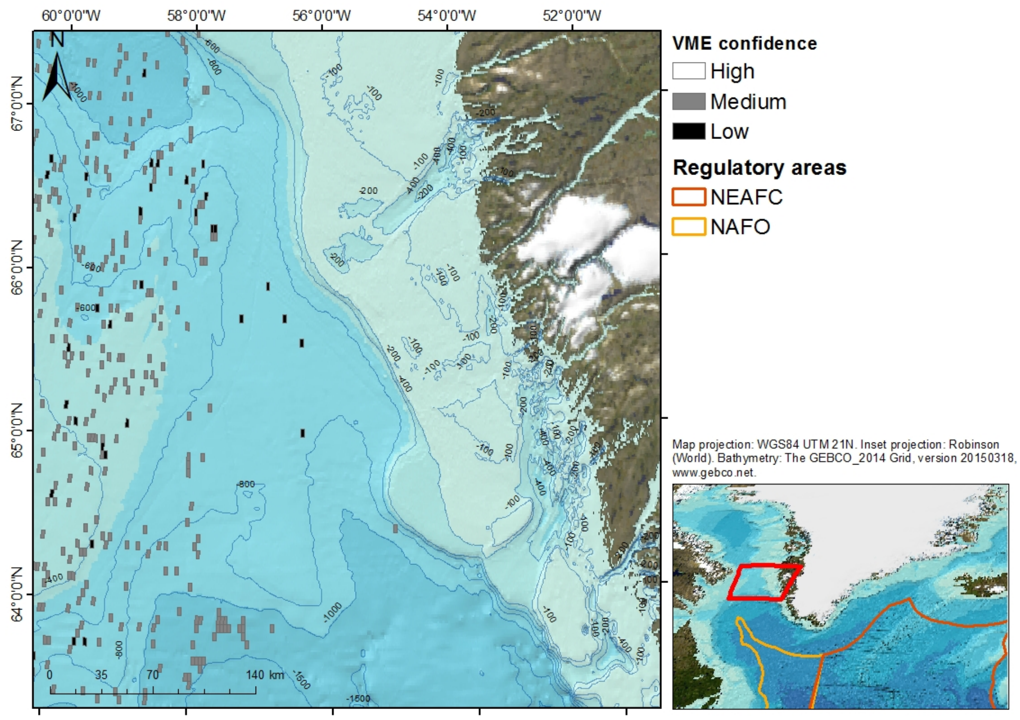

Figure 3.37. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.36). Actual records of VME (e.g. VME habitat) are not assigned a confidence rating. Note this includes all (not only 2018) records from the ICES VME database.

3.6.7.2 Greenland (South)

New VME indicator data were submitted for the south of Greenland (Figure 3.38). Records are from Tendal, 1992 and Zibrowius, 1980, as described in Section 3.3.4. These newly submitted data have contributed to updated outputs from the VME weighting algorithm. The VME index and confidence layers for the south of Greenland are shown in Figure 3.39 and Figure 3.40 respectively.

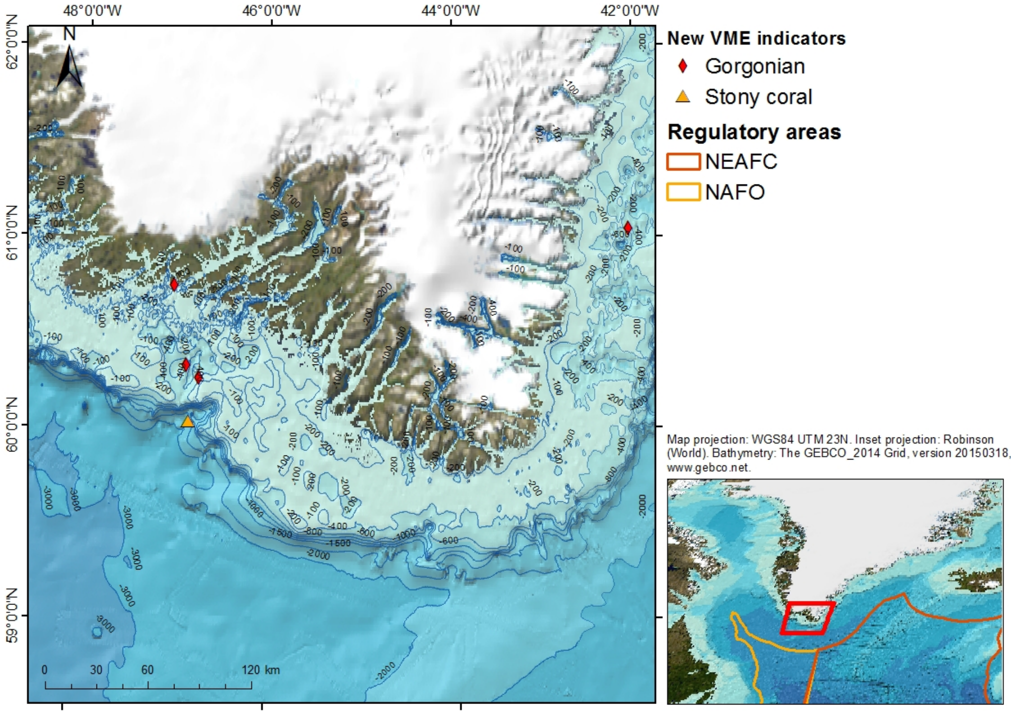

Figure 3.38. New VME indicator submitted for WGDEC 2018 off the south coast of Greenland within Greenland's EEZ.

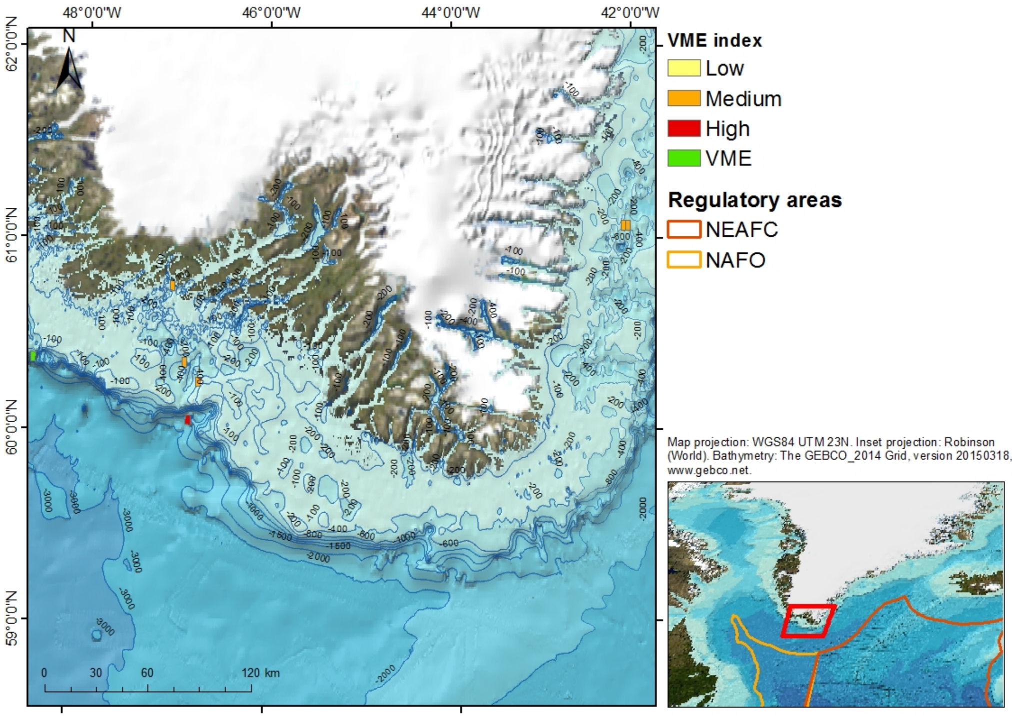

Figure 3.39. Output of the VME weighting algorithm for the area shown in Figure 3.38, showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high); and presence of actual VME. Note this includes all (not only 2018) records from the ICES VME database.

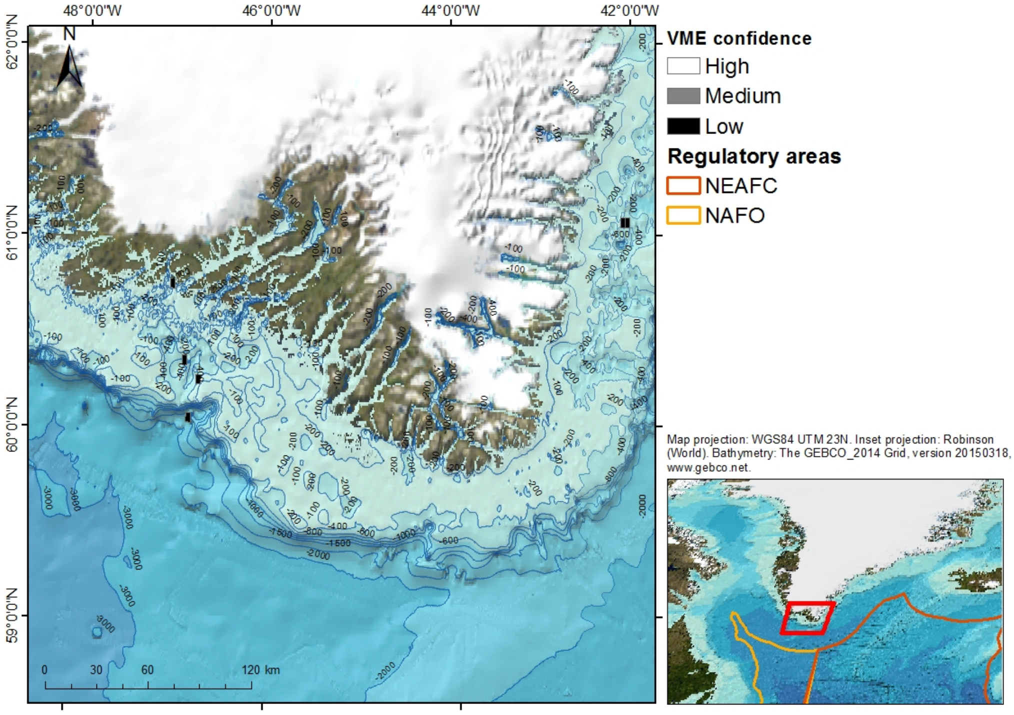

Figure 3.40. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.39). Note this includes all (not only 2018) records from the ICES VME database.

3.6.7.3 Greenland (East)

New VME indicator data were submitted for the east of Greenland (Figure 3.41). Records are from Klitgaard and Tendal, 2004, as described in Section 3.3.4. A further sponge indicator record from Burton, 1934 was submitted from further north along Greenland's East coast (longitude, latitude in decimal degrees; -22.360751, 71.730829) but this record is not displayed within the map extent.

These newly submitted data have contributed to updated outputs from the VME weighting algorithm. The VME index and confidence layers for the east of Greenland are shown in Figure 3.42 and Figure 3.43 respectively.

Some of the sponge bycatch records from Klitgaard and Tendal, 2004 have large weights (up to 2000 kg). The records and an indication of their weight are shown in Figure 3.44.

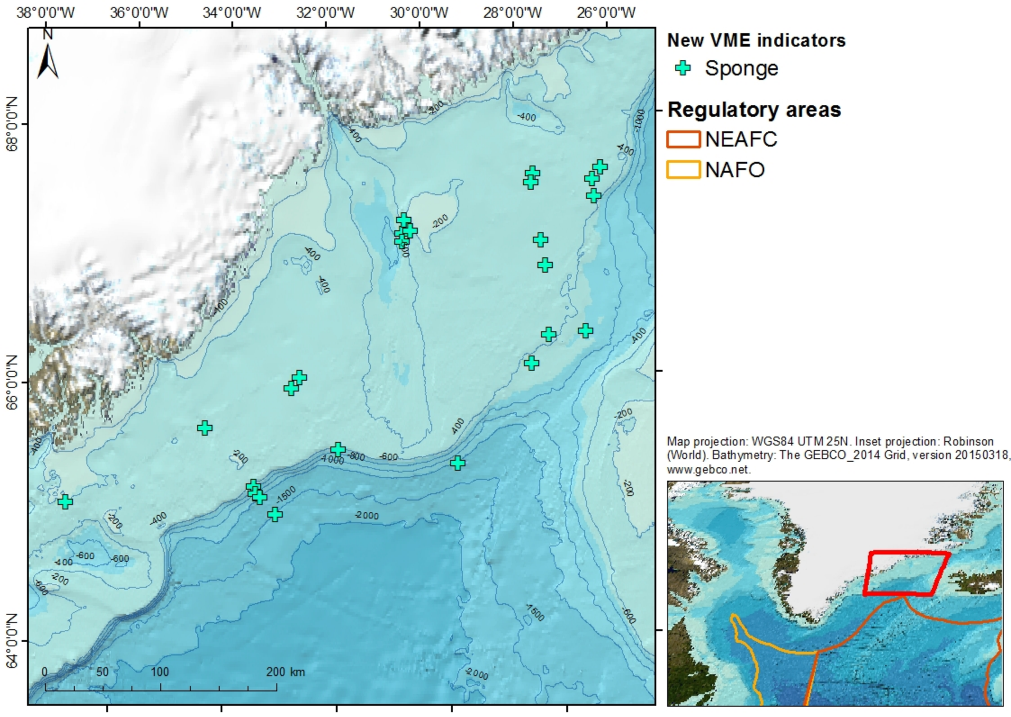

Figure 3.41. New VME indicator records submitted for WGDEC 2018 off the east coast of Greenland within Greenland's EEZ.

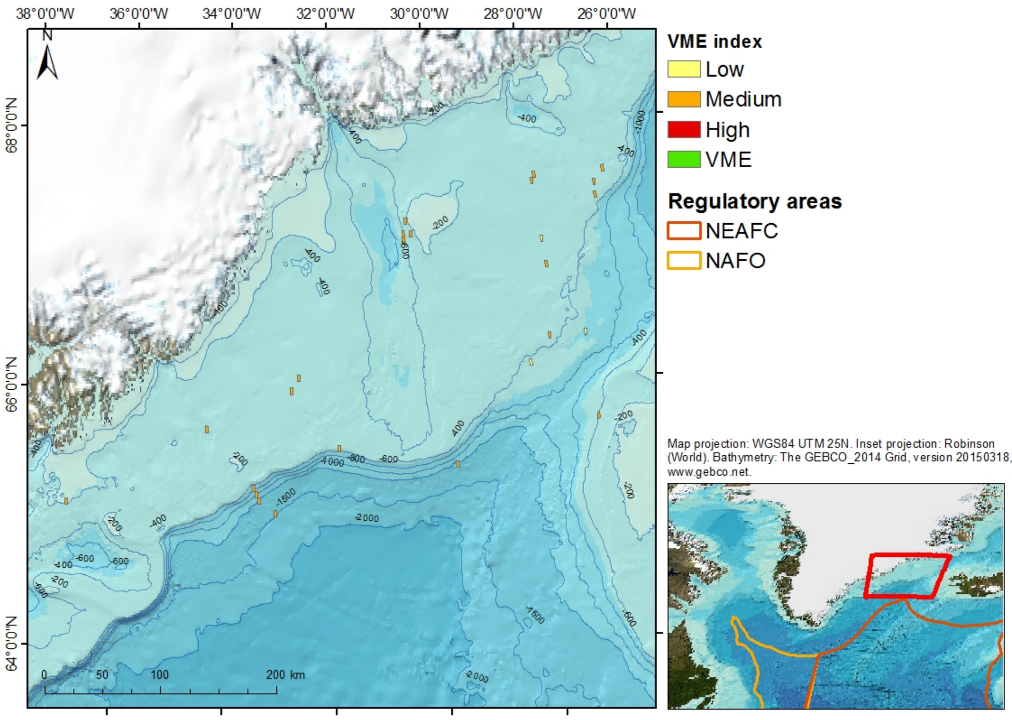

Figure 3.42. Output of the VME weighting algorithm for the area shown in Figure 3.41, showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high). Note this includes all (not only 2018) records from the ICES VME database.

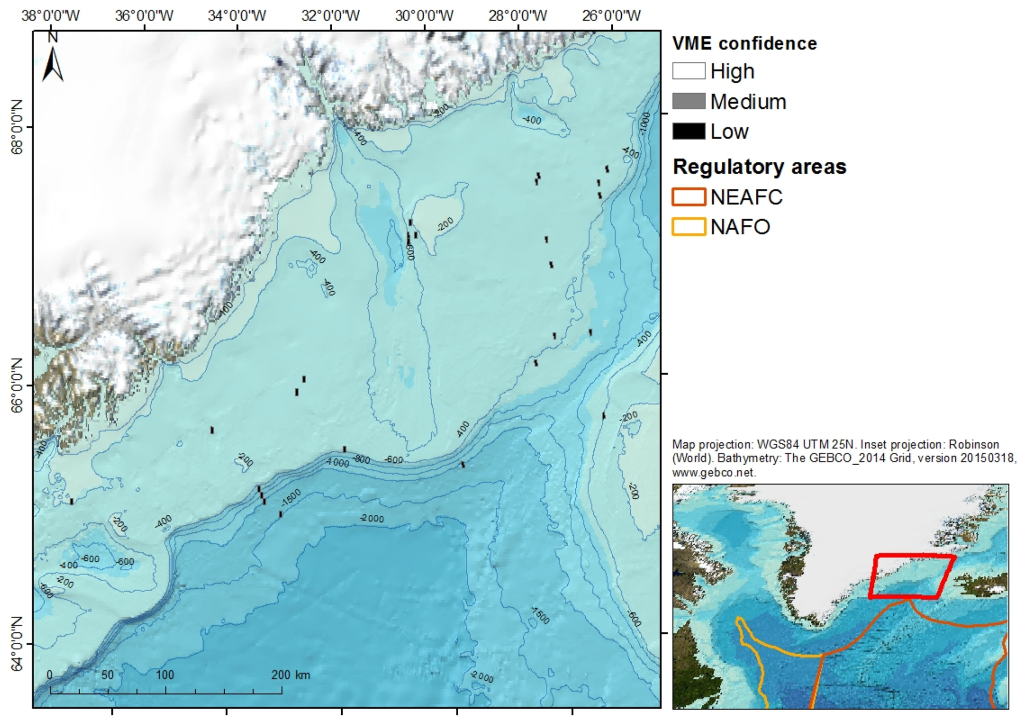

Figure 3.43. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.42). Note this includes all (not only 2018) records from the ICES VME database.

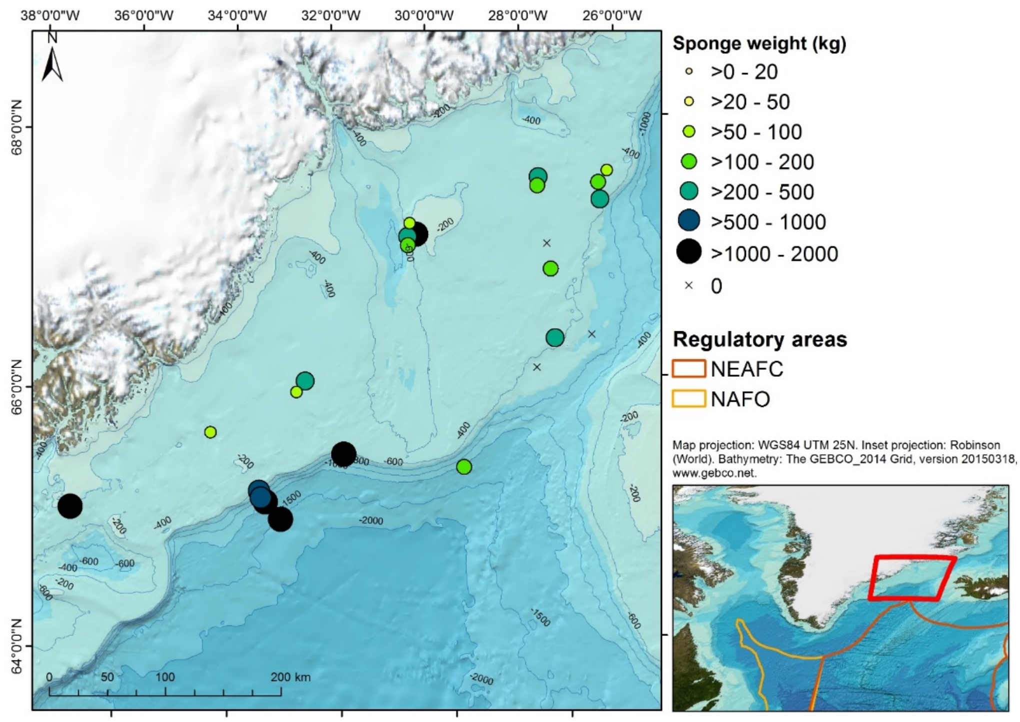

Figure 3.44. Recorded weights of sponge bycatch in trawls off the east coast of Greenland within Greenland's EEZ.

3.6.8 Reykjanes Ridge (Iceland)

Two new VME indicator records of stony coral were submitted by Greenland for the Reykjanes Ridge (Figure 3.45). One record is within Iceland's EEZ and one is within the NEAFC Regulatory Area (see Section 3.5.3). Both records are from Zibrowius, 1980, as described in Section 3.3.4.

These newly submitted data have contributed to updated outputs from the VME weighting algorithm. The VME index and confidence layers for Reykjanes Ridge are shown in Figure 3.46 and Figure 3.47 respectively.

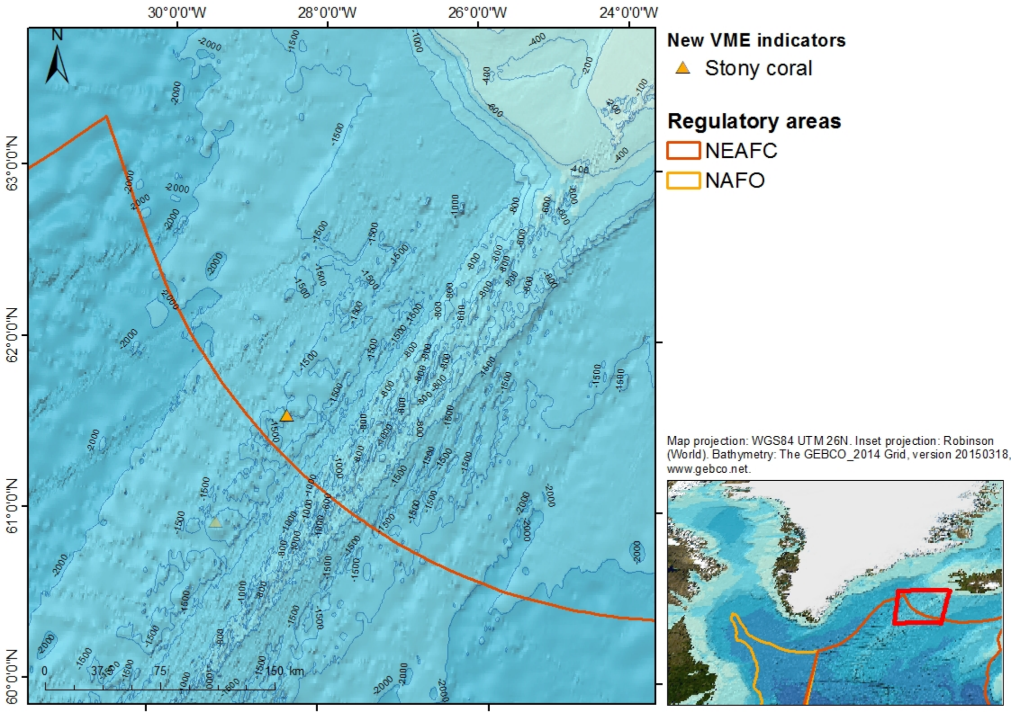

Figure 3.45. New VME indicator record submitted for WGDEC 2018 on the Reykjanes Ridge (the new record outside the Icelandic EEZ is displayed as transparent).

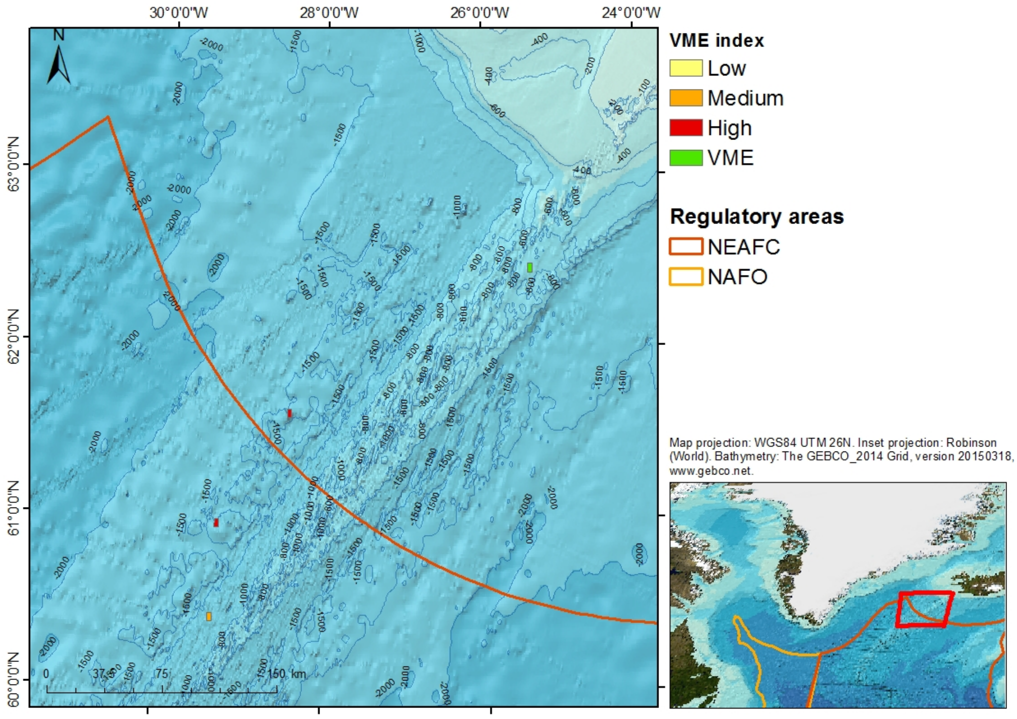

Figure 3.46. Output of the VME weighting algorithm for the area shown in Figure 3.45, showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high); and presence of actual VME. Note this includes all (not only 2018) records from the ICES VME database.

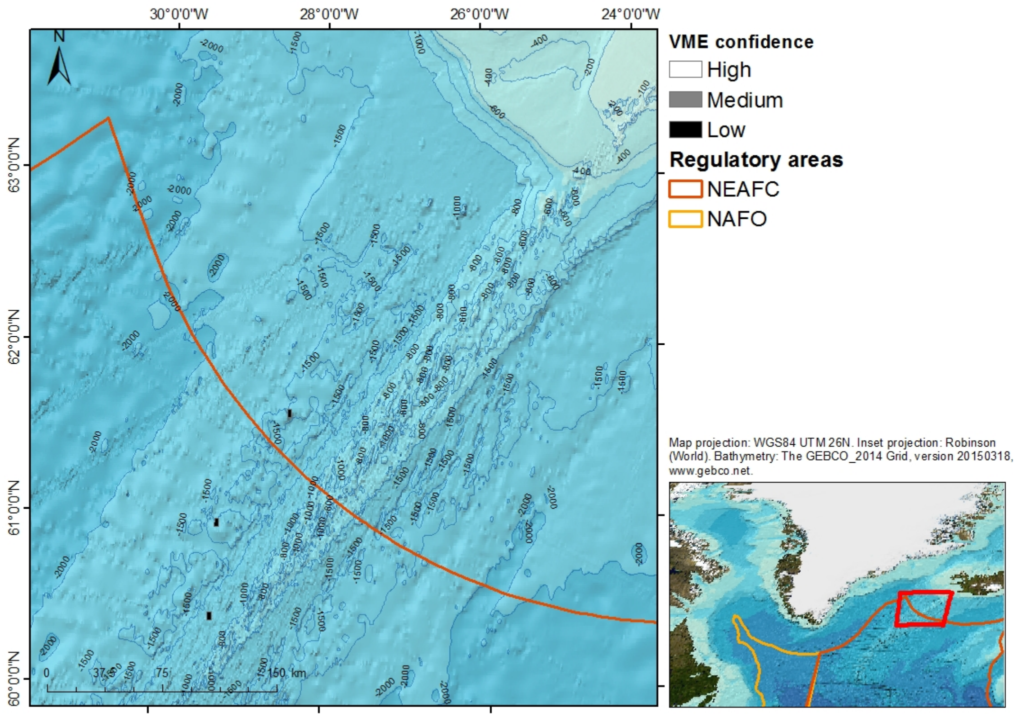

Figure 3.47. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.46). Actual records of VME (e.g. VME habitat) are not assigned a confidence rating. Note this includes all (not only 2018) records from the ICES VME database.

3.6.9 Canada

A total of 13 745 records of VME indicators and habitats were submitted by Canada within the Canadian EEZ, see Section 3.3.3 for more details. These data have contributed greatly to the ICES VME database.

Records include the VME indicators; gorgonian (Figure 3.48), seapen (Figure 3.49), and sponge (Figure 3.50). Additionally, VME habitats have been identified following the methods described in Kenchington *et al.* (2016) and DFO (2017). The locations of newly submitted coral garden, seapen field, and cold-water coral reef VME habitats are shown in Figure 3.51, Figure 3.52, and Figure 3.53 respectively.

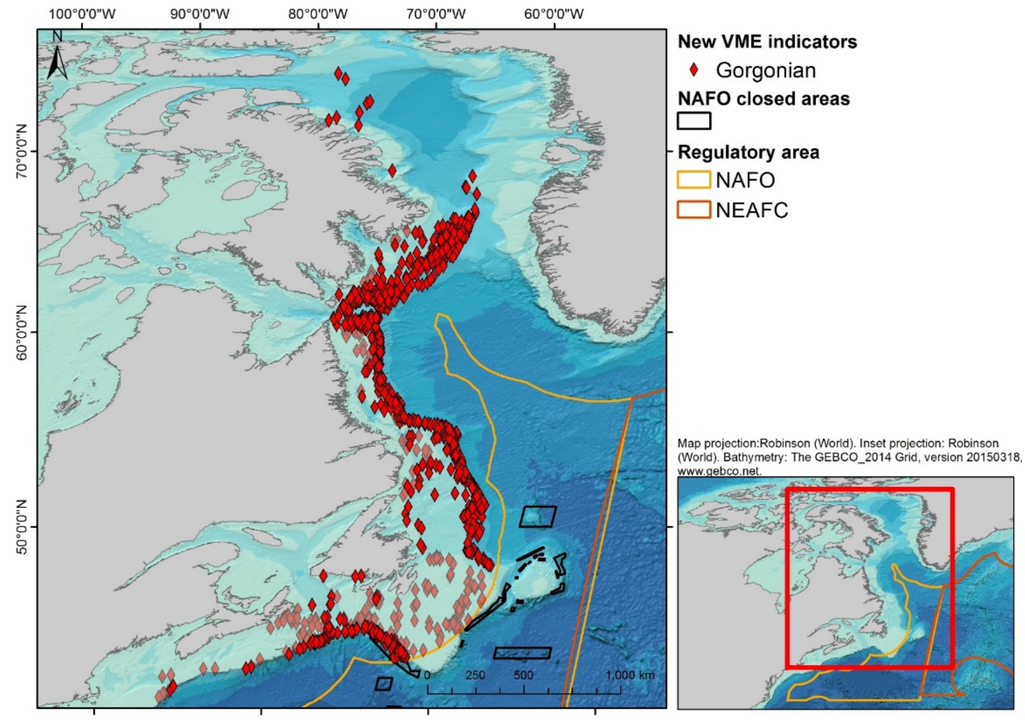

Figure 3.48. Distribution of Gorgonian indicator records submitted by Canada for WGDEC 2018. Records in waters shallower than 200 m are shown as transparent.

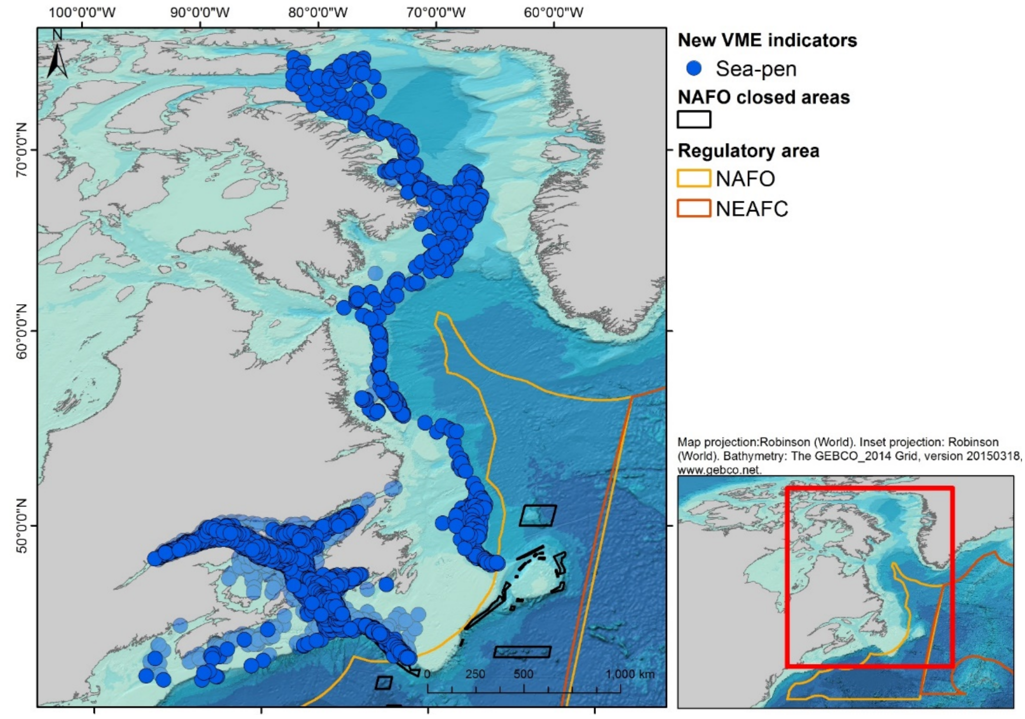

Figure 3.49. Distribution of seapen indicator records submitted by Canada for WGDEC 2018. Records in waters shallower than 200 m are shown as transparent.

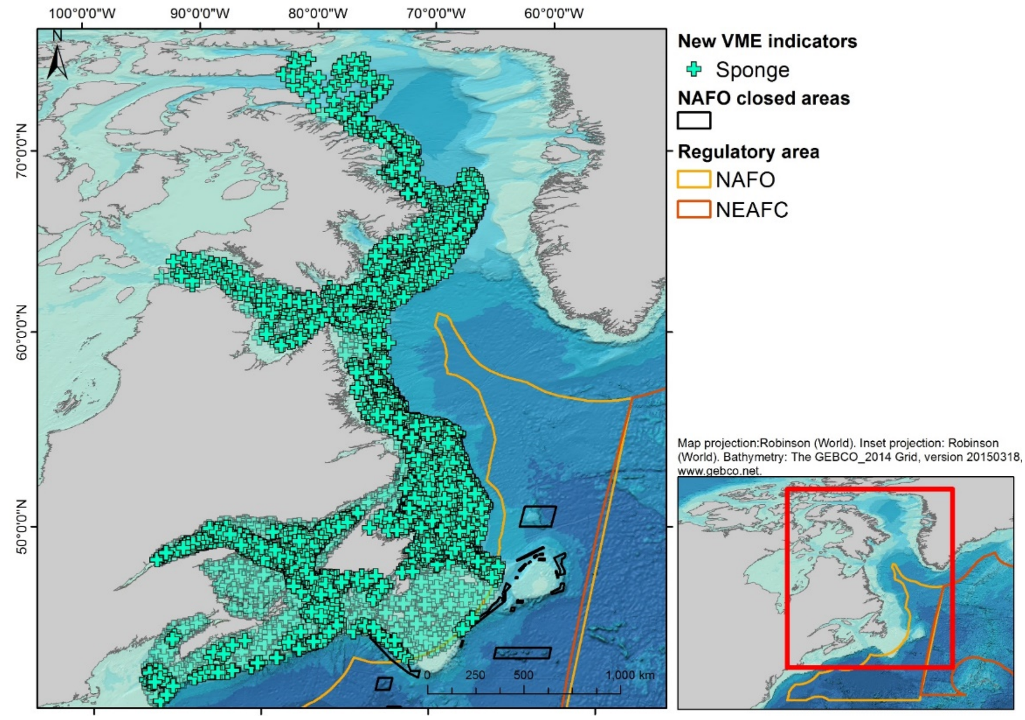

Figure 3.50. Distribution of Sponge indicator records submitted by Canada for WGDEC 2018. Records in waters shallower than 200 m are shown as transparent.

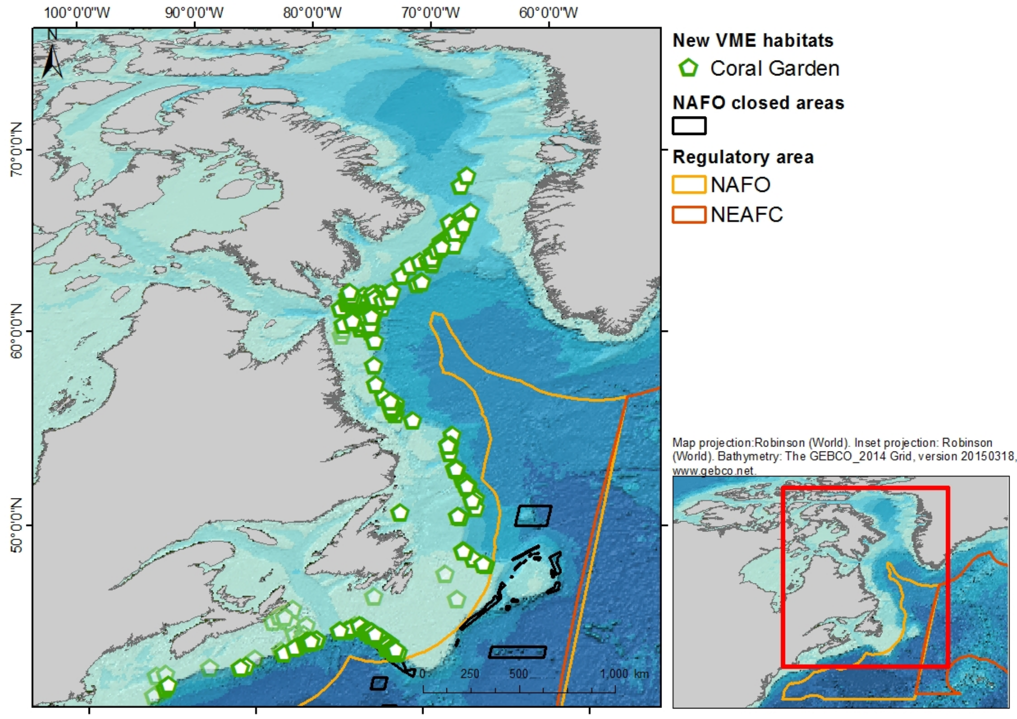

Figure 3.51. Distribution of coral garden VME habitat records submitted by Canada for WGDEC 2018. Records in waters shallower than 200 m are shown as transparent.

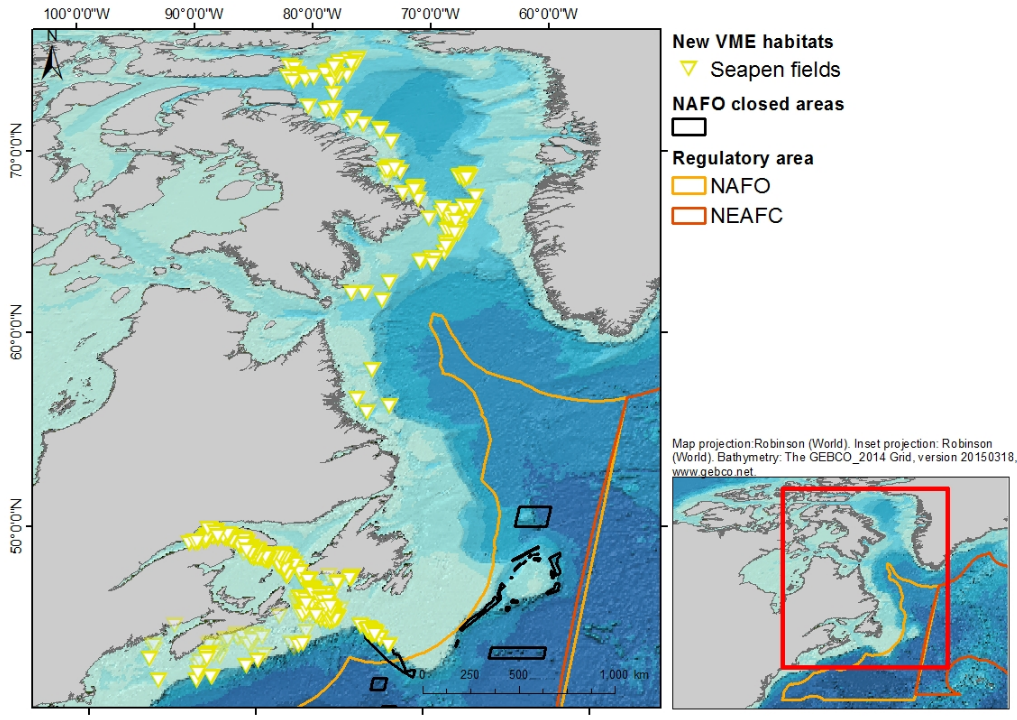

Figure 3.52. Distribution of seapen field VME habitat records submitted by Canada for WGDEC 2018. Records in waters shallower than 200 m are shown as transparent.

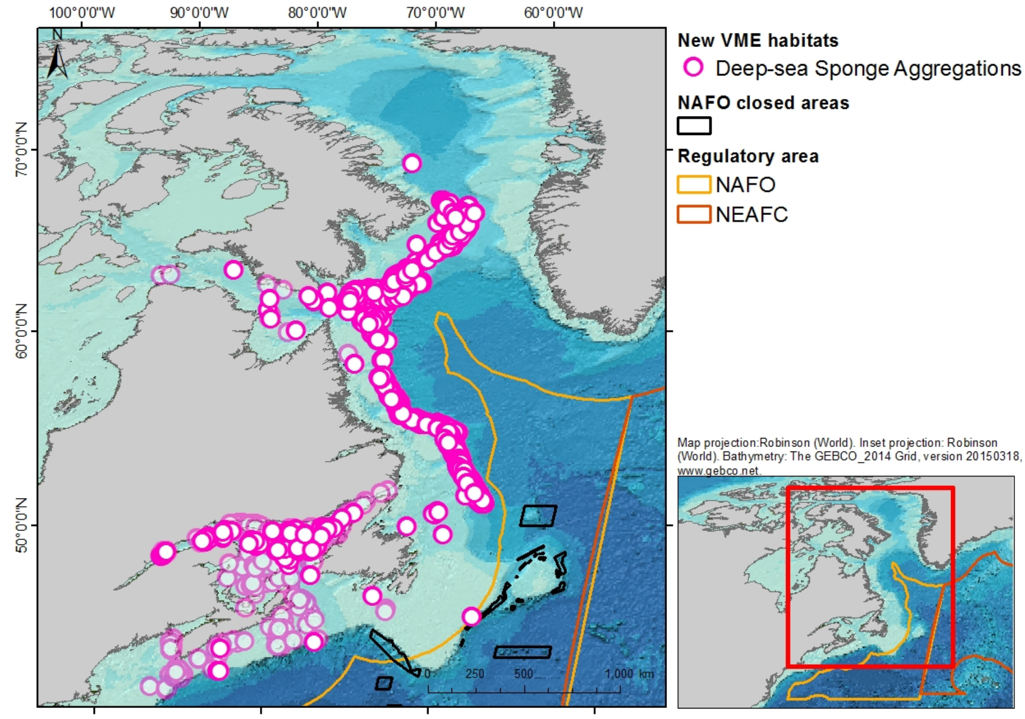

Figure 3.53. Distribution of deep-sea sponge aggregation VME habitat records submitted by Canada for WGDEC 2018. Records in waters shallower than 200 m are shown as transparent.

3.7 Review of existing data for the Josephine Seamount complex

The current ICES advice for the Josephine seamount complex was derived on the basis of records of VME indicators that had not been through the VME weighting system. As such, the group revisited the data for that area.

Maps were produced of the VME indicator records from the VME database weighted using the weighting algorithm. These show that all records on Josephine receive a moderate or low VME index (Figure 3.54). In addition, the confidence index for the same records are moderate or low (Figure 3.55). The latter reflects that the records are from the 1980s to almost a century ago.

The group still considers that Josephine is likely to have VMEs because, a) it is a seamount complex and thus has VME elements, and b) because records in the database are valid, albeit old. However, the data available are old and part of the area is an "existing fishing area" according to the NEAFC measure. The state of VMEs observed in the past is unknown.

The low and moderate confidence scores and the unknown state of the communities on Josephine led the Group to recommend that ICES, in relation to NEAFC, should encourage submission of data from past studies in this area and encourage new investigations. This would improve the basis for evaluations and advice.

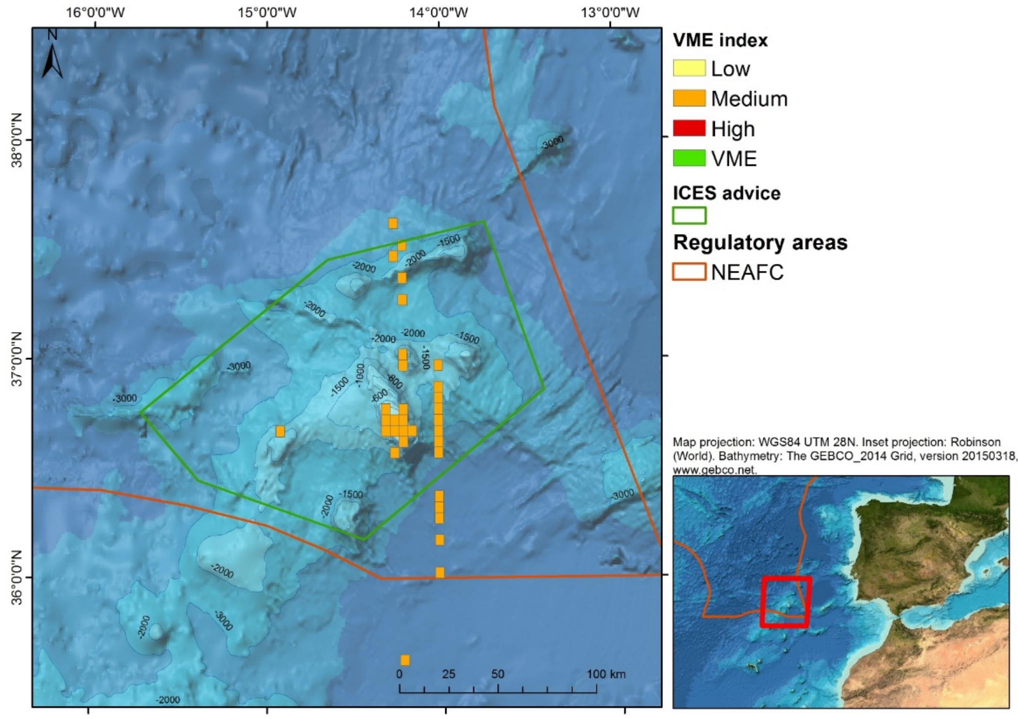

Figure 3.54. Output of the VME weighting algorithm for the Josephine seamount complex, showing the VME Index; the likelihood of encountering a VME within each grid.

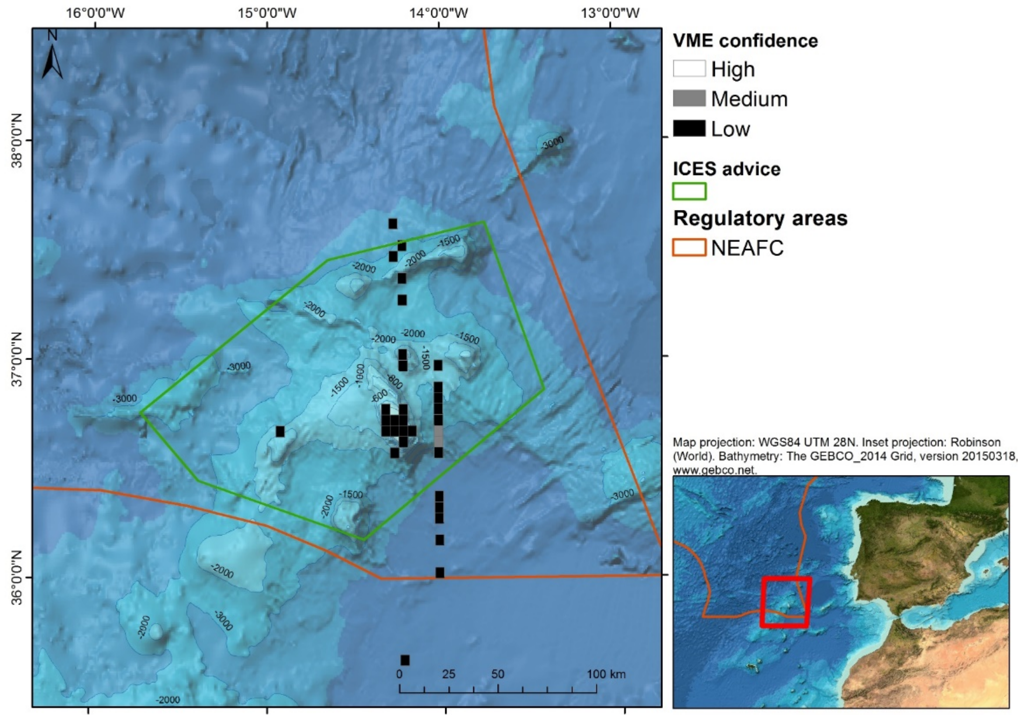

Figure 3.55. The confidence layer associated with the VME weighting algorithm's VME Index layer (Figure 3.54).

3.8 References

Burton. 1934. Report on the sponges of the Norwegian expeditions to east Greenland. Skrifter om Svalbard og Ishavet:1–33.

DFO. 2009. Development of a Framework and Principles for the Biogeographic Classification of Canadian Marine Areas. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/056.

DFO. 2017. Delineation of Significant Areas of Coldwater Corals and Sponge-Dominated Communities in Canada's Atlantic and Eastern Arctic Marine Waters and their Overlap with Fishing Activity. DFO Canadian Science Advisory Secretariat Science Advisory Report 2017/007. 45 p.

Huvenne, V.A.I, *et al*. 2011. RRS James Cook Cruise 60. 09 May-12 Jun 2011. Benthic habitats and the impact of human activities in Rockall Trough, on Rockall Bank and in Hatton Basin. Southampton. UK: National Oceanography Centre. Southampton. 133pp. (National Oceanography Centre Cruise Report. No. 04) https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/jc060.pdf

ICES. 2007. Report of the Working Group on Deep-water Ecology (WGDEC), 26–28 February 2007. ICES CM 2007/ACE:01 Ref. LRC. 61 pp.

ICES. 2016. Report of the Workshop on Vulnerable Marine Ecosystem Database (WKVME), 10–11 December 2015, Peterborough, UK. ICES CM 2015/ACOM:62. 42 pp.

JNCC. 2009. JNCC Offshore Natura Survey Anton Dohrn Seamount and East Rockall Bank Areas of Search 2009/03-JNCC Cruise Report, Report Number CR/09/113. http://jncc.defra.gov.uk/PDF/2009_3_JNCC_Cruise_Report_Public%20(2).pdf

Kenchington, E., Beazley, L., Lirette, C., Murillo, F.J., Guijarro, J., Wareham, V., Gilkinson, K., Koen-Alonso, M., Benoît, H., Bourdages, H., Sainte-Marie, B., Treble, M. and Siferd, T. 2016. Delineation of Coral and Sponge Significant Benthic Areas in Eastern Canada Using Kernel Density Analyses and Species Distribution Models. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/093. vi + 178 p.

Klitgaard, A. B. and Tendal, O. S. 2004. Distribution and species composition of mass occurrences of large-sized sponges in the Northeast Atlantic. Progress in Oceanography, No. 61 pp.: 57–98.

Orejas, C., Addamo, A., Alvarez, M., Aparicio, A., Alcoverro, D., Arnaud-Haond, S., … Zein, M. 2017. Cruise summary report - MEDWAVES survey (MEDiterranean out flow WAter and Vulnerable EcosystemS). Zenodo. http://doi.org/10.5281/zenodo.556516

Stewart, H. A., and Davies, J. S. 2007. SW Approaches MESH Survey, RV Celtic Explorer Cruise CE0705, BGS Project 07/06, Operations Report. British Geological Survey Commissioned Report, CR/07/123. http://www.emodnet-seabedhabitats.eu/PDF/SWApproachesMESHCruiseReport_v5_final.pdf

Tendal, O. 1992. The North Atlantic distribution of the octocoral *Paragorgia arborea* (L., 1758) (Cnidaria, Anthozoa). Sarsia 77: 213–217.

Zibrowius. 1980. Les Scleractiniaires de la Mediterranee et de l'Atlantique nord-oriental. Memoires de l'Institut Océanographique 11: 1–284.

4 In addition, prepare spatial layers and a list of areas where VMEs are likely to occur in the Northeast Atlantic, in particular in areas deeper than 800 m – ToR [a]

4.1 Developing a list of areas where VMEs occur, or are likely to occur, in the Northeast Atlantic

This Term of Reference undertaken by the group was in response to a request for ICES advice from the European Commission to establish a list of areas where VMEs occur, or are likely to occur, with respect to implementation of the deep-sea access regulation[1]. As the scope of this EU Regulation applies only to Union waters, as stated in Article 2, and in discussion with the ICES Secretariat, WGDEC agreed to exclude the consideration of the EEZs of the Faroe Islands, Greenland, Iceland and Norway when compiling this list of areas. Information provided under this Term of Reference is split by ICES reporting area.

To identify areas where VMEs occur, WGDEC first referred to the ICES VME database. This database contains many records of VME, primarily identified from underwater imagery. However, it is acknowledged that the VME database is impoverished with respect to data on VME occurrence from some areas of EU waters. Therefore, information on VME occurrence from the VME database was supplemented with VME records from peer reviewed literature and the OSPAR 2015 database[2], where they supported the identification of additional areas.

To identify where VMEs are likely to occur, WGDEC used the outputs of the VME weighting algorithm. The group focused on those c-squares which have been identified as having a 'high' VME index (most likely to represent a VME) **AND** those c-squares which are flagged as having a 'high' or 'medium' confidence. Further information regarding the VME weighting algorithm can be found in Section 7.2.

Areas where VMEs occur, or are likely to occur, have been identified for each ICES reporting area on a series of maps (highlighted by indicative red, dashed lines) within this section of the report, along with supporting text. Spatial layers (in the form of VME weighting algorithm outputs – VME index and associated confidence) have been made available to ICES ahead of this report being published, to be used in conjunction with supporting information provided within this section. These spatial layers (VME weighting algorithm outputs – VME index and associated confidence) can also be found on the VME Data Portal[3].

Finally, consideration of areas where VMEs occur, or are likely to occur, has been carried out across three depth bands, which are summarised in a table for each set of ICES reporting areas considered (Table 4.1, Table 4.2, Table 4.3 and Table 4.4). The three depth bands are:

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[1] REGULATION (EU) 2016/2336 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 December 2016 establishing specific conditions for fishing for deep-sea stocks in the Northeast Atlantic and provisions for fishing in international waters of the Northeast Atlantic and repealing Council Regulation (EC) No 2347/2002.

[2] https://odims.ospar.org/

[3] http://vme.ices.dk/map.aspx

1) Deeper than 800 m;
2) 800 m–400 m;
3) >200 m–400 m.

4.2 ICES Area IV, V & VI

4.2.1 Faroe-Shetland Channel

4.2.1.1 Sources of information

Known VME records (VME habitats) for the Faroe-Shetland Channel (Figure 4.1) were identified from the ICES VME database. Records originated from a 2006 Strategic Environmental Assessment (SEA/SAC) survey and a collaborative survey (1512S) between Marine Scotland Science (MSS) and the Joint Nature Conservation Committee (JNCC), both using drop-down camera systems.

4.2.1.2 Location

The Faroe-Shetland Channel is a deep channel located to the north of Scotland within the EEZ of two countries; UK and the Faroe Islands (Denmark). VME data were only reviewed for the area within the UK EEZ. VME records were identified along the shelf break of the Faroe-Shetland Channel.

4.2.1.3 VME occurrences

- Deep-sea sponge aggregations

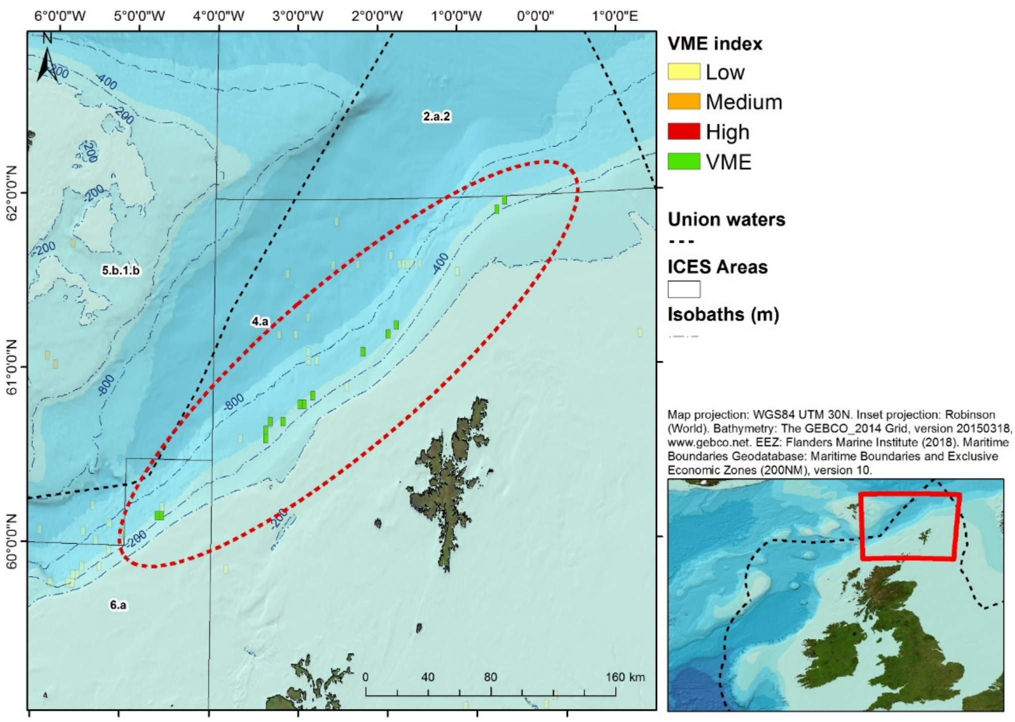

Figure 4.1. Map of the Faroe-Shetland channel showing the VME index of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour while those that do not are shown as transparent. The key records for the area have been circled with a red dashed line.

4.2.2 Rosemary Bank Seamount

4.2.2.1 Sources of information

Known VME records for the Rosemary Bank Seamount were identified from the ICES VME database (A, Figure 4.2). Records originated from a 2016 Plymouth University, University of Oxford, JNCC and British Geological Survey collaborative survey titled "DeepLinks" (JC136) using a remotely operated vehicle (ROV) to collect seabed imagery, and a 2016 MSS survey (1316S) using a VMUX towed video chariot system.

In addition, areas where VME are likely to occur (high VME index c-squares with medium confidence) were identified using the VME weighting algorithm (A, Figure 4.2 and Figure 4.3).

4.2.2.2 Location

Rosemary Bank is located in the Rockall Trough to the west of Scotland, within the UK's EEZ. VME records were identified on the flanks of Rosemary Bank Seamount.

4.2.2.3 VME occurrences

- Deep-sea sponge aggregations;
- Coral gardens;
- Cold-water coral reefs.

In addition to these known VME occurrences, there are a broad range of VME indicators which have a high VME index score.

4.2.3 Wyville Thomson Ridge / Darwin Mounds

4.2.3.1 Sources of information

Known VME records for the Wyville Thomson Ridge and Darwin Mounds were identified from the ICES VME database (B, Figure 4.2). Records originated from a 2011 National Oceanography Centre (NOC) survey (JC060) using a remotely operated vehicle (ROV) to collect seabed imagery, and a 2012 JNCC and MSS survey (1512S) using a drop-down video camera system.

In addition, areas where VME are likely to occur (high VME index c-squares with medium confidence) were identified using the VME weighting algorithm (B, Figure 4.2 and Figure 4.3).

4.2.3.2 Location

The Wyville Thomson Ridge occurs between Scotland and the Faroe Islands, within the UK's EEZ. VME records were identified on the Western edge of Wyville Thomson Ridge and in the region of the Darwin Mounds.

4.2.3.3 VME occurrences

- Deep-sea sponge aggregations;
- Cold-water coral reefs.

In addition to these known VME occurrences, there are a broad range of VME indicators which have a high VME index score.

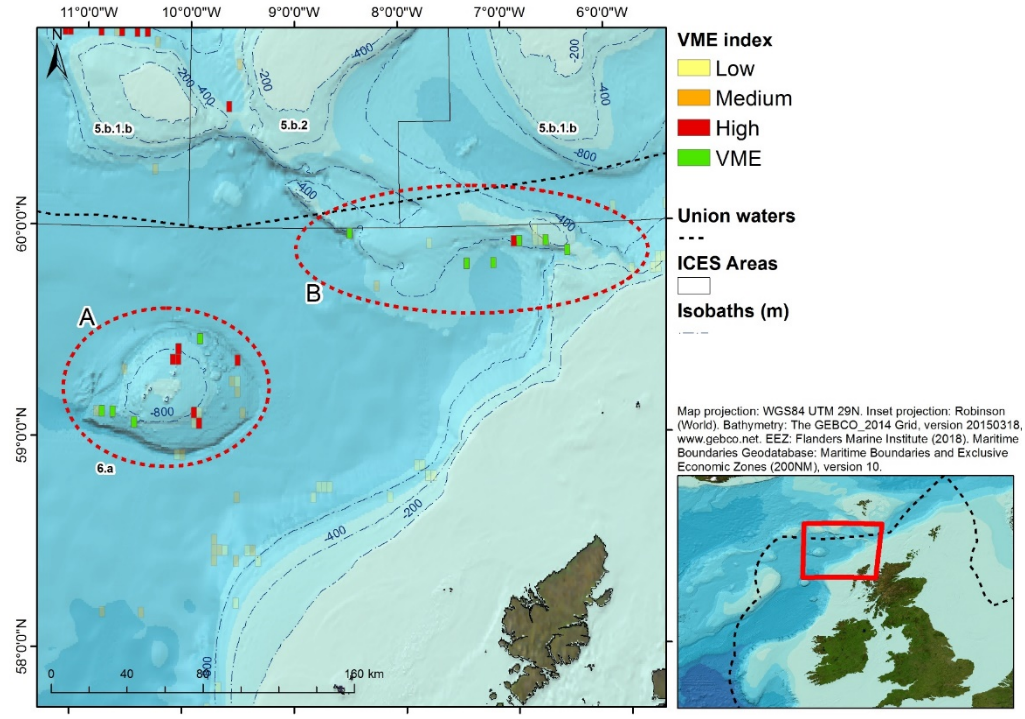

Figure 4.2. Map of Rosemary Bank Seamount (A), and Wyville Thomson Ridge and Darwin Mounds (B) showing the VME index of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour while those that do not are shown as transparent. The key records for the area have been circled with a red dashed line.

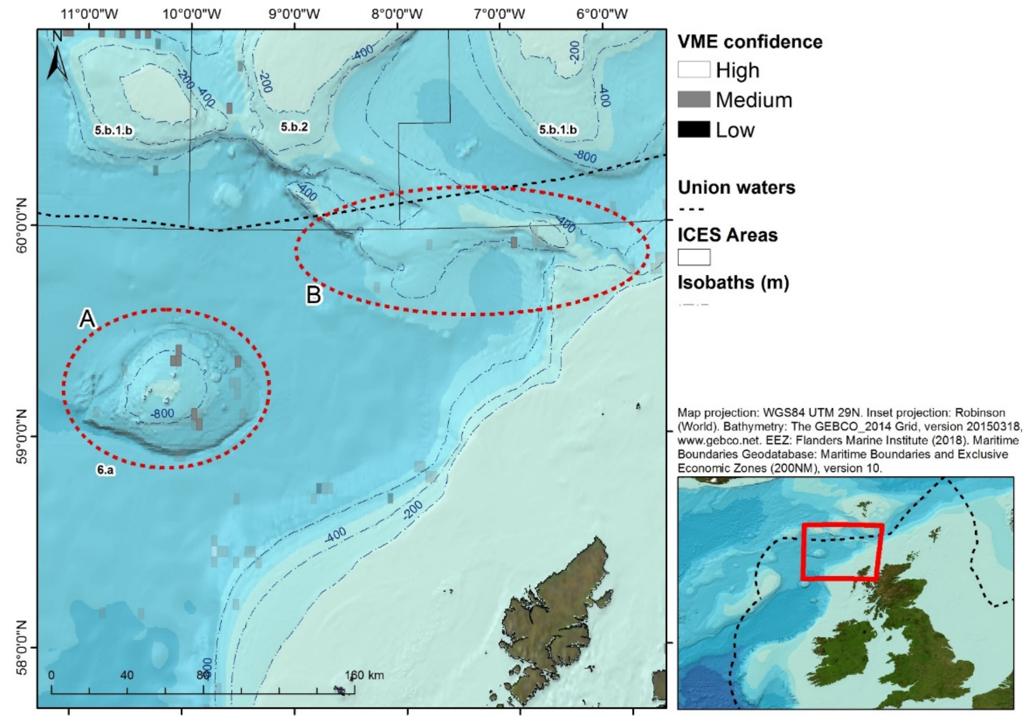

Figure 4.3. Map of Rosemary Bank Seamount (A), and Wyville Thomson Ridge / Darwin Mounds (B) showing the confidence of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour while those that do not are shown as transparent. The key records for the area have been circled with a red dashed line.

4.2.4 George Bligh Bank

4.2.4.1 Sources of information

Known VME records for George Bligh Bank were identified from the ICES VME database (A, Figure 4.4). Records originated from a 2005 Strategic Environmental Assessment survey (SEA7) which were obtained using a drop-down camera system. Additional data came from the 2016 DeepLinks survey (JC136) using an ROV.

4.2.4.2 Location

George Bligh Bank is located in the Rockall Trough to the west of Scotland, within the UK's EEZ. VME records were identified on the flanks of George Bligh Bank.

4.2.4.3 VME occurrences

- Coral gardens

4.2.5 Rockall Bank

4.2.5.1 Sources of information

Known VME records for Rockall Bank were identified using the ICES VME database (B, Figure 4.4). Records came from a range of surveys including MSS 2012, 2013 and 2016 surveys (1112S; 1113S; 1316S), a 2011 NOC survey (JC060) and a 2009 JNCC survey (2009/03-JNCC).

In addition, areas where VME are likely to occur (high VME index c-squares with high confidence) were identified using the VME weighting algorithm (Image B, Figure 4.4 and Figure 4.5).

4.2.5.2 Location

Rockall Bank is located off the west coast of Scotland and Ireland. The more gently sloping western side of the bank is located within the NEAFC regional area whereas the steeper, eastern side of the bank is within the EEZ of both the UK and Ireland. VME data were only reviewed for the area within the EEZ of UK and Ireland for this Term of Reference.

VME records were identified on the west of Rockall Bank within the existing bottom fishing closure, and on the north and east of Rockall Bank. VME indicator records were identified across the whole Rockall Bank area.

4.2.5.3 VME occurrences

- Cold-water coral reefs;
- Coral gardens.

In addition to these VME occurrences there are a broad range of VME indicators which have a high VME index score.

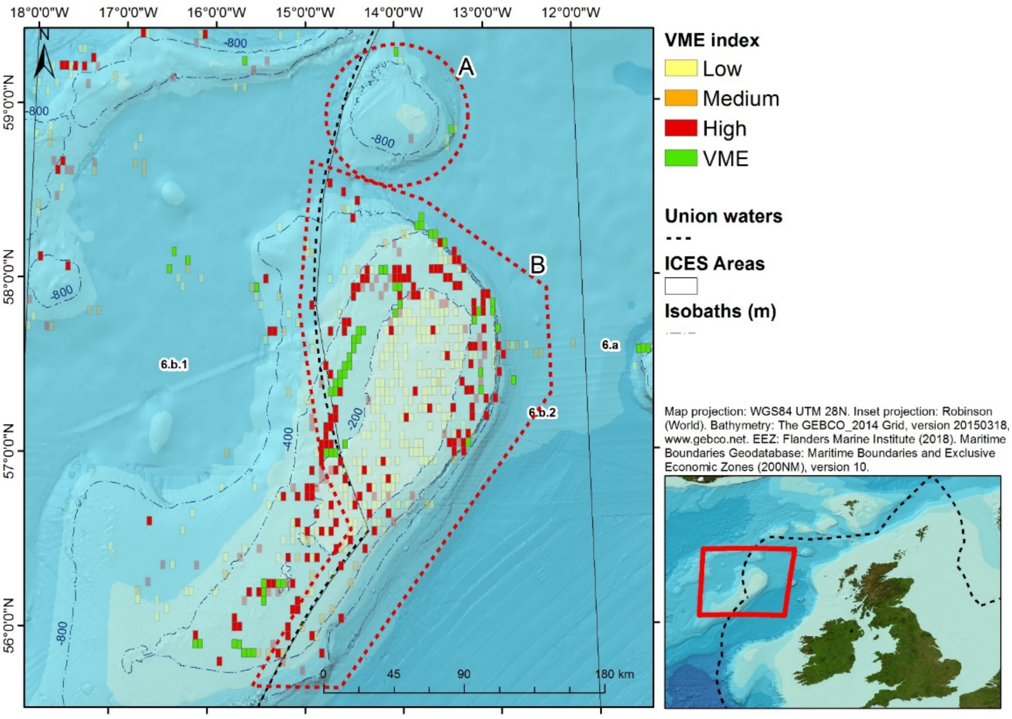

Figure 4.4. Map of George Bligh Bank (A), and Rockall Bank (B) showing the VME index of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour while those that do not are shown as transparent. The key records for the area have been circled with a red dashed line.

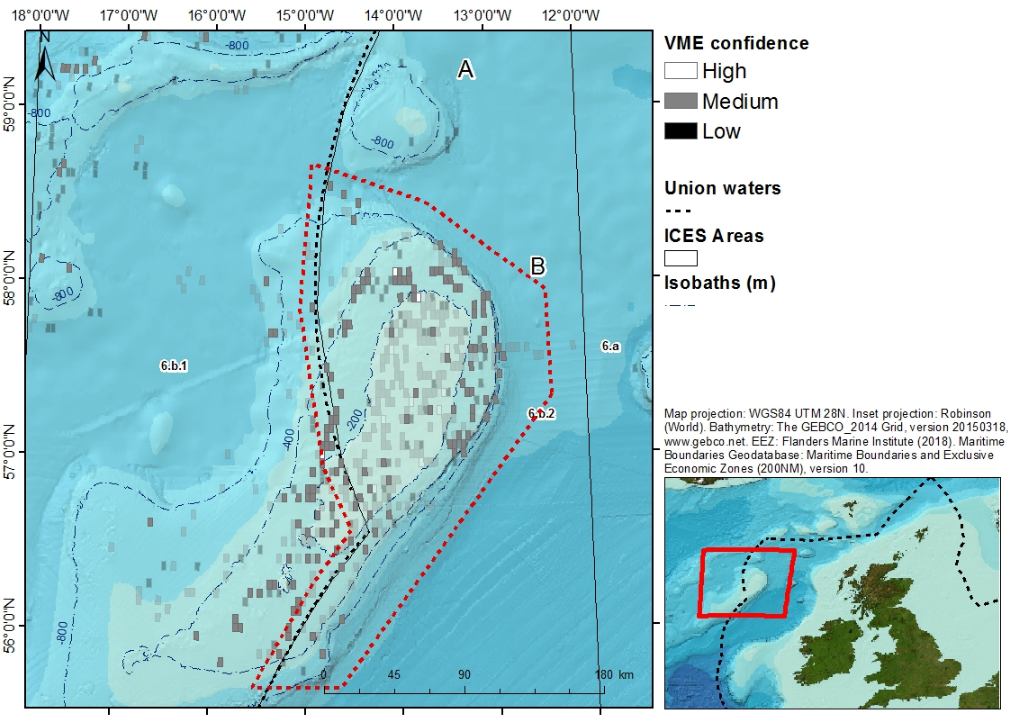

Figure 4.5. Map of Rockall Bank (B) showing the confidence of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour while those that do not are shown as transparent. The key records for the area have been circled with a red dashed line.

4.2.6 Anton Dohrn Seamount

4.2.6.1 Sources of information

Known VME records for Anton Dohrn Seamount were identified using the ICES VME database (A, Figure 4.6). Records came from a 2009 JNCC survey (2009/03-JNCC). These data were obtained used a drop-down camera system.

4.2.6.2 Location

Anton Dohrn Seamount is located in the Rockall Trough to the west of Scotland, within the UK's EEZ. VME records were identified on the flanks of Anton Dohrn Seamount.

4.2.6.3 VME occurrences

- Coral gardens;
- Cold-water coral reefs;
- Seamount.

4.2.7 Hebrides Terrace Seamount

4.2.7.1 Sources of information

Areas where VME are likely to occur on Hebrides Terrace Seamount (high VME index c-squares with medium confidence) were identified using the VME weighting algorithm (B, Figure 4.6 and Figure 4.7). Records originated from a NERC funded survey led by Heriot-Watt University in 2012 (JC073). These data were obtained using an ROV.

4.2.7.2 Location

The Hebrides Terrace Seamount is located in the Rockall Trough to the West of Scotland within the UK and Ireland's EEZs. VME indicator records were identified on the eastern flank of Hebrides Terrace Seamount.

4.2.7.3 VME occurrences

There are a broad range of VME indicators which have a high VME index score:

- Soft corals;
- Seapens;
- Sponges;
- Gorgonians;
- Black corals;
- Stony corals;
- Cup corals.

4.2.8 Irish Continental Shelf Break

4.2.8.1 Sources of information

Areas where VME are likely to occur on the Irish Continental Shelf Break (high VME index c-squares with medium confidence) were identified using the VME weighting algorithm (C, Figure 4.6 and Figure 4.7).

Records came from a range of MSS surveys in 2006 (1406S), 2007 (1307S), 2012 (1212S) and 2013 (1213S). These data represent bycatch whilst using bottom-trawl gear during fisheries research surveys.

4.2.8.2 Location

The Irish Continental Shelf Break occurs to the West of Ireland within Ireland's EEZ.

4.2.8.3 VME occurrences

There are a broad range of VME indicators which have a high VME index score:

- Black corals;
- Cup corals;
- Sponges;
- Stony corals;
- Seapens;
- Gorgonians;
- Stylasterids;

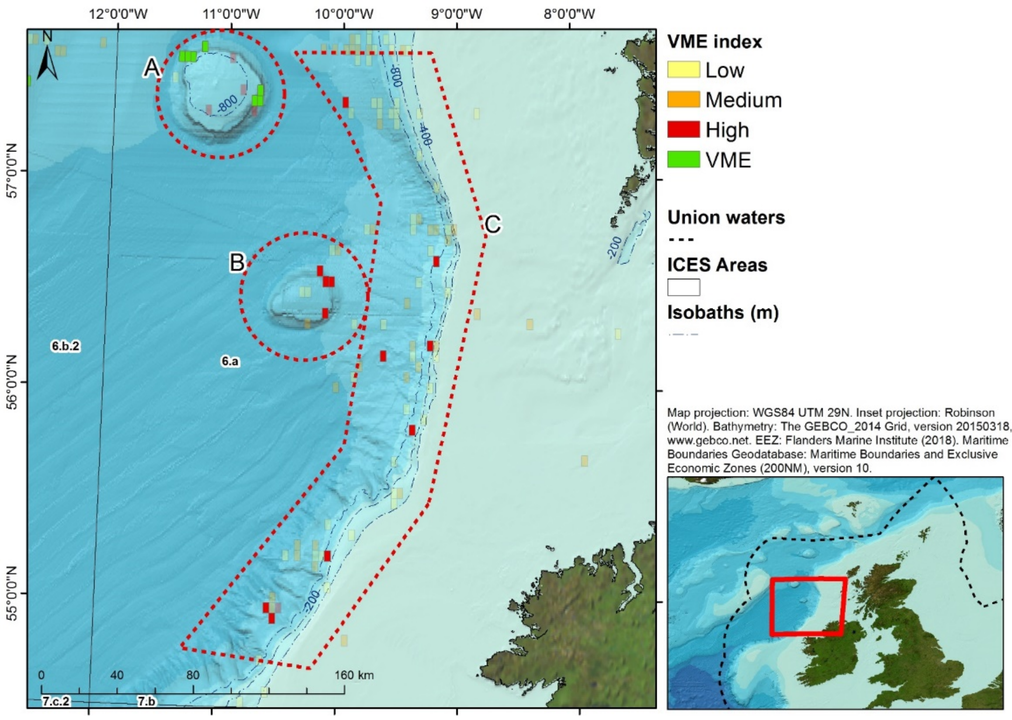

Figure 4.6. Map of Anton Dohrn Seamount (A), Hebrides Terrace Seamount (B), and the Irish Continental Shelf Break (C) showing the VME index of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour while those that do not are shown as transparent. The key records for the area have been circled with a red dashed line.

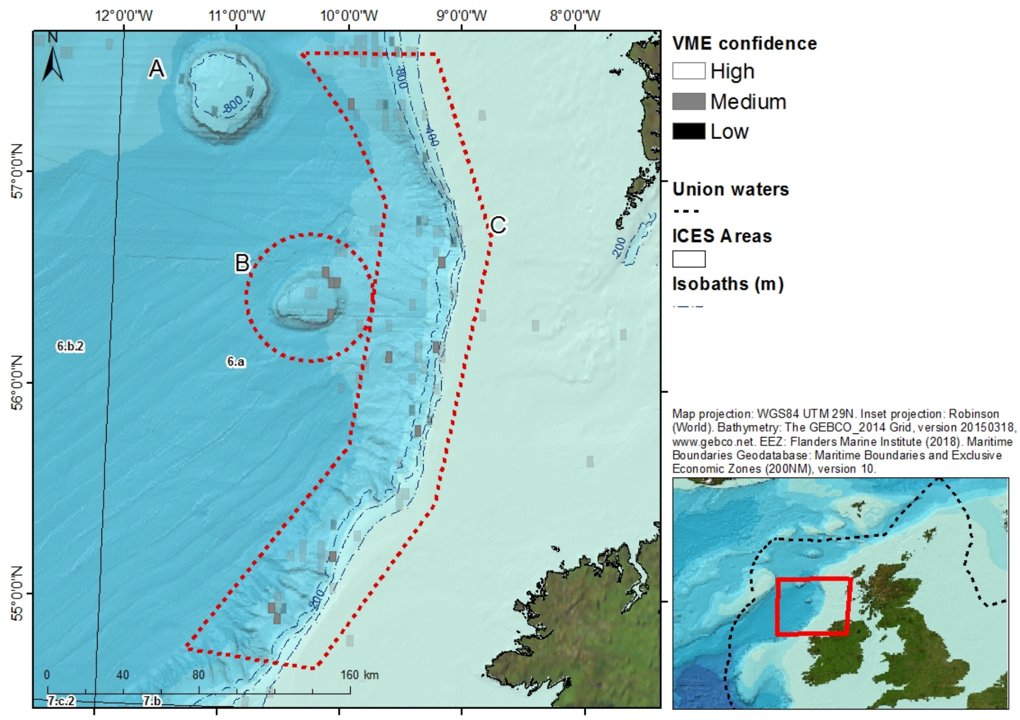

Figure 4.7. Map of Hebrides Terrace Seamount (B), and the Irish Continental Shelf Break (C) showing the confidence of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour while those that do not are shown as transparent. The key records for the area have been circled with a red dashed line.

Table 4.1. A summary of depth bands where VMEs occur, or are likely to occur, in ICES Areas IV, V & VI.

Area where VMEs occur, or are likely to occur	Country EEZ	Depth >800 m	Depth from 400 m – 800 m	Depth from 200 m – 400 m
Faroe-Shetland Channel	UK	-	Yes	Yes
Rosemary Bank Seamount	UK	Yes	Yes	-
Wyville Thomson Ridge/Darwin Mounds	UK	Yes	Yes	-
George Bligh Bank	UK	Yes	-	-
Rockall Bank	UK and Ireland	Yes	Yes	Yes
Anton Dohrn Seamount	UK	Yes	-	-
Hebrides Terrace Seamount	UK and Ireland	Yes	-	-
Irish Continental Shelf Break	Ireland	Yes	Yes	-

4.3 ICES Area VII

4.3.1 Whittard Canyon and adjacent canyons

4.3.1.1 Sources of information

Known VME records for the Whittard Canyon and its adjacent canyons were identified from the ICES VME database (Figure 4.8).

Records came from a 2010 Renard Centre of Marine Geology and Ghent University survey (Belgica 10–17B), 2011 and 2012 Ifremer surveys (EVHOE 2012 and BoBEco), and a 2007 joint-partner Mapping European Seabed Habitats (MESH) survey. These data were obtained using drop-down camera and ROV systems.

4.3.1.2 Location

The Whittard Canyon and its adjacent canyons are located on the continental margin of the Bay of Biscay, known as the Celtic Margin, within the UK, Ireland and France's EEZs.

4.3.1.3 VME occurrences

- Coral gardens;
- Seapen fields;
- Anemone aggregations;
- Cold-water coral reefs;
- Deep-sea sponge aggregations.

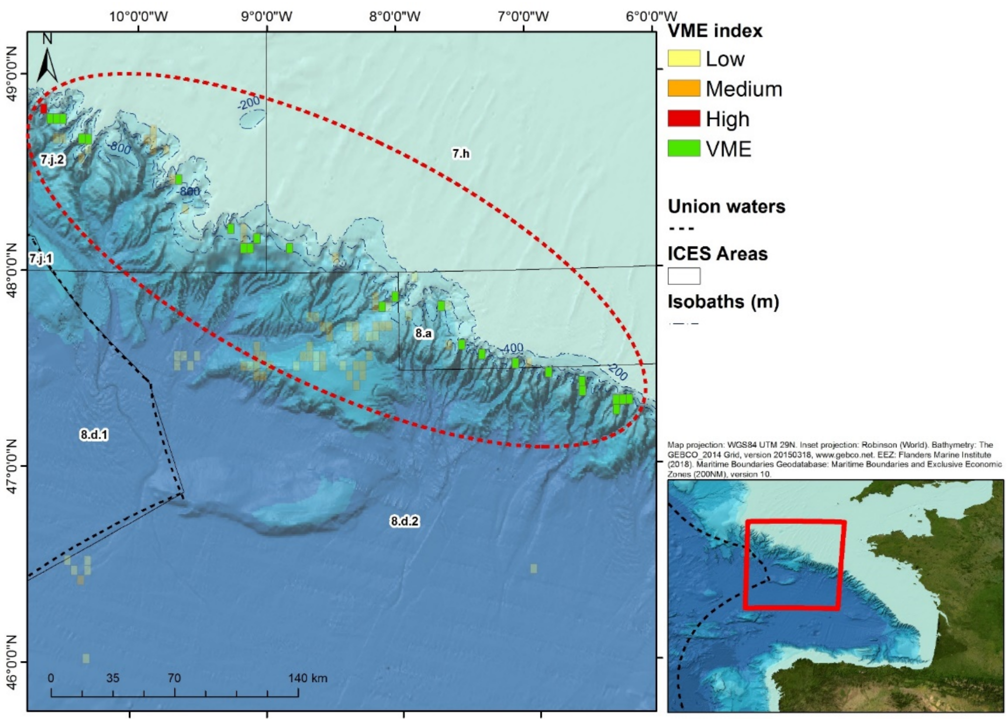

Figure 4.8. Map of the Whittard Canyon and adjacent canyons showing the VME index of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour while those that do not are shown as transparent. The key records for the area have been circled with a red dashed line.

4.4 ICES Area VIII

4.4.1 Bay of Biscay-French Continental Shelf Break

4.4.1.1 Sources of information

Known VME records for the Bay of Biscay French continental shelf break were identified from the ICES VME database (Figure 4.9).

Records came from 2009–2011 Ifremer surveys (BobGeo and BobEco) using ROV seabed imagery techniques.

4.4.1.2 Location

The Bay of Biscay occurs to the West of France within France's EEZ. VME records were identified along the continental shelf break.

4.4.1.3 VME occurrences

- Coral gardens;
- Cold-water coral reefs.

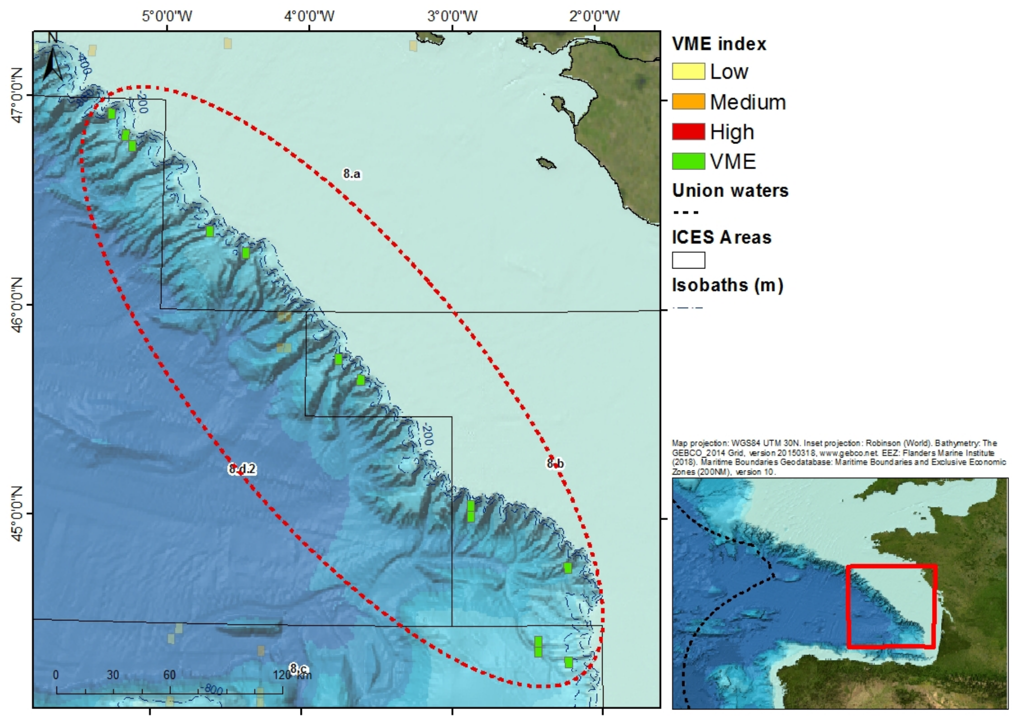

Figure 4.9. Map of the Bay of Biscay French Continental Shelf break showing the VME index of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour while those that do not are shown as transparent. The key records for the area have been circled with a red dashed line.

Table 4.2. A summary of depth bands where VMEs occur, or are likely to occur, in ICES Area VII and Area VIII.

Area where VMEs occur, or are likely to occur	Country EEZ	Depth >800 m	Depth from 400 m–800 m	Depth from 200 m–400 m
Whittard Canyon and adjacent canyons	UK, Ireland and France	Yes	Yes	-
Bay of Biscay – French Continental Shelf Break	France	Yes	Yes	Yes

4.5 ICES Area IX

4.5.1 Portuguese Continental Shelf – Ormonde Seamount

4.5.1.1 Sources of information

Known VME records for the Ormonde Seamount on the Portuguese Continental Shelf were identified using the ICES VME database and the OSPAR 2015 database (Figure 4.10).

Records came from the 2017 IEO survey (MEDWAVES) using ROV imagery and from a 2011 Oceana survey to the Gorringe Ridge on the vessel 'Ranger', also using ROV imagery.

4.5.1.2 Location

Ormonde Seamount is part of the Gorringe Ridge, which is located on the Portuguese continental shelf within the Portuguese EEZ.

4.5.1.3 VME occurrences

- Deep-sea sponge aggregations;
- Coral Gardens.

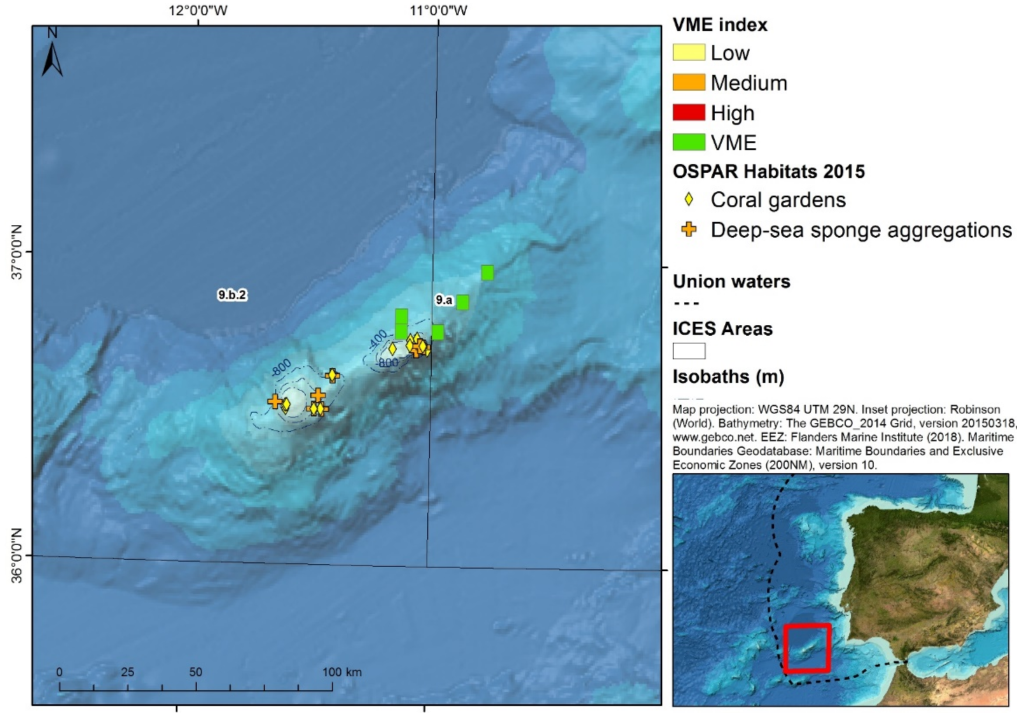

Figure 4.10. Map of the Ormonde Seamount showing the OSPAR habitat records that correlate with VME habitats and the VME index of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour.

4.5.2 Spanish Continental Shelf Break – La Gaviera Canyon, Avilés Canyon and Le Danois Bank

4.5.2.1 Sources of information

While no VME records for the Spanish Continental Shelf Break were available from the VME database, known VME records were identified from peer review scientific papers and from the OSPAR 2015 habitat database.

Records were identified from the following peer review sources:

- La Gaviera Canyon (A, Figure 4.11) - Sánchez *et al*. (2014);
- Avilés Canyon (A, Figure 4.11) - Louzao *et al*. (2010);
- Le Danois Bank (B, Figure 4.11) - Sánchez *et al*. (2008 and 2009).

The same records were also present within the OSPAR 2015 habitats database, submitted by the Spanish Institute of Oceanography (IEO).

4.5.2.2 Location

La Gaviera, Avilés Canyons and Le Danois Bank (Figure 4.11) are all VME element features located on the North Spanish continental shelf break, in the Cantabrian Sea (Gulf of Biscay).

The Avilés and La Gaviera Canyons are also located in the Cantabrian Sea, in the southern Bay of Biscay. The Avilés Canyon is one of the deepest canyons in the world. It is approximately 32 km in length from the 1000 to the 200 m isobaths and15 km in width at the 200 m isobath.

Le Danois Bank is a marginal shelf located in the Cantabrian Sea at 5°W longitude and 44°N latitude. In plan view, the Bank is convex southward for a length of about 72 km in an east–west direction and about 15 km wide from north to south; it has an almost flat surface with a minimum depth of 424 m, and is separated at 25 km from the Cantabrian Sea continental shelf by a deeper inner basin.

4.5.2.3 VME occurrences

Avilés Canyon

- Cold-water coral reefs of *Lophelia pertusa* and *Madrepora oculata* (378 and 1100 m)

La Gaviera Canyon

- Cold-water coral reefs of *Lophelia pertusa* and *Madrepora oculata* (650–670 m depth);
- Coral gardens dominated by black coral species *Leiopathes* sp. and *Parantipathes* sp. (675–725 m depth);
- Sponge fields dominated by *Phakellia robusta* (600–650 m depth).

Le Danois Bank

- Deep-sea sponge aggregations;
- Coral Gardens.

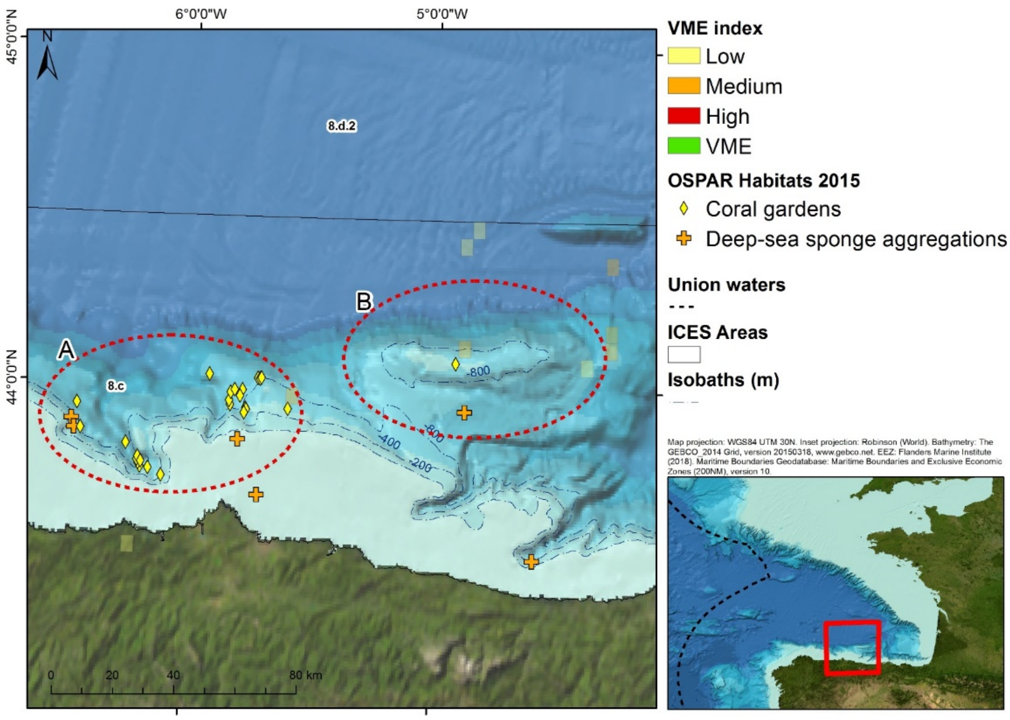

Figure 4.11. Map of the Avilés and La Gaviera Canyon System (A) and Le Danois Bank (B) showing OSPAR habitat records that correlate with VME habitats and the VME index of c-squares. No c-squares meet the criteria outline in Section 4.1 so all are shown as transparent. The key records for the area have been circled with a red dashed line.

4.5.3 Spanish Continental Shelf Break – Galicia Bank

4.5.3.1 Sources of information

While no VME records for Galicia Bank were available from the VME database, known VME records were identified from peer review scientific papers and the OSPAR 2015 habitat database.

Records were identified from Serrano *et al.*, 2017a and b. The same records were also present within the OSPAR 2015 habitats database, from data submitted in 1997 by the Freidrich-Alexander University (FAU) in Germany, and newer data (2009–2011) submitted by the Spanish Institute of Oceanography (IEO).

4.5.3.2 Location

Galicia Bank is an isolated non-volcanic seamount, located 120 nautical miles west of the NW Spanish shoreline (Figure 4.12). Across its top surface, depths range from 600 m (to the SE) to approx. 2000 m (to the W), showing a significant increase in slope (the bank break) at around 1000–1400 m. At approx. 1200–2000 m, there is a transitional area between the summit and the bank break characterized by a slight increase in slope.

4.5.3.3 VME occurrences

- Cold-water coral reefs of *Lophelia pertusa* and *Madrepora oculata* (800–1000 m);
- Coral gardens with mixed abundance of *Acanella arbuscula*, *Swiftia rosea*, *Stephanocyathus crassus*, *Umbellula* sp. (1000–1800 m).

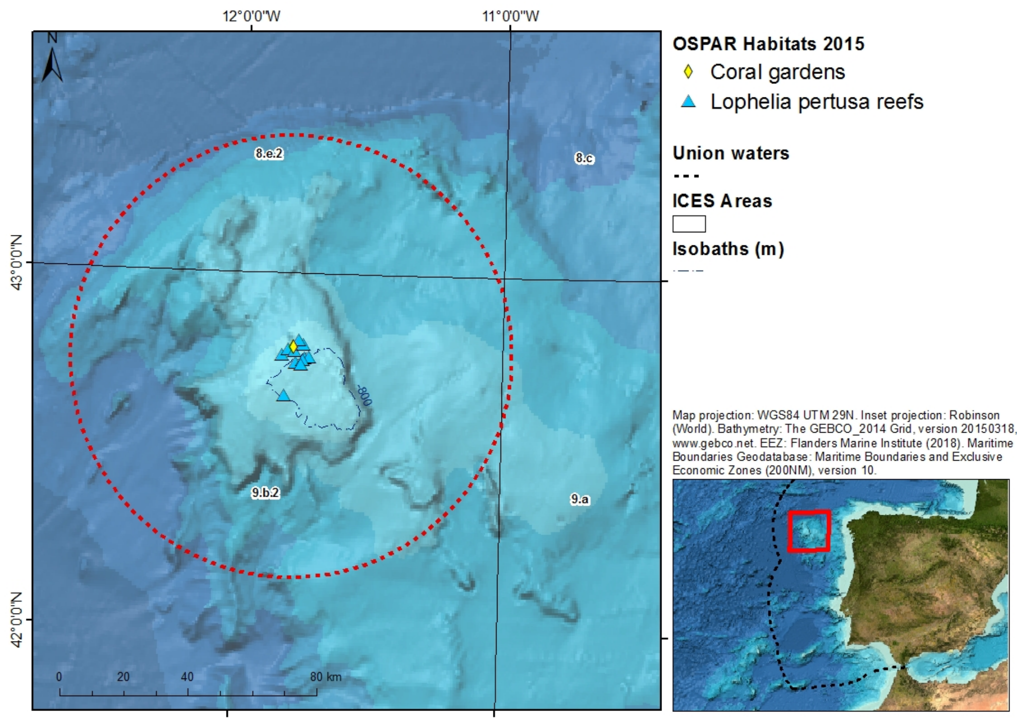

Figure 4.12. Map of Galicia Bank showing OSPAR habitat records that correlate with VME habitats. No records are present in the ICES VME database for this area. The key records for the area have been circled with a red dashed line.

4.5.4 Spanish Continental Shelf Break–Mud volcanoes of the Gulf of Cádiz

4.5.4.1 Sources of information

Known VME records for the Gulf of Cádiz on the Spanish continental shelf break were identified from the ICES VME database (Figure 4.13). Additional known VME records were identified from peer review scientific papers and the OSPAR 2015 habitat database.

Records from the VME database came from the Biogeography of Deep-Water Chemosynthetic Ecosystems (ChEss) project and represent the VME habitat 'cold seeps'. Additional VME habitat records were identified from Rueda *et al*. (2016), and a record of a deep-sea sponge aggregation was also identified from the OSPAR, 2015 habitats database from a 2011 Oceana survey at Guadalquivir Bank in the Gulf of Cádiz.

4.5.4.2 Location

The mud volcanoes are located at the upper and middle slope of the Spanish continental margin of the Gulf of Cádiz (Figure 4.13). The area consists of mud volcanoes, diapirs and diapir/mud volcano complexes, as well as other seabed features located nearby such as collapsed depressions, carbonate mounds and contourite deposits.

4.5.4.3 VME occurrences

- Cold seeps;
- Cold-water coral reefs dominated by *Lophelia pertusa* and *Madrepora oculata* (~360–400 m depth);
- Coral gardens with presence of several species (e.g. *Acanthogorgia hirsuta*, *A. granulata, Swiftia palida)* and different dominance (~350–530 m depth);
- Coral gardens dominated by *Leiopathes glaberrima* and other black corals (~360–700 m);
- Sponge fields dominated by *Asconema setubalenses* (~350–670 m);
- Sponge fields dominated by desmosponges (~350–670 m);
- Sponge fields dominated by *Pheronema carpentieri* (~835–1000 m);
- Sponge fields dominated by *Thenea muricata* (~480–1172 m);
- Coral gardens formed by *Isidella elongata* (~500–1172 m);
- Coral gardens formed by *Radicipes* (~500–950 m);
- Seapen fields (*Kophobelemnon stelliferum, Pennatula aculeata, Funiculina quadrangularis*) (~430–1000 m);
- Bathyal detritic bottoms with *Leptometra phalangium* (~490–595 m).

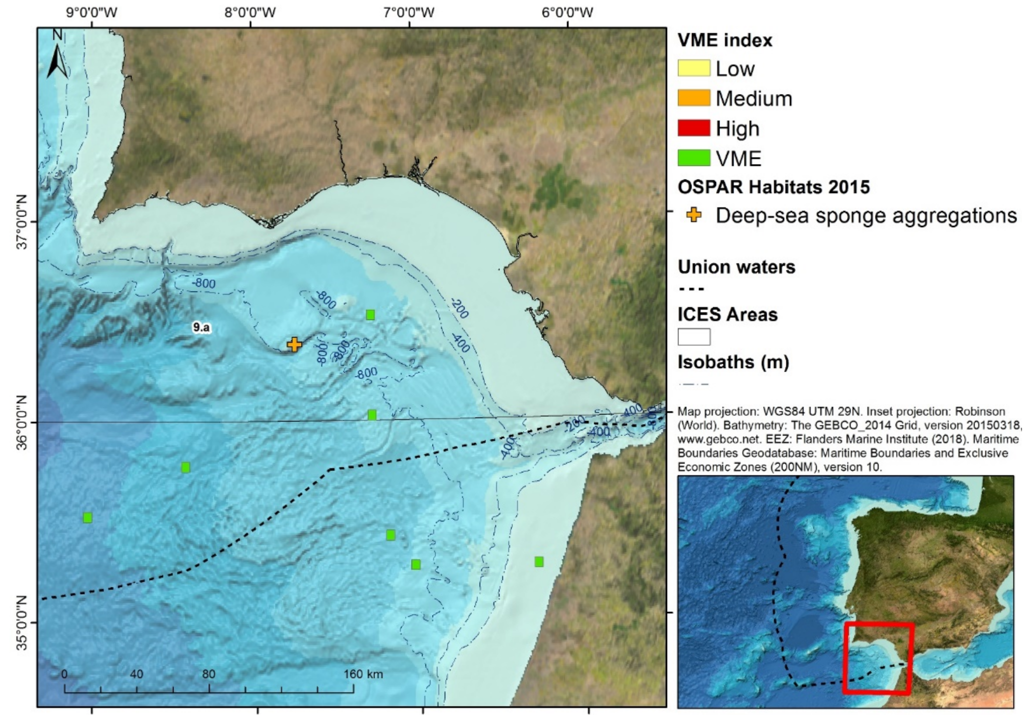

Figure 4.13. Map of the Gulf of Cádiz showing the OSPAR habitat records that correlate with VME habitats and the VME index of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour.

Table 4.3. A summary of depth bands where VMEs occur, or are likely to occur, in ICES Area IX.

Area where VMEs occur, or are likely to occur	Country EEZ	Depth >800 m	Depth from 400 m–800 m	Depth from 200 m–400 m
Ormonde Seamount	Portugal	Yes	Yes	Yes
La Gaviera canyon and Avilés canyon	Spain	Yes	Yes	-
Le Danois Bank	Spain	Yes	-	-
Galicia Bank	Spain	Yes	-	-
Mud volcanoes in Gulf of Cadiz	Spain	Yes	Yes	-

4.6 ICES Area X

4.6.1 Azores seamounts–Condor and Cabeço do Luís Seamounts

4.6.1.1 Sources of information

While no VME records for the Condor and Cabeço do Luís seamounts were available from the VME database, known VME records were identified from peer review scientific papers, and confirmed with data from the OSPAR 2015 habitat database (Figure 4.14).

Records were identified from the following peer review sources:

- Orejas *et al.*, 2017;
- de Matos *et al.*, 2014;

- Tempera *et al.*, 2012.

Records were also present within the OSPAR, 2015 habitats database, submitted by the Institute of Marine Research (IMAR), Azores, Portugal.

4.6.1.2 Location

The Azores is a Northeast Atlantic archipelago composed by nine islands of recent volcanic origin within the Portuguese EEZ. The Azores region comprises more than 460 seamounts. Most are small and deep but some are large and may rise from abyssal and bathyal depths into the epipelagic layer.

Condor seamount (A, Figure 4.14) is a ridge seamount located about 17 km to the WSW of Faial Island in the Azores. This ridge volcano is 39 km long and 23 km wide, with sloping flanks extending to over 1800 m depth from a narrow, flattened summit developing between 180 m and 250 m.

Cabeço do Luís Seamount (B, Figure 4.14) is a small volcanic elevation located one nautical mile away from the southwest coast of Pico Island, on the southern flank of the Faial-Pico Passage. The hill has a conical shape and rises from depths of 400 m in the north and 700 m in the south, culminating in a shallow peak at approximately 150 m.

4.6.1.3 VME occurrences

Condor seamount

- Cold-water coral reefs;
- Coral gardens of *Viminella flagellum* and *Dentomuricea* sp. (depth: 200–270 m);
- Coral gardens of a large primnoid gorgonian (depth: 200–270 m);
- Coral gardens of *Narella* cf. *bellissima* and sponges (*Pheronema carpentieri*) (750–1070 m);
- Coral gardens of *Candidella imbricata* (750–1070 m);
- Sponge fields dominated by *Pheronema carpenteri* (730 m).

Cabeço do Luís Seamount

- Coral garden of the black coral *Anthipatella subpinnata* extending from 150 to 196 meters depth. The coral gardens cover a surface area of approximately 67 333 m^2. Average colony density was 0.75 colonies/m^2, with a maximum density of 2.64 colonies/m^2 observed between 155 and 165m depths.

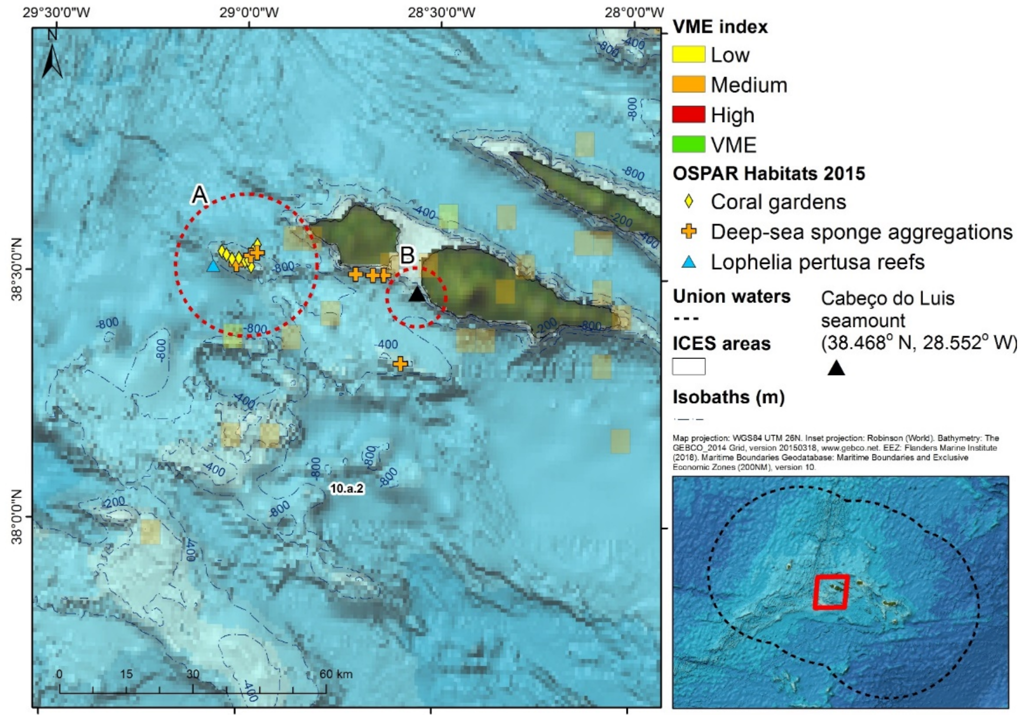

Figure 4.14. Map of the Condor Seamount (A) and Cabeço do Luís Seamount (B) showing OSPAR habitat records that correlate with VME habitats and the VME index of c-squares. No c-squares meet the criteria outline in Section 4.1 so all are shown as transparent. The key records for the area have been circled with a red dashed line.

4.6.2 Azores seamounts–Formigas Seamount

4.6.2.1 Sources of information

No VME records for the Formigas seamounts were available from the VME database. As such, known VME records were identified from peer review scientific papers and the OSPAR 2015 habitat database (Figure 4.15).

Known VME records for Formigas Seamount were identified from the following peer review sources:

- Orejas *et al*., 2017;
- de Matos *et al*., 2017;
- Tempera *et al*., 2012.

An old (1969) record of a coral garden was also identified from the OSPAR, 2015 habitats database, submitted by the Institute of Marine Research (IMAR), Azores, Portugal.

New VME data from Formigas seamount obtained during the MEDWAVES cruise (see Section 3.3.5) will be submitted to the ICES VME database for the WGDEC 2019 data call.

4.6.2.2 Location

Formigas Islets are part of a promontory named Formigas Bank. This promontory is located next to the junction of the East Azores Fracture Zone (EAFZ) and Terceira Rift; a rift belt that extends from the Mid-Atlantic Ridge to EAFZ crossing through Graciosa, Terceira and São Miguel Islands.

4.6.2.3 VME occurrences

- Coral gardens.

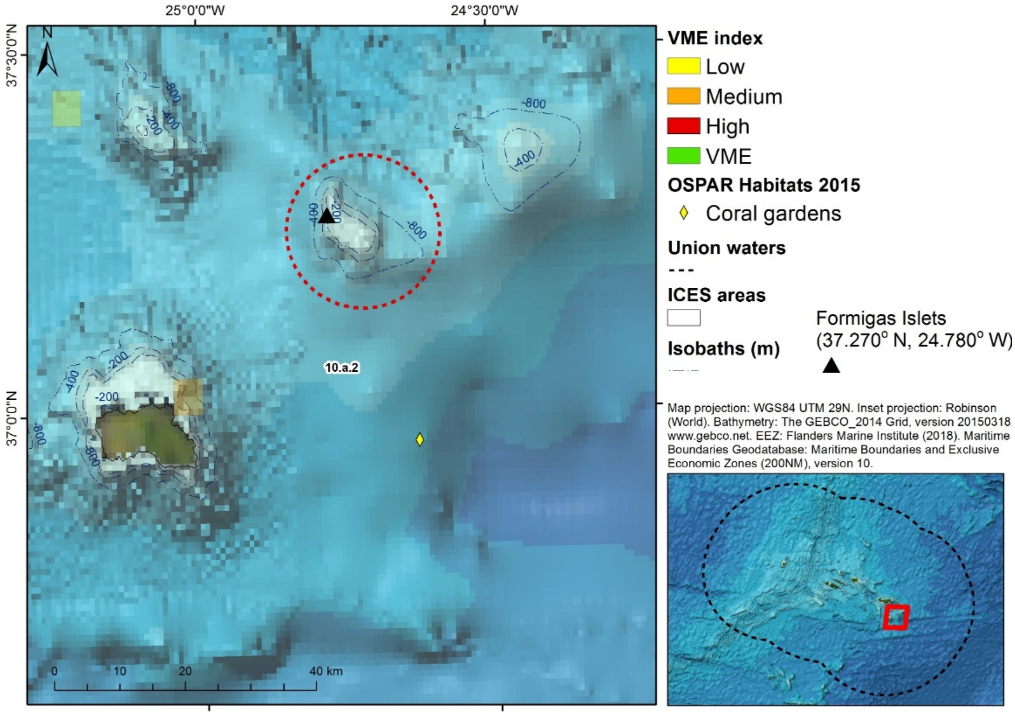

Figure 4.15. Map of the Formigas seamount showing OSPAR habitat records that correlate with VME habitats and the VME index of c-squares. No c-squares meet the criteria outline in Section 4.1 so all are shown as transparent. The key records for the area have been circled with a red dashed line.

4.6.3 Azores-Mid-Atlantic Ridge

4.6.3.1 Sources of information

Known VME records for the Mid Atlantic Ridge identified from the ICES VME database (Figure 4.16). Additional known VME records were identified from the OSPAR 2015 habitat database.

Records from the VME database came from the Interridge vent database[4] and represented the VME habitat 'Hydrothermal vents/fields'. Records from the OSPAR, 2015 database were from a range of surveys, submitted by the Institute of Marine Research (IMAR), Azores, Portugal.

4.6.3.2 Location

The area of the Mid-Atlantic Ridge considered here was within the Portuguese EEZ to the southeast of Corvo and Ilha das Flores in the Azores archipelago.

4.6.3.3 VME occurrences

- Coral gardens;
- Deep-sea sponge aggregations;

[4] http://vents-data.interridge.org/

- Cold-water coral reefs.

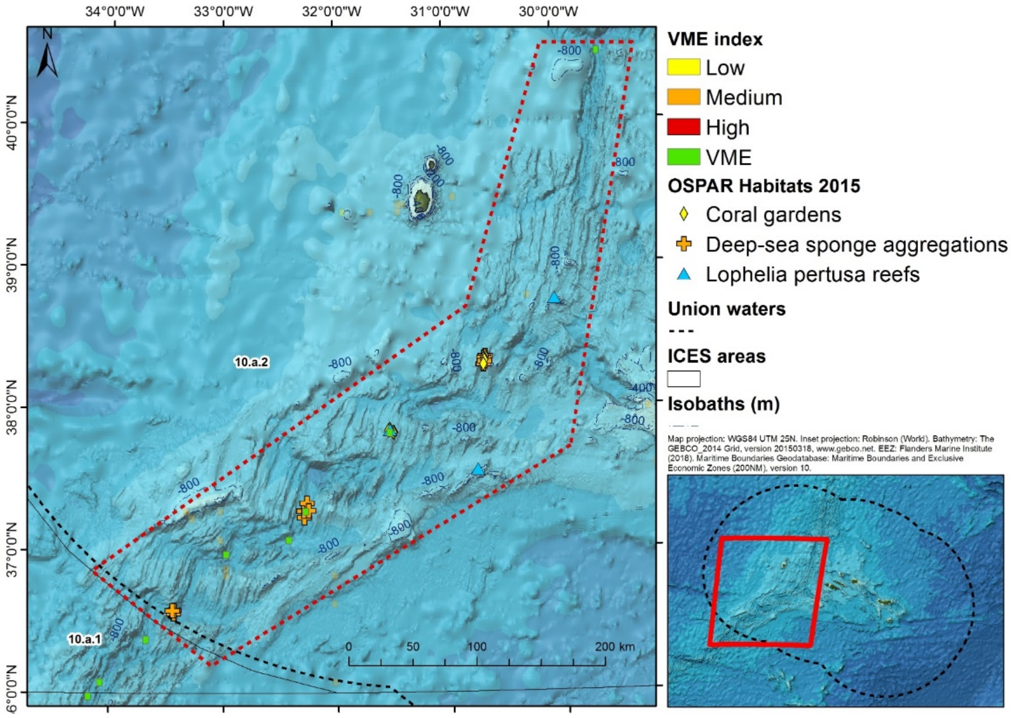

Figure 4.16. Map of the Mid-Atlantic Ridge within the Portuguese EEZ showing the OSPAR habitat records that correlate with VME habitats and the VME index of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour while those that do not are shown as transparent.

4.6.4 Azores-seabed between Terceira Island and São Miguel Island

4.6.4.1 Sources of information

Known VME records for the area of seabed between Terceira Island and São Miguel Island in the Azores were available from the VME database and the OSPAR, 2015 habitat database (Figure 4.17).

Records from the VME database came from the Interridge vent database and represented the VME habitat 'Hydrothermal vents/fields'. Records from the OSPAR, 2015 database were from a range of surveys, submitted by the Institute of Marine Research (IMAR), Azores, Portugal.

4.6.4.2 Location

The area covered lies between the Terceira Island and São Miguel Island in the Azores within the Portuguese EEZ.

4.6.4.3 VME occurrences

- Hydrothermal vents/fields;
- Coral gardens;
- Deep-sea sponge aggregations;
- Cold-water coral reefs.

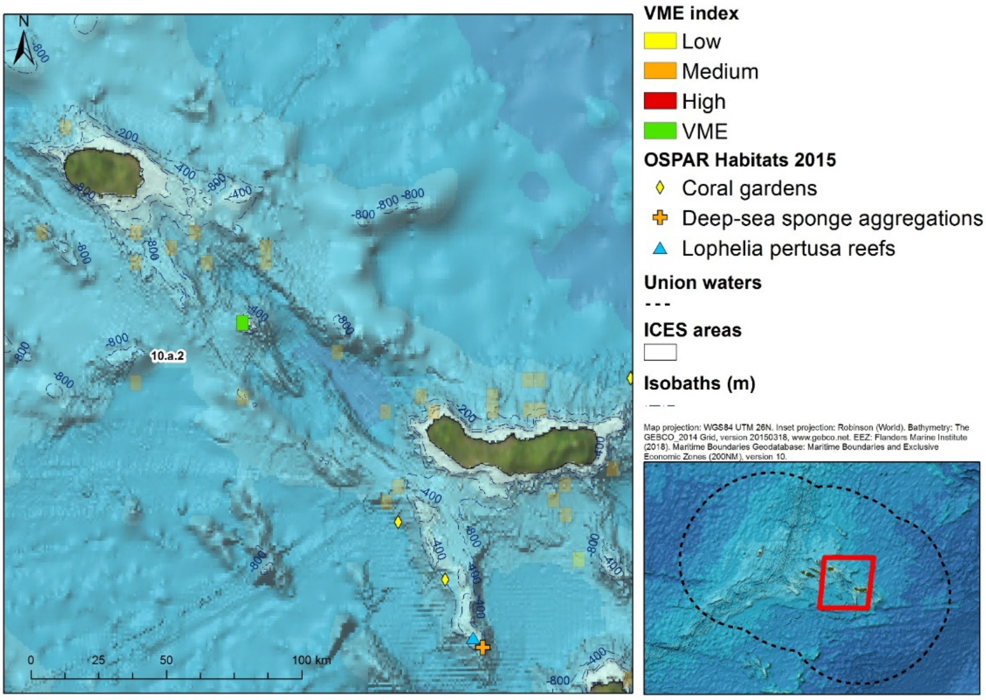

Figure 4.17. Map of seabed between Terceira Island and São Miguel Island showing the OSPAR habitat records that correlate with VME habitats and the VME index of c-squares. C-squares that meet the criteria outline in Section 4.1 are shown as solid colour while those that do not are shown as transparent.

Table 4.4. A summary of depth bands where VMEs occur, or are likely to occur, in ICES Area X.

Area where VMEs occur, or are likely to occur	Country EEZ	Depth >800 m	Depth from 400 m–800 m	Depth from 200 m–400 m
Azores - Condor and Cabeço do Luís Sea-mounts	Portugal	Yes	Yes	Yes
Azores - Formigas Seamount	Portugal	Yes	Yes	
Azores - Mid Atlantic Ridge	Portugal	Yes		
Azores - Seabed between Terceira Island and Sao Miguel Island	Portugal	Yes		

4.7 References

Louzao, M., Anadon, N., Arrontes, J., Alvarez-Claudio, C., Fuente, D.M., Ocharan, F., Anadon, A., and Acuna, J.L. 2010. Historical macrobenthic community assemblages in the Avilés Canyon, N Iberian Shelf: Baseline biodiversity information for a marine protected area. J Mar Syst 80:47–56.

de Matos, V., Gomes-Pereira, J.N., Tempera, F., Ribeiro, P.A., Braga-Henriques, A., and Porteiro, F. 2014. First record of *Antipathella subpinnata* (Anthozoa, Antipatharia) in the Azores (NE Atlantic), with description of the first monotypic garden for this species. Deep-Sea Research Part Ii-Topical Studies in Oceanography 99:113–121.

Orejas, C., Addamo, A., Alvarez, M., Aparicio, A., Alcoverro, D., Arnaud-Haond, S., and Zein, M. 2017. Cruise summary report - MEDWAVES survey (MEDiterranean out flow WAter and Vulnerable EcosystemS). Zenodo. http://doi.org/10.5281/zenodo.556516

Rueda, J.L., Gonzalez-Garcia, E., Krutzky, C., Lopez-Rodriguez, F.J., Bruque, G., Lopez Gonzalez, N., Palomino, D., Sanchez, R.F., Vazquez, J.T., Fernandez-Salas, L.M., and Diaz-del-Rio, V. 2016. From chemosynthesis-based communities to cold-water corals: Vulnerable deep-sea habitats of the Gulf of Cadiz. Marine Biodiversity 46:473–482.

Sánchez, F., Serrano, A., Parra, S., Ballesteros, M., and Cartes, J.E. 2008. Habitat characteristics as determinant of the structure and spatial distribution of epibenthic and demersal communities of Le Danois Bank (Cantabrian Sea, N. Spain). J Mar Syst 72:64–86.

Sánchez, F., Serrano, A., and Ballesteros, M.G. 2009. Photogrammetric quantitative study of habitat and benthic communities of deep Cantabrian Sea hard grounds. Cont Shelf Res 29:1174–1188.

Sánchez, F., González-Pola, C., Druet, M., García-Alegre, A., Acosta, J., Cristobo, J., Parra, S., Ríos, P., Altuna, Á., and Gómez-Ballesteros, M. 2014. Habitat characterization of deep-water coral reefs in La Gaviera Canyon (Avilés Canyon System, Cantabrian Sea). Deep Sea Research Part II: Topical Studies in Oceanography.

Serrano, A., Cartes, J.E., Papiol, V., Punzón, A., García-Alegre, A., Arronte, J.C., Ríos, P., Lourido, A., Frutos, I., and Blanco, M. 2017a. Epibenthic communities of sedimentary habitats in a NE Atlantic deep seamount (Galicia Bank). Journal of Sea Research 130:154–165.

Serrano, A., González-Irusta, J.M., Punzón, A., García-Alegre, A., Lourido, A., Ríos, P., Blanco, M., Gómez-Ballesteros, M., Druet, M., Cristobo, J., and Cartes, J.E. 2017b. Deep-sea benthic habitats modeling and mapping in a NE Atlantic seamount (Galicia Bank). Deep Sea Research I.

Tempera, F., Giacomello, E., Mitchell, N.C., Campos, A.S., Braga-Henriques, A., Bashmachnikov, .I, Martins, A., Mendonça, A., Morato, T., Colaço, A., Porteiro, F.M., Catarino, D., Gonçalves, J., Pinho, M.R., Isidro, E.J., Santos, R., and Menezes, G. 2012. Mapping Condor Seamount Seafloor Environment and Associated Biological Assemblages (Azores, NE Atlantic) In: Harris PT, Baker EK (eds) Seafloor geomorphology as benthic habitat: GeoHab Atlas of seafloor geomorphic features and benthic habitats. Elsevier, London.

5 Summarize existing knowledge of ecosystem functioning of deep-sea benthic communities and habitats and the ecosystem roles of chemical/physical structures such as vents, seeps, seamounts, canyons, etc. - ToR [c]

5.1 Introduction

WGDEC previously undertook an extensive review of new evidence from recent literature on ecosystem functioning and services of vulnerable marine ecosystem (VME) indicators in the North Atlantic, with a particular focus on results generated by the CoralFISH project (ICES, 2015). At that time, the available evidence suggested that:

- VMEs support higher abundance and diversity of fish through different mechanisms (habitat provision, nursery function, protection from predators, enhancement of food quantity and quality).
- VMEs provide support for secondary production (invertebrate abundance and biomass) and diversity across most, if not all, size ranges (micro-, meio-, macro- and megafauna).
- Habitat complexity is an important contributor to enhanced fish and invertebrate assemblages, and not necessarily linked only to VME presence.
- VMEs, particularly cold-water coral (CWC) reefs, contribute significantly to organic carbon processing, directly and indirectly.
- VMEs contribute significantly to water circulation and C/CO_2 exchange through physical modification of their environment, activity and growth, and supporting vertebrate and invertebrate production.
- Through biodiversity support and uniqueness of associated assemblages, VMEs hold significant potential for bioprospecting.

It was also noted that further research was needed to document the variety, quantity and quality of ecosystem functions of various VMEs.

The intention here was not to repeat the exercise from 2015, but rather take it as a starting point for investigating the latest scientific literature on the ecosystem functioning of VMEs, and of deep-sea benthic ecosystems more widely. The scope was widened beyond VME indicators, to include VME habitats and elements[5]. This review is not exhaustive, but represents an overview of the key insights from new investigations on ecosystem functionality in the deep sea. The text is organized into sections highlighting advances in different fields.

5.2 Overview of latest studies that provide new insight to the functionalities of the deep-sea benthic communities/habitats or ecosystems

In 2017, the journal of Deep-Sea Research Part II published an introduction and overview of advances in deep-sea biology: biodiversity, ecosystem functioning and conservation. The overview was based on the papers and material presented at the 14th Deep-

[5] For definitions and listings of VME indicators, habitats and elements, we refer to NEAFC amendment of Recommendation 19:2014 (through Recommendation 9:2015) at the NEAFC website: http://www.neafc.org/rec/2014/19.

Sea Biology Symposium (14DSCS), held in Averio, Portugal in 2015. An additional review published in 2017 examined the major impacts of climate change on deep-sea benthic ecosystems (Sweetman *et al.*, 2017), providing a detailed overview of the impacts changing environmental parameters will have on deep-sea benthic ecosystems by 2100. They also considered how these changing environmental parameters could combine with anthropogenic stressors. Both of these recent overviews provide a sound basis when considering our knowledge of ecosystem functioning of deep-sea benthic communities and habitats.

This section will be considered across five main categories:

Biological traits: comprising biodiversity (locally and globally), biodiversity ecosystem functioning (temporal and small scale), trophic ecology related studies including energy flow, biochemical cycling (i.e. carbon-, nitrogen-, oxygen cycles), energy recycling, sponge loop.

4) Functions in ecological elements: Deep-sea elements including the small-scale reefs (coral and sponge), vent systems (hydrothermal and seeps) to the large-scale elements like seamounts, canyons and continental slopes.

5) Population connectivity; including larval dispersal, species distribution pathways, population genetic.

6) Changes, pressure and impact: Understanding potential impact of global changes (climate change) and anthropogenic impact (i.e. fisheries, mining, disposals).

7) Conservation and management measures: need for conservation of different habitats or species calls for multidisciplinary studies, predictive measures, modelling.

5.2.1 Biological traits

5.2.1.1 Trophic relationship-tracing the origin of the food source

Many recent studies focus on topics related to *trophic ecology;* how the benthic systems transfer the fluxes in the water mass through biochemical cycles, to another trophic level. Researches have focused on both different habitat types (such as seeps, continental slope, coral reefs and sponge aggregations) and species (such as specific sponge species, Asteroidea, fish and shrimp).

The practice of using the stable isotope analysis (SIA) within specific ecosystems or habitats is now commonplace to trace 'who eats who'. SIA is used to study the diets of fish (Parzanini *et al.*, 2017; Kopp *et al.*, 2017), deep-water shrimp (Bayhan *et al.*, 2015; Cartes *et al*., 2014) and deep-sea asteroids (Gale *et al*., 2013). Furthermore, it is also being used at the wider ecological/habitat level, showing how different species contribute to the trophic web.

The high biodiversity of coral reefs results in complex trophic webs where energy and nutrients are transferred between species through a multitude of pathways (Rix *et al*., 2018). The prominent role of coral reefs and adjacent sponge grounds in biogeochemical cycling in the food-limited deep ocean is increasingly supported (White *et al*., 2012; Cathalot *et al*., 2015). CWCs can act as *ecosystem engineers* boosting organic matter deposition at the seafloor by altering internal currents (van Oevelen *et al*., 2009; Soetaert *et al*., 2016). Rix *et al*. (2018) demonstrated how sponges, in the vicinity of CWCs, transfer coral-derived organic matter (DOM) and make it accessible to the associated reef fauna, confirming that sponges provide a trophic link between corals and higher trophic levels. Sponge aggregations have also been shown providing assailable C and N to fuel the food chains of oligotrophic reefs (Maldonado *et al*., 2016).

Measuring the magnitude of seawater filtering by sponge communities in Northern Norway demonstrate the important role of these communities to the benthic boundary layer (Kutti *et al*., 2013). The glass sponge reefs formed by the hexactinellid sponge *Aphrocallistes vastus* in the northeast Pacific extract seven times more carbon (3.4±1.4 g C m^{-2} d^{-1}) than can be supported by vertical flux of total carbon alone: this means that these sponge reefs require productive waters and steady currents to sustain this need for carbon (Kahn *et al*., 2015). This needs to be considered as climate change and ocean conditions rapidly change in the next century and since there is a high likelihood that feeding/filtering by deep-sea sponges are sensitive to both biotic and abiotic changes (Robertson *et al*., 2017). Different foodwebs for seeps and vents relying on methanotrophs and thiotrophs respectively, have been revealed (Portail *et al*., 2016).

5.2.1.2 Microbes, viruses and the sediment

The role of microbes and even viruses is very little understood, but is gaining more attention. Microbes may comprise a fraction of the sponges' total carbon budget (Leys *et al*., 2018). In addition to carbon and nitrogen, genomic analyses in the deep-sea glass sponge *Lophophysema eversa* also revealed autotrophic sulphide scavengers (Tian *et al*., 2016). Microbial communities on ferromanganese crusts potentially play a significant role in biogeochemical cycling between oceans and seamounts (Nitahara *et al*., 2017).

New insights for evaluating deep-sea viral diversity are provided with metagenomic analysis, (the study of genetic material recovered directly from environmental samples). These analyses reveal that the deep-sea sediments are a hot spot of novel viral genotypes and functions (Corinaldesi *et al*., 2017). The interaction between viral infections and archaea in deep-sea sediment are indicated to play a profound, previously underestimated role in the functioning of deep-sea ecosystems and in global biogeochemical cycles (Danovaro *et al*., 2016).

5.2.2 Ecological elements

5.2.2.1 Small-scale elements

Smaller elements, like hydrothermal vents, seeps, coral reefs and sponge reefs or aggregations, have been shown to be very important to their associated fauna, providing habitat, feeding grounds, refuge, etc.

While cold-water corals (CWCs), and now more increasingly, sponge aggregations and reefs have for some time received considerable attention, cold seeps and hydrothermal vents are types of ecosystems that are gaining attention. Still very little is known about the functions of these systems. Portail *et al*. (2016) showed a high similarity in ecosystem functioning in vents and seeps despite the environmental differences, suggesting that the ecological niches are not specifically linked to the nature of fluids. Studies indicate that these systems can be beneficial for animals like bacteria, shells, polychaetes, and even fish. Interesting new discoveries on how hydrothermal vents and cold seeps play an important role for deep-water ecosystem functioning are shown in the unique behaviour of a deep-sea skate which seems to actively use the high temperature of a hydrothermal vent in Galápagos to naturally incubate egg cases (Salinas de León *et al*., 2018). Cold-seep ecosystems are also believed to have served as nurseries for predatory elasmobranch fishes (skate and sharks) since at least the late Eocene period (Treude *et al*., 2011).

Authigenic carbonate rocks at methane seeps are important features, hosting high diversity and abundance of invertebrate assemblages. The significant influence of seepage activity on taxonomic composition, density, diversity and biological traits have been documented. For example, rocks exposed to active seepage had 34 times higher total macrofaunal densities than under inactive conditions (Levin *et al*., 2017).

At Del Mar Methane Seep the diverse biogenic microhabitats, like clam beds, carbonate rocks, microbial mats, polychaeta beds, vestimentiferan tubeworm clumps, and fields of *Bathysiphon filiformis* tubes, create a biomass hot spot. The chemosynthetic production enhances also animal densities outside the seep center (Grupe *et al.*, 2015).

The structural function of CWCs is well documented, and their role in biochemical cycling is slowly being uncovered. CWCs occur across a wide environmental habitat range; their wide range has been partly explained by the availability of particulate matter, which is their food source (Buhl-Mortensen *et al.*, 2016).

5.2.2.2 Large-scale elements

Large geomorphological features, like canyons, seamounts and slopes can be considered as ecosystems in their own right. Within these features, there may be unique cycles of currents, nutrient flows and distribution of species.

5.2.2.3 Canyons and seamounts

Submarine canyons and seamounts are large geomorphic elements that are known to host vulnerable habitats, putting them in the focus of conservation interest. They are considered as vulnerable marine ecosystem (VME) elements (ICES, 2013). The importance of canyons as a habitat for gorgonian corals, sea pens and sponges were tested using Maxent[6] modelling by Miller *et al*. (2015), who showed that canyons seemed to contain more high-quality habitat for structure-forming invertebrates compared to other slope areas. Canyons were also found to support abundant and diverse fish communities. Other habitats such as CWC reefs and methane seeps can also be found in canyons (Ross *et al*., 2015). Fernandez-Arcaya *et al*. (2017) highlighted the need for a better understanding of anthropogenic impacts on canyon ecosystems and proposed research ideas to help inform management measures to protect canyon ecosystems.

Victorero *et al*. (2018) investigated the processes behind beta-diversity found in seamounts. Beta diversity measures the change in diversity of species from one environment to another. They identified ecologically unique sites on the Annan Seamount (Equatorial Atlantic) and distinguished between two beta-diversity processes: species replacement and changes in species richness over a depth gradient. They found that the key difference between communities was the identity of the species, rather than the number of species.

5.2.2.4 Deep seabed sediments

It has been suggested that heterogeneity of the deep seabed can influence ecosystem functions and the relationship between biodiversity and ecosystem functioning (BEF) (Zeppilli *et al*., 2016). Deep-sea sediments represent the largest but least known ecosystem on earth. Sinniger *et al*. (2016) demonstrated the potential of eDNA metabarcoding

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[6] https://www.gbif.org/tool/81279/maxent

from sediment samples of the bathyal and abyssal depths worldwide to accelerate the assessment of deep-sea biodiversity. They also emphasized the necessity to integrate such new approaches with traditional morphology-based examination of deep-sea organisms. Although the method is promising, the main challenge from a taxonomic perspective in deep-sea biodiversity research is to expand the reference database (Sinniger *et al*., 2016).

5.2.3 Population connectivity–distribution

5.2.3.1 Larval dispersal in the deep sea

Deep-sea benthic species can have wide distributional range. Interestingly, larvae of the endemic deep-sea methane seeps mussel species *Bathymodiolus childressi* and an associated gastropod, *Bathynerita naticoidea*, were found to be transported for extended periods of time in the euphotic zone, sometimes dispersing for more than one year (Arellano *et al*., 2014). This study may partly explain the genetic similarities between eastern and western Atlantic seep fauna.

Baco *et al*. (2016) showed that dispersal distances were generally greater for fishes than invertebrates, with mollusca being the least dispersive phylum sampled. Benthic species from soft-substrate habitats were generally less dispersive than species from hard substrate. Deep-sea reserve design will need to consider the enormous variety of taxa, life histories, hydrodynamics, spatial configuration of habitats and patterns of species distributions (Baco *et al*., 2016).

Hilário *et al*. (2015) assessed the current knowledge of planktonic larval duration (PLD) for deep-sea species and compared with those of shallow-water species; the PLD had been estimated for 21 species in the deep sea compared with 212 species from shallow waters. They showed that larvae of deep-sea species had longer PLDs than shallow-water species.

5.2.3.2 Modelled distribution

Predictive habitat and species distribution models for the deep sea are continually evolving (Robert *et al*., 2016; Bennecke and Metaxas, 2017). These models help to make informed decisions about managing the deep-sea environment in the absence of extensive actual observations (Gonzales-Mirelis and Buhl-Mortensen, 2015).

5.2.4 Changes, pressure and impact

5.2.4.1 Climate change

There is an increasing demand to better understand the potential impact of global changes, such as ocean acidification (OA) linked to climate change, on different habitats or species. The effects of climate change in the deep sea, such as temperature rise, OA, deoxygenation, changes in thermohaline circulation and altered foodwebs may threaten biodiversity and expose vulnerable ecosystems to stress (Levin and Le Bris, 2015; Rahmstorf *et al*., 2015; Yamamoto *et al*., 2015).

Sweetman *et al*. (2017) provided an overview of the potential impacts of changing environmental parameters on deep seafloor ecosystems. Using an Earth-system-model analysis, they predicted what changes will most likely be seen by 2100 in continental margin, abyssal and Polar regions. During the process, they used expert opinion, current literature and the output of the IPCC (Intergovernmental Panel on Climate Change) Fifth Assessment Report (AR5) models. They also considered how these changes may combine with other anthropogenic stressors (e.g. fishing, mineral mining, oil and gas extraction) to further impact deep seafloor ecosystems and discussed the possible societal implications. Their predictions showed that the highest temperature changes were likely to occur at the abyssal seafloor in the North Atlantic, Southern and Arctic oceans. They presented the findings of Mora *et al*. (2013) who modelled water temperature increases of 3.6°, 4.4° and 3.7°C in the Pacific, Atlantic, and Arctic Oceans respectively, with lower temperature increases in the Indian and Southern Oceans. In the North Atlantic and in the Arctic waters, changes related to climate change have already been observed. Warming and salinification in the deep Greenland Sea over the last three decades are among the highest trends in the deep oceans, contributing to an increase in World Ocean heat content and global sea level rise (Somavilla *et al*., 2013). This is also the case in bathyal waters off Antarctica (Purkey and Johnson, 2010).

Experiments have been carried out to explore the effects of future OA scenarios on CWC reefs. The work highlighted that not only the living part of the reef, but the dead coral framework would be affected by OA, with dramatic consequences for the reef structure but also to the associated fauna (Hennige *et al*., 2015). Biastoch *et al*. (2011) highlighted the risk around the release of methane (CH4) stored in continental margin sediments through global warming.

5.2.4.2 Industrial mining

The development of deep-ocean industrial mining is an emerging pressure in the deep sea. Polymetallic nodules in the abyssal plains, deposits of seafloor massive polymetallic sulphides (SMS) from hydrothermal vents and cobalt crusts from seamounts are all considered to be at risk from deep-sea mining activities (Hilário *et al*., 2015). Levin *et al*. (2016), outlined the potential impacts from deep-seabed mining: direct removal and destruction of seafloor habitat and organisms; alteration of the substrate and its geochemistry; modification of sedimentation rates and foodwebs; changes in substrate availability, heterogeneity and flow regimes; suspended sediment plumes; released toxins and contamination associated with noise, light or chemical leakage during the extraction and removal processes.

Studies by Vanreusel *et al*. (2016) on polymetallic nodule mining sites have shown almost complete removal of epifauna and slow recovery after mining. They also found that VME indicator species such as black coral and alcyonaceans were correlated to the presence of polymetallic nodules.

5.2.4.3 Fisheries / Trawling

Compared with untrawled areas, trawled sediments in the deep-sea regions are characterized by a lower organic carbon (C) turnover and are significantly depleted in organic matter content, meiofauna abundance and biodiversity, and nematode species richness and individual biomass (Pusceddu *et al*., 2014). The effects of deep-sea trawling extend not only to food availability for the benthos but also to the key ecosystem function of C cycling. Therefore, in deep-sea ecosystems, persistent trawling-induced resuspension of large amounts of high-quality nutritional resources, coupled with a slowdown of the organic C cycling, indicates that bottom trawling can exacerbate the natural food limitation of the deep-sea sediments. (Pusceddu *et al*., 2014).

5.2.4.4 Microplastics and disposals

Microplastics are a relatively recent threat, which is gaining attention, albeit mainly in coastal waters. Woodall *et al*. (2014) showed that the deep sea is not excluded from this theat. They found that in deep-sea sediments, levels of microplastic, in the form of fibres, was increased by four orders of magnitude (per unit volume) in deep-sea sediments from the Atlantic Ocean, Mediterranean Sea and Indian Ocean than in contaminated surface waters. They showed evidence that deep-sea sediments can form a large and formerly unknown repository of microplastics.

5.2.5 Conservation and management measures

Many of the studies in the deep sea are driven by the urgency to improve our understanding of the biodiversity, vulnerability, connectivity and functionality as anthropogenic pressure is rapidly increasing.

Initial attention (from a conservation and management perspective) was focused on cold-water corals, and now deep-sea sponge aggregations are gaining more attention. Both of these ecosystems are within the reach of fisheries, consequently, these are the most obvious threats to these ecosystems. But as there is increasing intention to utilize the deeper oceans and its resources, such as seafloor mining or hydrocarbon extraction, scientists have expanded their focus to examine these targeted areas. Studies in many of these areas have shown that they hold unique habitats, and species. Endemic organisms that have been found at vents are particularly at risk from habitat loss and localised extinction with mining activities, as they are expected to remove all large organisms and suitable habitat in the immediate area (Boschen *et al.*, 2016).

5.3 Conclusion

Managing the human activities in the deep sea and the ecosystem integrity calls for fundamental knowledge and understanding of the diverse ecosystems; function, diversity and fragility. This comprises evaluation of the risk of damage, species richness or habitat loss, the ability of affected populations to replace themselves, degradation of long-term natural productivity of habitats, functional destruction and how to predict the influence of dramatic changes, like climate change.

5.4 References

Arellano, S.M., Van Gaest, A.L., Johnson, S.N., Vrijenhoek, R.C. and Young, C.M. 2014. Larvae from deep-sea methane seeps disperse in surface waters. Proceedings of the Royal Society B 281.

Baco, A.R., Etter, R.J., Ribeiro, P.A., von der Heyden, S., Beerli, P., Kinlan, B.P. 2016. A synthesis of genetic connectivity in deep-sea fauna and implications for marine reserve design. Molecular Ecology 26. 3276–3298.

Bayhan K., Cartes J. and Fanelli E. 2014. Biological condition and trophic ecology of the deep-water shrimp *Aristaeomorpha foliacea* in the Levantine Sea (SW Turkey). Mediterranean Marine Science, 16(1), 103–116.

Bennecke S. and Metaxas A. 2017. Is substrate composition a suitable predictor for deep-water coral occurrence on fine scales? Deep-Sea Research Part I, 124. 55–65.

Biastoch A., Treude T., Rüpke LH., Riebesell U., Roth C., *et al*. 2011. Rising Arctic Ocean temperatures cause gas hydrate destabilization and ocean acidification. Geophysical research Letters. 38:8.

Boschen RE, Collins PC, Tunnicliffe V, Carlsson J, Gardner JPA, Lowe J, McCrone A, Metaxas A, Sinniger F, Swaddling A. 2016. A primer for use of genetic tools in selecting and testing the suitability of set-aside sites protected from deep-sea seafloor massive sulfide mining activities. Ocean & Coastal Management 122: 37–48.

Buhl-Mortensen, P., Buhl-Mortensen, L., Purser, A. 2016 Trophic Ecology and Habitat Provision in Cold-Water Coral Ecosystems. In: Marine Animal Forests, S. Rossi (ed.).

Cartes JE., Fanelli E., Kapiris K., Bayhan YK., Ligas A., López-Pérez C., Murenu M., Papiol V., Rumolo P and Scarcella G. 2014. Spatial variability in the trophic ecology and biology of the deep-sea shrimp *Aristaeomorpha foliacea* in the Mediterranean Sea. Deep Sea Reasearch Part I: Oceanographic Research Papers 87. 1–13.

Cathalot C., Van Oevelen D., Cox TJS., Kutti T., Lavaleye M., Duineveld G. and Meysman FJR. 2015. Cold-water coral reefs and adjacent sponge grounds: hotspots of benthic respiration and organic carbon cycling in the deep sea. Front. Mar. Sci. 2:37.

Corinaldesi C., Tangherlini M. and Dell'Anno A. 2017. From virus isolation to metagenome generation for investigating viral diversity in deep-sea sediments. Scientific Reports 7. 8355.

Danovaro R., Dell'Anno A., Corinaldesi C., Rastelli E., Cavicchioli R., Krupovic M., Noble R.T., Nunoura T. and Prangishvili D. 2016. Virus-mediated archaeal hecatomb in the deep seafloor. Science Advances 2:10.

Deep-Sea Research Part II, 137. 1–5. Advances in deep-sea biology: biodiversity, ecosystem functioning and conservation. An introduction and overview.

Fernandez-Arcaya U., Ramirez-Llodra E., Aguzzi J., Allcock AL., Davies JS., Dissanayake A., Harris P., Howell K., Huvenne VAI., Macmillan-Lawler M., Martín J., Menot L., Nizinski M., Puig P., Rowden AA., Sanchez F. and Van den Beld IMJ. 2017. Ecological Role of Submarine Canyons and Need for Canyon Conservation: A Review. Frontiers in Marine Science 4:5.

Gale KSP., Hamel J-F. and Mercier A. 2013. Trophic ecology of deep-sea Asteroidea (Echinodermata) from eastern Canada. Deep-Sea Research I, 80. 25–36.

Gonzalez-Mirelis G. and Buhl-Mortensen P. Modelling benthic habitats and biotopes off the coast of Norway to support spatial management. Ecological Informatics, 30. 284–292.

Grupe BM., Krach ML., Pasulka A.L. *et al*. 2015. Methane seep ecosystem functions and services from a recently discovered southern California seep. Marine ecology 36. 91–108.

Hennige SJ., Wicks LC., Kamenos NA., Perna G., Findlay HS. and Roberts JM. 2015. Hidden impacts of ocean acidification to live and dead coral framework. Proc Biol Sci, 282(1813).

Hilário A., Metaxas A., Gaudron SM., Howell KL., Mercier A., Mestre NC., Ross RE., Thurnherr AM and Young C. 2015. Estimating dispersal distance in the deep sea: challenges and applications to marine reserves. Frontiers in Marine Science 2:6. 1–14.

ICES. 2013. Section 1.5.5.3 Special request - Assessment of the list of VME indicator species and elements. Report of the ICES Advisory Committee 2013. ICES Advice, 2013. Book 1.

ICES. 2015. Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC), 16–20 February 2015, Horta, Azores, Portugal. ICES CM 2015/ACOM:27. 113 pp.

Kahn AS., Yahel G., Chu JW., Tunnicliffe V. and Leys SP. 2015. Benthic grazing and carbon sequestration by deep-water glass sponge reefs. Limnology and Oceanography, 60:78–88.

Kopp D., Robert M. and Pawlowski L. 2017. Characterization of food web structure of the upper continental slope of the Celtic Sea highlighting the trophic ecology of five deep-sea fishes. Journal of Applied Ichthyology, 34. 73–80.

Kutti T., Bannister R.J. and Fosså J.H. 2013. Community structure and ecological function of deep-water sponge ground in the Traenadypet MPA-Northeren Norway continental shelf. Continental Shelf Research, 69. 21–30.

Levin LA. and Le Bris N. 2015. The deep ocean under climate change. Science, 350 (6262). 766–768.

Levin LA., Baco AR., Bowden DA., Colaco A., Cordes EE., Cunha MR., Demopoulos AWJ., Gobin J., Grupe BM., Le J., Metaxas A., Netburn AN., Rouse GW., Thurber AR., Tunnicliffe V., Lee Van Dover C., Vanreusel A. and Watling L. 2017. Hydrothermal Vents and Methane Seeps: Rethinking the Sphere of Influence. Frontiers in Marine Science, 3:72.

Leys SP., Kahn AS., Fang JKH., Kutti T. and Bannister RJ. 2018. Phagocytosis of microbial symbionts balances the carbon and nitrogen budget for the deep-water boreal sponge *Geodia barretti*. Limnology and Oceanography, 63:1. 187–202.

Maldonado M., Aguilar R., Bannister RJ., Bell JJ., Conway KW., Dayton PK., Díaz C., Gutt J., Kelly M., Kenchington ELR., Leys SP., Pomponi SA., Rapp HT., R€utzler K., Tendal OS., Vacelet J. and Young CM. 2016. Sponge Grounds as Key Marine Habitats: A Synthetic Review of Types, Structure, Functional Roles, and Conservation Concerns. IN: S. Rossi (ed.), Marine Animal Forests.

Miller RJ., Juska C. and Hocevar J. 2015. Submarine canyons as coral and sponge habitat on the eastern Bering Sea slope. Global Ecology and Conservation 4. 85–94.

Mora C., Wei C-L Rollo A., Amaro T., Baco AR. *et al*. 2013. Biotic and human vulnerability to projected changes in ocean biogeochemistry over the 21st century. PLoS Biology 11: e1001682.DOI: http://dx.doi.org/10.1371/journal.pbio.1001682.

Nitahara S., Kato S., Usui A., Urabe T., Suzuki K. and Yamagishi A. 2017. Archaeal and bacterial communities in deep-sea hydrogenetic ferromanganese crusts on old seamounts of the northwestern Pacific. PLOS ONE 12 (2).

Parzanini C., Parrish CC., Hamel J-F. and Mercier A. 2017. Trophic ecology of a deep-sea fish assemblage in the Northwest Atlantic. Marine Biology 164: 206.

Portail M, Olu K, Dubois SF, Escobar-Briones E, Gelinas Y, Menot L and Sarrazin J. 2016. Food-Web Complexity in Guaymas Basin Hydrothermal Vents and Cold Seeps. PLOS ONE 11 (9).

Purkey SG. and Johnson GC. 2010. Warming of global abyssal and deep Southern Ocean waters between the 1990s and 2000s: Contributions to global heat and sea level rise budgets. J Clim 23: 6336–6351.

Pusceddu A., Bianchelli S., Martín J., Puig P., Palanques A., Masqué P. and Danovaro R. 2014. Chronic and intensive bottom trawling impairs deep-sea biodiversity and ecosystem functioning. PNAS 111:24. 8861–8866.

Rahmstorf S., Box JE., Feulner G., Mann ME. and Robinson A. *et al*. 2015. Exceptional twentieth-century slowdown in Atlantic Ocean overturning circulation. Nature Clim Change 5: 475–480.

Rix L., de Goeij JM., van Oevelen D., Struck U., Al-Horani FA., Wild C. and Naumann MS. 2018. Reef sponges facilitate the transfer of coral-derived organic matter to their associated fauna via the sponge loop. Marine ecology progress series. 589. 85–96.

Robert K., Jones DOB, Roberts JM. and Huvenne VAI. 2016. Improving predictive mapping of deep-water habitats: Considering multiple model outputs and ensemble techniques. Deep-Sea Research I, 113. 80–89.

Robertson LM., Hamel JF. and Mercier A., 2017. Feeding in deep-sea demosponges: Influence of abiotic and biotic factors. Deep Sea Research Part I: Oceanographic Research Papers, 127. 49–56.

Ross S., Rhode M. and Quattrini A. 2015. Demersal fish distribution and habitat use within and near Baltimore and Nortfolk Canyons, US middle Atlantic slope. Deep Sea Research Part I: Oceanographic Research Papers, 103. 137–154.

Salinas-de-Leon P., Phillips B., Ebert D., Shivji M., Cerutti-Pereyra F., Ruck C., Fisher CR., Marsh L. 2018. Deep-sea hydrothermal vents as natural egg-case incubators at the Galapagos Rift. Scientific Reports 8, 1788.

Sinniger F., Pawlowski J., Harii S., Gooday AJ., Yamamoto H., Chevaldonné P., Cedhagen T., Carvalho G. and Creer S. 2016. Worldwide analysis of sedimentary DNA reveales major gaps in taxonomic knowledge of deep-sea benthos. Frontiers of Marine Science 3:92.

Soetaert K., Mohn C., Rengstorf A., Grehan A. and van Oevelen D. 2016. Ecosystem engineering creates a direct nutritional link between 600-m deep cold-water coral mounds and surface productivity. Sci Rep 6: 35057.

Somavilla R., Schauer U. and Budéus G. 2013. Increasing amount of Arctic Ocean deep waters in the Greenland Sea. Geophysical Research Letters, 40. 4361–4366.

Sweetman AK., Thurber AR., Smith CR., Levin LA., Mora C., Wei C-L., *et al*. 2017. Major impacts of climate change on deep-sea benthic ecosystems. Elem Sci Anth. 5:4. DOI:http://doi.org/10.1525/elementa.203.

Tian RM., Sun J., Cai L., Zhang WP., Zhou GW., Qiu JW. and Qian PY. 2016. The deep-sea glass sponge *Lophophysema eversa* harbours potential symbionts responsible for the nutrient conversions of carbon, nitrogen and sulfur. Environmental microbiology, 18(8). 2481–2494.

Treude T., Kiel S., Linke S., Peckamann J. and Goedert JL. 2011. Elasmobranch egg capsules associated with modern and ancient cold seeps: a nursery for marine deep-water predators.

Vanreusel A., Hilario A., Ribeiro PA., Meont L. and Martiínez Arbizu P. 2016. Threatened by mining, polymetallic nodules are required to preserve abyssal epifauna. Sci. Rep. 6, 26808; doi: 10.1038/srep26808.

White M., Wolff GA., Lundälv T., Guihen D., Kiriakoulakis K., Lavaleye M. and Duinevaeld G. 2012. Cold-water coral ecosystem (Tisler Reef, Norwegian Shelf) may be a hotspot for carbon cycling. Marine Ecology Progress Series, 465. 11–23.

Woodall LC., Sanches-Vidal A., Canals M., Paterson GLJ., Coppock R., Sleight V., Calafat A., Rogers AD., Narayanaswamy BE. and Thompson RC. 2018. The deep sea is a major sink for microplastic debris. Royal Society open science 1:140317.

Yamamoto A., Abe-Ouchi A., Shigemitsu M., Oka A., Takahashi K., *et al*. 2015. Global deep ocean oxygenation by enhanced ventilation in the Southern Ocean under long-term global warming. Global Biogeochem Cycles 29: 1801–1815.

Victorero L., Robert K., Robinson LF., Taylor ML. and Huvenne VAI. 2018. Species replacement dominates megabenthos beta diversity in a remote seamount setting. Scientific Reports, 8:4152.

Zeppilli D., Pusceddu A., Trincardi F. and Danovaro R. 2016. Seafloor heterogeneity influences the biodiversity-ecosystem functioning relationships in the deep sea. Scientific Reports 6:26352.

6 Review how vulnerable marine ecosystems (VMEs) have been defined previously (e.g. from other RFMOs or States) and through the use of case studies for specific VMEs (e.g. seapen fields and cold-water coral reefs), suggest a procedure and consider approaches relevant to the available data and species of the NE Atlantic for developing a biological basis for defining how VMEs are identified, which will allow us in future to have an ecological basis for determining when a VME indicator record (or group of) transitions into a VME - ToR [d]

6.1 Introduction

The need to define 'Vulnerable Marine Ecosystems (VMEs)' originates from calls from the United Nations General Assembly (Resolution 61/105 and other pertinent resolutions) to regional fisheries management organizations (RFMOs) concerning responsible fisheries in the marine ecosystem, including deep-sea fisheries. As a response to the UNGA resolutions and in order to assist RFMOs and States, the FAO developed the International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO, 2009). These guidelines apply to the high seas and for deep-sea fishing. In accordance with international law, the RFMOs and States have the legal mandate and obligation to regulate deep-sea fisheries. Introduction of measures to minimize negative impact on the marine ecosystems is an element of that process.

In the years after the publication of the FAO Guidelines, RFMOs and States have reported on progress to the UNGA, and FAO has published reviews of RFMO actions (FAO, 2016) and on the FAO VME Database portal[7].

Building on the UNGA Resolution's priorities and general definitions, the FAO Guidelines include definitions and descriptions of VMEs to be used as guidance for the RFMOs and States in their development of concrete assessment and management processes.

Several RFMOs have adhered to the FAO Guidelines' definitions of VMEs without regional adaptation, others such as the Northwest Atlantic Fisheries Organization (NAFO) developed rigorous methods to identify and map VMEs. The main obstacle is that in several RFMOs, the basic data needed are lacking, making approaches such as that adopted in NAFO of limited use. NAFO benefited from having a long time-series of trawl survey data with geo-referenced data on benthic invertebrate bycatch. In other RFMOs the data are much more scattered and patchy. For vast areas of the world ocean, the challenge is to develop appropriate definitions and actions for data-poor areas. In this situation, precautionary measures have been implemented based on best available science, using the VME definitions contained in the VME guidelines.

Most RFMOs, the EU and many States requested that their scientific advisory bodies produce regional lists of VME indicator taxa for use in their assessments and management measures. The assessments generally aim to determine where VME indicator taxa occur, and thus where VMEs are likely to occur. In some cases, visual observations of VME taxa forming concentrations or communities compatible with the descriptions in the FAO Guidelines were made, permitting immediate designation of a VME. In other

[7] http://www.fao.org/in-action/vulnerable-marine-ecosystems/en/

cases, designations are made by scientific advisory bodies based on consistent methods generated for data-poor situations and using data from, e.g. survey trawl bycatch. In these cases, and when visual observations are available, it may be concluded that VMEs are known or likely to occur in an area. This acceptance of expert opinion of VME status and managers' satisfaction with the degree of scientific evidence used, following the precautionary approach, has allowed RFMOs to make good progress in protecting VMEs in the high seas.

Another approach, used in the more remote and unknown areas of, e.g. the North East Atlantic Fisheries Commission (NEAFC) and the South East Atlantic Fisheries Organisation (SEAFO), is to base protective action such as fishing closures on best available regional knowledge of the general distribution patterns of VME taxa. This has led to the closing of biogeographically representative subareas assumed to have VMEs, e.g. fishing closures along the mid-Atlantic Ridge and several areas in the SEAFO Convention Area. These are precautionary actions taken without more than the general definition of VMEs provided in the FAO Guidelines.

6.2 Examples of Approaches to VME Designations

The term VME is now employed in many different contexts; and RFMOs, other organizations and States may use variations of the original definition or adapted versions suitable for their management needs. This is compatible with the provision in Para. 43 of the 2009 FAO Guidelines which reads: VME criteria "should be adapted and additional criteria should be developed as experience and knowledge accumulate, or to address particular local or regional needs."

The FAO Guidelines do however provide examples of *"species groups, communities and habitat forming species that are documented or considered sensitive and potentially vulnerable to deep-sea fisheries (DSFs) in the high-seas, and which may contribute to forming VMEs":*

i. *certain coldwater corals and hydroids, e.g. reef builders and coral forest including: stony corals (Scleractinia), alcyonaceans and gorgonians (Octocorallia), black corals (Antipatharia) and hydrocorals (Stylasteridae);*
ii. *some types of sponge dominated communities;*
iii. *communities composed of dense emergent fauna where large sessile protozoans (xenophyophores) and invertebrates (e.g. hydroids and bryozoans) form an important structural component of habitat; and*
iv. *seep and vent communities comprised of invertebrate and microbial species found nowhere else (i.e. endemic).*

Examples of topographical, hydrophysical or geological features, including fragile geological structures, that potentially support the species groups or communities, referred to above:

i. *submerged edges and slopes (e.g. corals and sponges);*
ii. *summits and flanks of seamounts, guyots, banks, knolls, and hills (e.g. corals, sponges, xenophyphores);*
iii. *canyons and trenches (e.g. burrowed clay outcrops, corals);*
iv. *hydrothermal vents (e.g. microbial communities and endemic invertebrates); and*
v. *cold seeps (e.g. mud volcanoes for microbes, hard substrates for sessile invertebrates)"* (FAO 2016).

These guidelines clarify, by examples, what organisms, communities and geomorphological features may constitute or support VMEs. They do not, however, provide clear approaches for how to consistently define, in a regional setting or on a case-by-case basis, what constitutes a VME.

As noted in paragraph 5.1, for many RFMOs, (including e.g. NEAFC and SEAFO), the possibility that these VME indicators could be VMEs or that geomorphological features such as seamounts are likely to have VMEs has been sufficient for management actions to proceed. Another example, the South Pacific Regional Fisheries Management Organisation (SPRFMO), has defined VMEs using the FAO guidelines as follows: "*Benthic ecosystems that include organisms [VME indicators] with these characteristics are referred to as 'vulnerable marine ecosystems' (VMEs)*"[8]. Examples where further scientific advice has been produced and partly used to evaluate VMEs are provided in Sections 5.2.1–5.2.5.

In order to provide consistent evaluations, WGDEC recognises the need for improved approaches for use in the Northeast Atlantic, especially when the background data are often scattered, patchy records of observations of organisms (VME indicator taxa), rather than direct observations of communities or features at relevant spatial scales (e.g. by video surveys).

6.2.1 Identification of VMEs in the NAFO Regulatory Area based on biomass-area relationships

NAFO has identified significant concentrations of VME indicators based on a combination of high biomass and discreteness of the area occupied, assessed using geospatial tools. These significant concentrations of large gorgonian corals, small gorgonian corals, sea pens, and sponges are considered to be VMEs (NAFO, 2013). Canada has also used this approach to identify significant benthic areas (SBAs) for coral and sponges under their equivalent domestic policy (DFO, 2017).

Biomass data for the analyses were from depth stratified random trawl surveys conducted by Canada and the EU. These surveys have been recording coral and sponge catch for over a decade and the dataset is quite unique among Regional Fisheries Management Organizations (RFMOs). Kernel density estimation (KDE) was the primary approach used to identify the general location of the significant concentrations of VME indicators (Kenchington *et al*., 2014). KDE is a simple non-parametric neighbour-based smoothing function that relies on few assumptions about the structure of the observed data (cf. Kenchington *et al*., 2016). It has been used in ecology to identify hot spots, i.e. areas of relatively high biomass (e.g. Nelson and Boots, 2008). Using the kernel surface, polygons were drawn around successively smaller catch values and the area occupied by each polygon was calculated. Area-catch weight curves were used to identify the weight thresholds defining the significant concentrations (Kenchington *et al*., 2014; 2016). Species distribution modelling was then used to interpolate between survey trawl locations within the VME polygons, to evaluate further the delineation of the VMEs. For many of the areas, *in situ* observations were made to validate the VME presence.

6.2.2 Possible approaches for Hydrothermal vents and Cold seeps

Hydrothermal vents occur mostly on mid-ocean ridges, back-arc spreading centres and volcanic island arcs, and most occur at depths between 200 and 5000 m (Beaulieu,

[8] https://www.sprfmo.int/assets/Meetings/Meetings-before-2013/Scientific-Working-Group/SWG-06-2008/a-Miscellaneous-Documents/SPRFMO-Bottom-Fishing-Impact-Assessment-Standardagreed-Vanuatu-Fri23Sep2011-1140am.pdf

2015). Active vents are rare, occurring on a narrow 60 000 km band that runs along the axis of the middle ridge in the world's oceans; each vent field is no bigger than an auditorium, many are much smaller than that, and in total are estimated to comprise 50 km^2 (Van Dover *et al*., 2018). Active vents host unique ecosystems of high biomass that are based on chemosynthetic primary production by microbes and are characterized by highly adapted symbioses; most species that live at active hydrothermal vents are endemic and can live nowhere else (Van Dover *et al*., 2018). Although at many active vents a few species dominate the biomass, rarity is also common, with many taxa comprising < 5% of total abundance with some being represented by single specimens even in high sampling efforts (Van Dover *et al*., 2018). It has been assumed that recovery of vent ecosystems from disturbance can be relatively quick and at sub-decadal time-scales, but this assumption is based on recovery at two well-studied sites characterized by intermediate to high frequency of natural disturbance and cannot be generalized (Mullineaux *et al*., 2018; Van Dover *et al*., 2018). The FAO Guidelines include vent ecosystems as VMEs that should be protected against significant adverse impacts from fishing. Experts have called for the use of the precautionary approach by protecting all active hydrothermal vents from human impacts, direct and indirect (Van Dover *et al*., 2018).

Similar considerations apply to cold seeps that are widespread and occur mostly, but not exclusively, on soft sediments on most continental margins, but also at trenches and active subduction zones, at depths ranging from <15 to >7400 m (Levin, 2005). The resilience of these ecosystems to perturbations is unknown but is likely to be low and recovery slow, taking decades or longer depending on the magnitude of disturbance (Cordes *et al*., 2016). Experts have proposed that cold seep communities with high biomass fit the criteria for VMEs and recommended that they should be afforded protection, through spatial management (Cordes *et al*., 2016). There is however little guidance on what biomass is to be regarded as "high enough" to class a seep ecosystem as a VME.

6.2.3 Potential approaches for defining Coral gardens

Coral gardens include morphologically diverse groups of taxa (Christiansen, 2010a), some of which provide substrate or shelter for other species (Buhl-Mortensen and Mortensen, 2005) and others that could be regarded as dominating large species, for instance, the sea pens (Pennatulacea) or their associated fauna.

Rogers and Gianni (2009) define coral gardens as a community of characteristic species where the density of colonies reaches >10 times background densities with >0.1 colonies per m^2. The problem with this definition is that it is not clear how to estimate the background density. Bullimore *et al*. (2013) estimate background density as the mean of all samples with occurrence of habitat-characterising species. However, this estimate would overestimate the background density if samples from the "true" habitats are also included. The background density should be defined as the mean of samples with occurrence outside the "true" habitats. Identification of patches in the observational data could be an alternative way of identifying background levels. In any case, observational data with high spatial resolution are needed.

A simpler way of defining threshold values is to identify natural breaking points or deflection points in density distribution curves (Kenchington *et al*., 2014). These points represent densities characteristic for the edges of the habitats where the density changes rapidly. Such thresholds are less influenced by the bias from variation of the proportion of "true" habitat relative to the proportion of samples representing background levels. Surveys of non-reefal megafaunal habitats should use established threshold values for the region or estimate the local threshold values in accordance with natural threshold levels displayed in abundance data from sufficient observational data.

Density estimates for megafauna depends both on observation or sampling method and observational scale. The abundance of habitat-characterising species and the distribution of a specific habitat should be studied at a scale that allows documentation of its patchiness. For taxa with small patch sizes, large samples will provide low maximum values and fail to display the natural variability.

A coral garden is recognizable and densities can be determined when sufficient and appropriate data are available from e.g. from visual censuses of appropriate spatial scales. In such cases, which may however be relatively uncommon, a density threshold may be used to determine a density above which the assemblage should be regarded a VME. However, methods are also needed for areas in which the only data available are records of occurrences in bottom samplers (e.g. bottom trawls). It remains a challenge to consistently determine when an aggregation of records of occurrences/quantities from, e.g. trawl catches, reflect a coral garden.

6.2.4 Cold-water coral reefs

Globally, there are six major cold-water scleractinians that build reefs (Henry and Roberts, 2014), where *Lophelia pertusa* is by far the most common. The *L. pertusa* reefs mainly occur in the North Atlantic Ocean (e.g. along the Norwegian shelf, around the Faroes, the Logachev mounds, and the Porcupine Bank) and the Gulf of Mexico. The number of verified *L. pertusa* reefs off Norway (>1200 verified and >6000 indicated from detailed bathymetry) increases rapidly as the Norwegian habitat mapping program MAREANO[9] proceeds, and the shelf off Norway represents a core area for this species, almost at the end of the "Gulf Stream".

Compared with other VMEs, L. pertusa reefs are easy to define. Davies et al. (2008) defines *L. pertusa* reefs as "biogenic structures formed by *L. pertusa* that alter sediment deposition, provide complex structural habitat, and are subject to the processes of growth and (bio)erosion". This definition expresses mainly the same features as Wood (1999): "discrete carbonate structure formed in-situ, or bound organic compounds that develop topographic relief upon the seafloor".

L. pertusa occur as coral reefs when the substrate below the living coral colonies is made up of a combination of coral debris and trapped sediments. However, the species may also occur at low densities as small colonies without the coral debris foundation. This habitat is very different from the reefs. *L. pertusa* can also be found on vertical walls in some canyons and fjords. Here, aggregation of coral debris is not possible.

Occurrences on vertical walls, and in settings where skeletal aggregation does not occur, do not match the reef definition and have been classified under the habitat type 'Hard bottom coral gardens' (Howell, 2010).

In 1999, the Norwegian fisheries authorities established a regulation for the protection of cold-water coral reefs, *Lophelia pertusa*, against damage from bottom trawling, including: prohibition of intentional destruction, precaution when fishing near known sites and, for certain locations, a total ban of bottom trawling. In this regulation all reefs, regardless of size, are treated as VME of equal value.

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[9] www.mareano.no

In 2015, Fosså *et al*. (2015) published an assessment report to evaluate the representativeness of existing protection areas, taking into account new information on coral reef distribution. This evaluation was a response to a request from the Directorate of Fisheries to "evaluate areas for protection of coral reefs" and introduced a system for prioritizing certain of these reefs for protection. The request included three tasks:

1) Describe the distribution of reefs near the protected areas on the background of new knowledge. (The directorate used this information to consider whether or not the present borders of protection areas were appropriate).
2) Evaluate whether the existing protection areas were representative for the reefs.
3) Consider whether new sites could add to the total representativeness of protected reefs. (The representativity of larger known *L. pertusa* sites was evaluated based on a combination of growth form and geographical location).

The aim was to provide a background for creating a network of protected coral areas that represented the different reef forms in four defined sub-coral provinces and seascapes along the Norwegian coast and shelf: Skagerrak, Western Norway, Mid-Norway and Northern-Norway.

Six different reef forms were identified:

1) elongated or cigar-like;
2) droplet shaped to elongated, with or without signs of seabed erosion at the reef front facing the current;
3) reef-complexes consisting of hundreds or thousands of coral domes growing close to each other or merged together;
4) single and circular of up to 50 m in height;
5) wall-reefs consisting of colonies growing on steep walls or on overhangs in fjords, and;
6) hill-reefs growing in sloping terrain on the coast and in fjords, for example on sills of fjords.

As a framework for assessing representativeness, the Norwegian waters were divided into three seascapes: 1) coast and fjords, 2) continental shelf, 3) shelf break including the slope. The Norwegian coast borders three seas: the North Sea with Skagerrak, the Norwegian Sea and the Barents Sea. Although these regions are all influenced by the Northeast Atlantic water, they have distinct physical conditions that will, for instance, influence the connectivity between *L. pertusa* in Norwegian waters and the reefs further southwest in the Atlantic Ocean. The hypothesis was that the higher the exposure of an area to the inflow of Atlantic water, the higher the connectivity among reefs in the Atlantic Ocean and Norwegian waters. This hypothesis and the general hydrographical situation were the basis for an identification of the four coral sub-provinces. Within these sub-provinces, Fosså *et al*. (2015) suggested new sites that added to the representativeness of protected reefs. They also suggested the closure of at least one site in each of the coral subprovinces to all fishing activities, including longline and gillnet fishing. These areas may serve as reference areas for monitoring and the study of other impact factors, such as climate change and ocean acidification.

The Norwegian experience relies on good knowledge of the occurrence and character of the reefs, and hence defining reefs is not the challenge, rather designating what reefs should be afforded what protective action. In general, for many other areas of the North Atlantic, it remains a challenge to determine when scattered coral records reflect occurrence of aggregations or reefs constituting VMEs.

6.2.5 Seamounts

Seamounts are widespread, estimated at more than 200 000 in all the world's oceans, although most abundant in the Pacific Ocean. They are geomorphological features that are regarded as likely to have VMEs (FAO Guidelines). They exhibit a range of physiographies, topographies and sizes, and occur at a wide range of depths and elevations. Ecosystems on seamounts can fulfil several criteria of VMEs, such as rarity, high productivity and high biodiversity, fragility and slow recovery because of the member species that occur there (Clark *et al.*, 2014). For these reasons, some experts recently called for the *protection of all seamounts* and their *management as a VME* (Watling and Auster, 2017).

Seamounts in the North Atlantic are already regarded by ICES (in its previous advice to NEAFC), as VME elements and thus regarded as features likely to have VMEs. The challenge is to determine what criteria should be used to determine, based on records of organisms from seamounts, when a seamount should be regarded as a VME and not only as a feature 'likely to have a VME'. There is furthermore a need for approaches to define, at least for large seamounts or seamount complexes, what subareas of seamounts are most likely to have the most vulnerable communities. The latter may be the more relevant issue in relation to concrete recommendations for management actions.

6.3 Expert Opinion to Define VMEs

Expert opinion is commonly used to identify VMEs in the absence of robust data for quantitative or semi-quantitative analyses. For example, CCAMLR CM 22-07 set a guideline of ≥10 kg VME indicator units/1200 m² (CCAMLR, 2009) to define a VME, with an indicator unit being any combination of VME indicators equal to 1 kg. Jones and Lockhart (2011) used this threshold for detecting VMES using trawl survey data and ground-truthing with underwater imagery and found it to be a useful threshold.

Expert opinion forms the base of VME identification in WGDEC using the VME weighting algorithm (see Section 7.2). Weighting criteria are applied to data within the VME database based on criteria in the FAO 2009 guidelines (FAO, 2009). Additionally, data submitters use expert judgement to assign a record to a VME Indicator or a VME Habitat.

6.3.1 South Pacific Regional Fisheries Management Organization (SPRFMO) Criteria

When exploring the concept of the use of expert opinion in identifying VMEs, there are, embedded in the management frameworks, thresholds associated with "Move-On Rules". These are usually (but not always) based on expert opinion. In some ways, these thresholds embody the concept of a VME and so they are explored here to examine whether they could be used to define a VME in some instances.

Criteria for using the 'move-on rules' that are currently in force within the South Pacific Regional Fisheries Management Organization (SPRFMO) area are detailed in Table 6.1

below, and were reviewed during the SPRFMO Scientific Commission meeting in September 2017 (SC5-DW08[10]). There are no comprehensive conservation and management measures for the entire SPRFMO area; currently it's a work-in-progress (see SC5-DW03[11]). However, Australia and New Zealand are considered the most advanced SPRFMO "stakeholders" in this respect, possessing their own criteria for implementation of move-on rules and fisheries closures. A new approach has been adopted by New Zealand using diversity-based criteria. Three different VME indicator taxa in a tow (for an approximate list see AEBR-135, though it lists ten taxa and not eleven) trigger the move-on rule, suggesting that this threshold indicates that a VME could be present and warrants further investigation.

Table 6.1. Criteria for using the 'move-on rules' currently in force within the South Pacific Regional Fisheries Management Organization (SPRFMO) area.

Member	Taxa	Move-on criteria	Move-on response	Relevant implementation details	Other management measures in place to protect VMEs
Bottom trawl fisheries (including midwater trawls for bentho-pelagic species)					
Australia	Live & dead corals & sponges	50 kg per tow	Move 5 n. miles from the tow track and remain away for duration of permit. Area closed to all Australian flagged vessels using same gear type	5 mile movement is away from any point on trawl track or on line between locations of longline anchors	No spatial closures (all trawl footprint "open" subject to move-on)
New Zealand	Live & dead sponges	50 kg per tow	If any one of the criteria is met, the vessel must move 5 miles from the tow track and remain away for duration of trip. Area remains open to other vessels	5 mile movement is away from the location at which the trawl tow commenced	Nested within spatial closures (move-on applies within moderately-fished areas only)
	Live & dead scleractinians	30 kg per tow			
	Live & dead gorgonians	1 kg per tow			
	Live & dead black corals	1 kg per tow			
	Live & dead soft corals	1 kg per tow			
	Live & dead hydrozoans	1 kg per tow			
	11 named taxa, live or dead	Presence of any 3 taxa in a tow			
Bottom line fisheries					
Australia	Live corals & sponges	10 kg per line section	Move 5 miles from the set and remain away for duration of permit. Area closed to all Australian flagged vessels using same gear type	Line section is 1000 hooks or 1200 m whichever shorter	No spatial closures (all line-fishing footprint "open" subject to move-on)
New Zealand	N/A	N/A	N/A	N/A	No spatial closures (all line-fishing footprint "open" and not subject to move-on)

6.3.2 Sensitive environment definitions from New Zealand

Sensitive environments (see Annex 5: Schedule 6 sensitive environments) are included in the New Zealand legislation act, namely the EEZ and Continental Shelf (Environment Effects – Permitted Activities) Regulations, and align well with VMEs in ABNJ. However, although similar in description, a sensitive environment is not a VME. The provisions presented do not apply to fisheries, instead they include a list of non-fishery activities such as marine research, seismic research, underwater cables, bottom construction, etc. Thus, it's the approach itself that can be useful, not the application. These regulations provide some definitions based on both catch evidence and *in situ* visual observations of percent cover.

6.4 Conclusions

WGDEC has neither adopted nor developed definitions of VMEs. The VME database identifies VME habitats based on expert opinion following some elaboration of the FAO (2009) guidelines (Section 4). The majority of records in the current VME database used by WGDEC for both international and national waters are catch records of VME

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[10] http://www.sprfmo.int/assets/00-SC5-2017/SC5-DW08-Utility-move-on-rules.pdf
[11]https://www.sprfmo.int/assets/00-SC5-2017/SC5-DW03-Bottom-fishing-CMM-proposals.pdf

indicator taxa from research studies and exploratory fishing, obtained by a multitude of samplers. Added to these are records from camera observations from several different vehicles. Georeferencing is good for recent data, but less precise for the historical records that are also included in the database. Data sources are patchily distributed and often at a small spatial scale. Consequently, efforts to produce quantitative measures of VMEs are most suited to adopting a strategy similar to that outlined in the New Zealand Sensitive Environments regulations that is based on percentage cover per unit area with some concept of nearest neighbour distances between sampling points. Biomass data would not be produced readily from imagery and so would not be as generally relevant to this region. If WGDEC wishes to go in that direction, it will need to establish guidelines and encourage data providers to report differently from the *status quo*. The group is aware of ongoing international and national projects that are working on this issue and more examples of thresholds to define VMEs may be available in the near future. It is clear that there is insufficient information to hold a workshop on this subject. If a workshop is to go forward, it should focus on the best way to utilize the data types within the NE Atlantic.

6.5 References

Beaulieu, S.E. 2015. InterRidge Global database of Active Submarine Hydrothermal Vent Fields. Prepared for InterRidge, Version 3.3, kml file produced 16 September 2015. Available online at: http://vents-data.interridge.org

Bullimore, R.D., Foster, N, and Howell, K.L. 2013. Coral characterised benthic assemblages of the deep N. E. Atlantic: defining 'Coral Gardens' to support future habitat mapping efforts. ICES Journal of Marine Science; doi:10.1093/icesjms/fss195, 12 pp.

Buhl-Mortensen, L., and Mortensen P.B. 2005. Distribution and diversity of species Associated with Deep-sea gorgonian corals off Atlantic Canada. Pp 849–879 in Freiwald, A. and Roberts J.M. (eds). Cold-water Corals and Ecosystems. Springer-Verlag Berlin Heidelberg, 1244 pp.

CCAMLR. 2009. ConservationMeasure 22-06. Bottom fishing in the Convention Area. Schedule of Conservation Measure in Force 2009/10. CCAMLR, Hobart, Austalia. /http://www.ccamlr.org/pu/e/e_pubs/cm/09-10/22-06.pdfS.

Clark, M.R., Rowden, A.A., Schlacher, T.A., Guinotte, J., Dunstan, P.K., Williams, A., O'Hara, T.D. *et al*. 2014. Identifying ecologically or biologically significant areas (EBSA): a systematic method and its application to seamounts in the South Pacific Ocean. Ocean Coast Manag 91: 65–79.

Cordes, E.E., Jones, D.O., Schlacher, T.A., Amon, D.J., Bernadino, A.F., Brooke, S., Carney, R., DeLeo, D.M., Dunlop, K.M., Escobar-Briones, E.G., Gates, A.R., Génio, L., Gobin, J., Henry, L.A., Herrera, S., Hoyt, S., Joye, S., Kark, S., Mestre, N.C., Metaxas, A., Pfeifer, S., Sink, K., Sweetman, A.K. and Witte, U.F. 2016. Environmental impacts of the deep-water oil and gas industry: a review to guide management strategies. Frontiers in Environmental Science 4: dx.doi.org/10.3389/fenvs.2016.00058.

Davies A.J., Wisshak, M., Orr, J.C. and Roberts, J.M. 2008. Predicting suitable habitat for the coldwater coral *Lophelia pertusa* (Scleractinia). Deep Sea Research I 55, 1048–1062.

DFO. 2017. Delineation of Significant Areas of Coldwater Corals and Sponge-Dominated Communities in Canada's Atlantic and Eastern Arctic Marine Waters and their Overlap with Fishing Activity. DFO Canadian Science Advisory Secretariat Science Advisory Report 2017/007. 45 p.

FAO. 2016. Vulnerable Marine Ecosystems: Processes and Practices in the High Seas, by Anthony Thompson, Jessica Sanders, Merete Tandstad, Fabio Carocci and Jessica Fuller, eds. FAO Fisheries and Aquaculture Technical Paper No. 595. Rome, Italy.

FAO. 2009. International Guidelines for the Management of Deep-sea Fisheries in the High Seas. FAO, Rome. 73 p.

Fosså, J.H., Kutti, T., Buhl-Mortensen, P. and Skjoldal, H.R. 2015. Vurdering av norske korallrev. Rapport fra Havforskningen Nr. 8–2015, 64 pp.

Henry, L.A. and Roberts, J.M. 2014. Developing an interim technical definition for Coral Gardens specific for UK waters and its subsequent application to verify suspected records. JNCC Report No: 507, ISSN 0963 8901, 38 pp.

Howell, K.L. 2010. A benthic classification system to aid in the implementation of marine protected area networks in the deep/high seas of the NE Atlantic. - Biological Conservation 143:1041–1056.

Jones, C.D., Lockhart, S.J. 2011. Detecting Vulnerable Marine Ecosystems in the Southern Ocean using research trawls and underwater imagery. Marine Policy 35: 732–736.

Kenchington, E., Beazley, L., Lirette, C., Murillo, F.J., Guijarro, J., Wareham, V., Gilkinson, K., Koen-Alonso, M., Benoît, H., Bourdages, H., Sainte-Marie, B., Treble, M. and Siferd, T. 2016. Delineation of Coral and Sponge Significant Benthic Areas in Eastern Canada Using Kernel Density Analyses and Species Distribution Models. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/093. vi + 178 p.

Kenchington, E., Murillo, F.J., Lirette, C., Sacau, M., Koen-Alonso, M., Kenny, A., Ollerhead, N., Wareham, V., and Beazley, L. 2014. Kernel Density Surface Modelling as a Means to Identify Significant Concentrations of Vulnerable Marine Ecosystem Indicators. PLoS ONE 10(1): e0117752. doi:10.1371/journal.pone.0117752.

Levin, L.A. 2005. Ecology of cold seep sediments: interactions of fauna with flow, chemistry and microbes. Ocean, Mar. Biol. Ann. Rev. 43: 1–46.

Mullineaux, L.S, Metaxas, A., Beaulieu, S., Bright, M., Gollner, S., Grupe, B., Herrera, S., Kellner, J, Levin, L.A., Mitarai, S., Neubert, M.G., Thurnherr, A.M., Tunnicliffe, V., Watanabe, H. and Won, Y-J. 2018. Exploring the ecology of deep-sea hydrothermal vents in a metacommunity framework. Frontiers in Marine Science 5; doi: 10.3389/fmars.2018.00049.

NAFO. 2013. Report of the 6th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WGESA). NAFO Scientific Council Summary Document 13/024, Serial No. N6277, 207 pp.

Nelson, T.A. and Boots, B. 2008. Detecting spatial hot spots in landscape ecology. Ecography 31: 556–566.

Rogers, A.D. and Gianni. M. 2009. Implementation of UN Resolution 61/105 in the management of deep-sea fisheries on the High Seas. Provisional Report: North Atlantic status and recommendations. International Programme on the State of the Ocean. London. November 2009, 97 pp.

Van Dover, C.L., Arnaud-Haond, S., Gianni, M., Helmreich, S., Huber, J.A., Jaeckel, A.L., Metaxas, A., Pendleton, L.H., Petersen, S., Ramirez-Llodra, E., Steinberg, P.E., Tunnicliffe, V and Yamamoto, H. 2018. Scientific rationale and international obligations for protection of active hydrothermal vent ecosystems from deep-sea mining. Marine Policy 90: 20–28.

Watling, L. and Auster P. 2017. Seamounts in the high seas should be managed as Vulnerable Marine Ecosystems. Front. Mar. Sci., 25 January 2017. https://doi.org/10.3389/fmars.2017.00014.

Wood, R. 1999. Reef evolution. Oxford University Press, Oxford, 414 pp.

7 Propose parameters for use within the VME database that would serve to remove the effect of the passage of time in the evaluation of confidence in the weighting system, associated with each data entry. In addition, consider anthropogenic impacts that might be used to reintroduce uncertainty in such records – ToR [e]

7.1 Background

Over the past few years, WGDEC have provided information on the distribution of Vulnerable Marine Ecosystems (VMEs) within North Atlantic waters in the form of maps showing data from the ICES VME database. The ICES VME database contains records of both VME indicators (e.g. species records from trawl survey bycatch) and actual VME (e.g. VME habitat records from ROV surveys), and this information, together with fishing pressure maps developed through the ICES Working Group on Spatial Fisheries Data (WGSFD) is used in the ICES Advice drafting stage to respond to advice requests from ICES clients.

Data in the VME database was originally only captured in the form of VME indicators. WGDEC appreciated that there needed to be some understanding of the confidence and quality of these VME indicator records, if recommendations coming from the Working Group were to be transparent and based on best available evidence. A specific challenge in relation to this was the likelihood of a VME indicator representing an actual VME. Up until 2015, this had been based solely on the expert opinion of the data providers, requiring knowledge of for example, estimates of the amount of VME found, the type of survey method used and whether the specimen was alive or dead. However, as this was not a formalized process, WGDEC sought to develop a system that would formalize expert opinion and utilize as much relevant information as possible from the ICES VME database.

The VME weighting algorithm was developed during the WGDEC 2015 (ICES, 2015) and 2016 (ICES, 2016a) meetings, taking into account changes made to the VME list and VME database format during the ICES Workshop on Vulnerable Marine Ecosystem Database (WKVME) (ICES, 2016b). The weighting process for VME indicator records now used by WGDEC is summarised below.

7.2 VME weighting algorithm

The VME weighting algorithm produces an index that shows the likelihood of an area containing an actual VME, based on the underlying data from the VME database. The index is created on a spatial c-square grid of 0.05 x 0.05 degrees (approximately 3 km x 5 km), allowing multiple records of VME indicator in the same grid cell to be used to detect likelihood. Cells are scored as ‘high’, ‘medium’ or ‘low’ likelihood. In addition, a confidence index has been developed based on a series of criteria (see Section 7.5.2) and this is applied to each VME index cell.

To create the likelihood score, known as the VME index, and the VME confidence index, the following steps are applied automatically using the weighing algorithm.

7.2.1 Step 1a-Applying a VME vulnerability score

During WGDEC 2016, each of the VME indicators identified during the WKVME workshop (ICES, 2016b) were ranked according to vulnerability. This was based on the five

FAO criteria used for the identification of VMEs, as detailed within the FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO, 2009):

1) **Uniqueness or rarity:** if the indicator is a) red listed by IUCN; b) known to be endemic; c) is assessed to be rare; d) is assessed to be threatened or declining.
2) **Functional significance of the habitat:** if the indicator is a) known to form a breeding habitat for other species; b) has a higher-level ecosystem role, for example nutrient cycling and water filtration.
3) **Fragility:** if the indicator a) is considered fragile and easily broken by physical contact; b) grows to a height well above the seabed.
4) **Life history:** if the indicator a) has a slow growth rate; b) has a late age of maturity; c) has a low or unpredictable recruitment d) is long-lived.
5) **Structural complexity:** if the indicator is a) frame-building and creates structural habitat; b) has commensal or closely associated species.

Each VME indicator was assigned a score from 1 (low) to 5 (high) against these five criteria, using expert judgement of the WGDEC meeting attendees. This was on the understanding that scores could, and should, be adjusted in future as and when new evidence became available. These scores were then averaged across the five criteria to produce a final VME vulnerability score (Table 7.1).

To distinguish between the fact that sponges could be comprised of large, aggregation-forming sponges such as *Asconema*, *Geodia* and *Pheronema*, or could be made up of smaller encrusting species such as *Alpsylla sulphuria,* which would likely have different vulnerability scores, two categories of sponge were included in the scoring process, 'Large sponge' and 'Sponge' respectively.

These VME indicator scores are automatically assigned to the VME indicator records within the VME database when the weighting algorithm is run.

Table 7.1. Ranking of each of the VME indicators identified at WKVME according to the FAO criteria for VMEs (FAO, 2009).

	Fao habitat criteria					
VME INDICATOR	Uniqueness/ Rarity	Functional	Fragility	Life History	Structural complexity	VME Indicator score
Stony coral	3	4	5	5	5	4.40
Black coral	5	2	4	5	2.5	3.70
Large Sponge	2	5	4	4	3	3.60
Chemosynthetic spp. (seeps and vents)	5	5	1	4	3	3.60
Gorgonian	4	3	3	5	2.5	3.50
Xenophyophores	2	3	5	2	2	2.80
Stylasterids	4	1	4	2.5	2	2.70
Sponge	2	3	3	3	2	2.60
Seapen	2	3	3	2	2	2.40
Stalked crinoids	4	1	2	4	1	2.40
Cup coral	2	1	2	4	1	2.00
Soft coral	1	1	2	2	2	1.60
Anemones	1	1	2	2	1	1.40

7.2.2 Step 1b-VME abundance score

For each record in the database, the abundance, where recorded, is evaluated against the VME thresholds for corals (30 kg) or sponges (200 kg). As there are no agreed thresholds for VME indicators such as gorgonians, black corals or seapens, the same value for corals (30 kg) has been used. This is almost certainly too high a threshold for such VME indicators, but without agreed thresholds, this was considered the most appropriate option (ICES, 2015).

Scores are assigned to each VME indicator record based on whether the abundance is above (5) or below (1) the threshold, or if no data on abundance is available (0) (Table 7.2)

Table 7.2. VME abundance scores.

	Vme abundance score		
VME indicator	**5**	**1**	**0**
Stony coral	≥ 30 kg	< 30 kg	No data
Sponge	≥ 200 kg	< 200 kg	No data
Black coral	≥ 30 kg	< 30 kg	No data
Gorgonian	≥ 30 kg	< 30 kg	No data
Lace coral	≥ 30 kg	< 30 kg	No data
Seapen	≥ 30 kg	< 30 kg	No data
Cup coral	≥ 30 kg	< 30 kg	No data
Soft coral	≥ 30 kg	< 30 kg	No data
Hydroid	≥ 30 kg	< 30 kg	No data

7.2.3 Step 1c–VME index score

The vulnerability score and the abundance score are then combined, using a 90% weighting for vulnerability and a 10% weighting for abundance, to create the VME index score, per record:

- VME index = VME indicator score * 0.9 + abundance score *0.1.

A low weighting is assigned to the abundance score because there was some doubt as to the relevance of thresholds when little is known about how much VME are retained as bycatch (ICES, 2015).

7.2.4 Step 1d–VME habitats

In 2016, revisions to the ICES VME database enabled the submission of data showing presence of actual VME, based on data such as ROV footage. As such, a category in the VME weighting algorithm was added for 'VME habitat'. Records of VME habitat submitted to the database are therefore automatically assigned to this category when the weighting algorithm is run.

7.2.5 Step 1e–Mapping the VME index and VME habitats

The VME index scores for each VME indicator are aggregated per c-square grid cell. The maximum VME index score is used as the overall value for that cell. This is done to prevent down-weighting of highly vulnerable records by less vulnerable records. It is therefore acknowledged that some cells will have high scores even if many low VME indicator score records are present in that cell.

The Jenks natural breaks classification method (Jenks, 1967) has been used to create splits between three VME index categories, so scores are assigned to these categories as follows:

- Low VME index, for total scores <2.6;
- Medium VME index, for total scores between 2.6 and 3.7;
- High VME index, for total scores >3.7.

Any cell that contains a VME habitat record is automatically assigned to the VME habitat category, irrespective of the presence of other VME indicators.

To map the VME index scores, each cell is coloured as follows:

- VME habitat-Green;
- High VME index-Red;
- Medium VME index-Orange;
- Low VME index-Yellow.

7.2.6 Step 2a–VME confidence index

To account for confidence in the data, such as data quality issues and the varying degree of knowledge of each geographical area (e.g. how well it has been surveyed), a data confidence index was also developed. Each VME indicator record in the VME database is scored against four measures of confidence, with a score of 1 (high confidence), 0.5 (medium confidence) or 0 (low confidence), as shown in Table 7.3.

Table 7.3. Measures of confidence and associated scores.

	VME CONFIDENCE INDEX		
Measure of confidence	1 - High	0.5 - Medium	0 - Low
Type of survey method used	Visual survey	Fisheries data or any scientific data without visual information	Inferred from indirect methods (e.g. acoustic methods)
Number of surveys (within c-square)	> 5 surveys	3–5 surveys	<3 surveys
Time span or range of surveys undertaken	> 20 years	10–20 years	<10 years
Time since last survey	<10 years ago	10–30 years ago	>30 years ago

The confidence measures can be explained further as follows:

Type of survey method used – Survey method used. This ranges from visual surveys using methods such as drop-down camera or ROV (high confidence) to fisheries and scientific trawl bycatch surveys (medium confidence) to indirect methods such as acoustic data (low confidence).

Number of surveys (within c-square) – The total number of surveys, irrespective of the time-scale they have occurred in, that have collected data on VME indicators within the c-square. Scores can range from >five surveys (high confidence) to 3–5 surveys (medium confidence) to <three surveys (low confidence).

Time span or range of surveys undertaken – The span or range of time (in years) between the first and last (most recent) surveys that have taken place in that c-square. For example, if the first survey going to a c-square area was in 1996 and the most recent was 2017, the time range would be 21 years, so this would score high confidence (i.e. long time period). Scores can range from >20 years in range (high confidence) to 10–20 years in range (medium confidence) to <10 years in range (low confidence).

Time since last survey – The number of years that have passed since the most recent survey occurred in that c-square and the year the weighting algorithm was run (i.e. the age of the data). For example, if the weighting algorithm was run in 2018 and the VME indicator records in that c-square were from surveys in 1998, 2007 and 2009, the number of years from the most recent survey to the date of running the algorithm would be 2018–2009 = nine years. This would therefore score high confidence. Scores can range from <ten years (high confidence) to 10–30 years (medium confidence) to >30 years (low confidence).

7.2.7 Step 2b-Mapping the VME confidence index

The resulting data confidence index for each grid cell is calculated as the average of these scores. However, only the records that contribute to the maximum VME score in each cell are used to calculate this (or the mean of highest scoring VME index if there was more than 1 record of maximum value).

The confidence index has been split into three categories using equal breaks, with scores assigned to these categories as follows:

- High confidence, for total scores >0.51;
- Medium Confidence, for scores between 0.51–0.70;
- Low confidence, for scores >0.70.

To map the confidence index, each cell is coloured as follows:

- High confidence-White;
- Medium confidence-Grey;
- Low confidence-Black.

7.3 Proposed changes to the VME weighting system in 2018

7.3.1 Use of vulnerability scoring as an element of the VME weighting index and duplicate records of VME in a c-square

During WGDEC 2018, some concerns were raised over the expert-judgement led ranking of VME indicators into different vulnerability scores, which are subsequently used to determine high, medium or low VME index scores. Concerns related to the fact that little is known about the vulnerability criteria, e.g. fragility or life history, for certain VME indicator species such as seapens, and thus ranking them could result in an underestimate of vulnerability, and a lower VME index score. Where lower VME index scores are present, these are not put forward as key areas of VME to the advice drafting group on VME for subsequent consideration for fisheries closures.

Although underestimates of vulnerability could occur due to the method used, it was agreed that the expert judgement based scoring approach was the best method to use with the limited evidence available on these vulnerability criteria for each VME indicator. However, vulnerability scoring should be updated as and when new evidence and information on VME indicators becomes available. It is therefore important that this remains as a standing item on the WGDEC Terms of Reference to ensure updates are made when new research is undertaken, and that members bring this information to the group each year.

7.3.2 Use of VME abundance thresholds

An additional problem was considered by the group about the relevance of the VME abundance thresholds used in step 1b of the weighting algorithm. These are currently based on the NEAFC VME encounter threshold of 30 kg for corals and half of the encounter threshold value for

sponges (200 kg) (Article 9 NEAFC Recommendation 19:2014[12]). When developing the VME weighting system, these thresholds were chosen just for the purposes of trialling the system, however these have not yet been updated.

It was felt that these thresholds were not appropriate to the purposes of identifying actual VME using the VME weighting system as this is not what the thresholds were designed for. Additionally, at present, all VME indicators except for sponges are considered against the coral threshold of 30 kg. This was felt to be too high a threshold for some species such as seapens or black corals, and should be revised. For example, in New Zealand, 1 kg is used as the 'move-on' rule threshold for gorgonians, black corals, soft corals and hydrozoans (see Section 6.3.1).

No changes were made at this stage, but it was agreed this should be reviewed at WGDEC 2019 to implement more appropriate thresholds per VME indicator, based on current knowledge of these species.

7.3.3 Proposals to remove the effect of the passage of time in the confidence score

The ICES VME database contains a range of data types from historical records provided through databases such as the octocoral database (a collation of records based on literature searches and historical survey data) through to new survey data collated and provided to the VME database each year by member states. Time of last survey is included as a measure of confidence in the VME weighting system, with scores split into three categories:

- High confidence: <ten years ago;
- Medium confidence: 10 to 30 years ago;
- Low confidence: >30 years ago.

At WGDEC 2017, the group discussed that although much of the new data provided are robust, they will reduce in confidence with the passage of time, unless another more recent survey takes place in that c-square, due to the way this confidence measure is scored in the weighting system. For example, over time a VME indicator from a particular survey will change from < 10 years old to 10 – 30 years old as the weighting system is run each year, and thus it will reduce in confidence. This was discussed further at WGDEC 2018, and the group felt that although this could reduce VME indicated confidence, it wasn't deemed to be a significant issue. Confidence would not reduce for ten years due to the categories chosen, and it is possible that confidence could realistically be deemed to be lower after this time frame.

In general, the historical records in the VME database are from literature sources. As such, confidence should be considered low for these as actual VME presence has not been confirmed, and the confidence scoring categories are considered accurate, i.e. many of these records would fit into the category >30 years equating to low confidence. In time, the group may want to revisit this confidence measure, but for now felt no changes were needed.

[12] http://neafc.org/system/files/Rec19-Protection-of-VMEs_0.pdf

7.3.4 Geographical Positioning considerations

Geographical Positioning System (GPS) accuracy could affect confidence in the locational data provided for VME indicators submitted to the database. This would therefore lead to reduced confidence in VME presence based on these records within the VME weighting system.

GPS was available for non-military use from around the late 1980s/early 1990s. As such, any historical records of VME indicators prior to this time would have lower confidence assigned to them (from a spatial accuracy perspective). Additionally, Selective Availability (an intentional degradation of public GPS signals implemented for national security reasons) was also used when GPS was first put in place, and wasn't ended until 2000. Therefore, VME records from pre-2000 would have lower confidence than those from post-2000.

At present, the VME confidence index assigns confidence for age of data under the criteria 'time of last survey' as noted in Section 7.3.2. Since the lowest confidence is assigned to data >30 years' old, this aligns well with when GPS was put in place. Additionally, any data from pre-2000 would be assigned a medium confidence score as it fits within the 10–30 year range for medium confidence. As such, the confidence categories sufficiently address this spatial accuracy issue at this time.

7.3.5 Consideration of anthropogenic impacts that might be used to reintroduce uncertainty in such records

One aspect that the group felt could influence the confidence measure 'time of last survey' was anthropogenic impact. For example, if the most recent survey had occurred in 2010 but known fishing activity had taken place in the c-square region from 2010 to 2018 (when the weighting algorithm was run), there may be less confidence that the VME indicator still existed due to potential impact from this activity.

At WGDEC 2018, the group discussed this issue but felt that it was difficult to assume fishing activity had affected the VME indicators to a significant enough level that confidence would be reduced. Additionally, different VME indicators are likely to be influenced differently from fishing activity, and as such, adding a generic rule to reduce confidence in VME indicator presence due to fishing activity for all indicator types was considered unreliable.

It was also discussed that presence or absence of fishing activity was more relevant to understanding how exposed VMEs may be to human impact, and thus whether fisheries closures are necessary, and was not as relevant to whether VME habitat was actually present as broad assumptions would need to be made. Therefore, the group agreed this should not be considered within the VME index likelihood scoring.

7.4 Conclusion

It is recognised that the VME weighting algorithm has some aspects that could be improved. Proposed future changes included:

- Updating the vulnerability scoring for VME indicators when new evidence becomes available;
- Ensuring attendees bring new evidence, such as research papers, on the vulnerability criteria for VME indicators to future WGDEC meetings;
- Reviewing evidence on appropriate abundance thresholds for VME indicators, and updating the abundance scoring against these thresholds;

- Ensuring potential effects of the passage of time are considered within the confidence index scores as time moves on and older data with lower spatial accuracy are still assigned lower confidence than data post-2000.

No changes were considered necessary for the VME weighting algorithm during WGDEC 2018, and thus the algorithm was run for 2018 following the process described in Section 7.2 to support ToRs (a) and (b).

7.5 References

FAO. 2009. International guidelines for the management of deep-sea fisheries in the high seas. Rome: Food and Agriculture Organization of the United Nations, 73 pp.

ICES. 2015. Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC), 16–20 February 2015, Horta, Azores, Portugal. ICES CM 2015/ACOM:27. 113 pp.

ICES. 2016a. Report of the Joint ICES/NAFO Working Group on Deep-water Ecology (WGDEC), 15–19 February 2016, Copenhagen, Denmark. ICES CM 2016/ACOM:28. 82 pp.

ICES. 2016b. Report of the Workshop on the Vulnerable Marine Ecosystem Database (WKVME), 10–11 December 2015, Peterborough, UK. ICES CM 2015/ACOM:62. 42 pp.

8 Identifying potential links between the Joint ICES/NAFO Working Group on Deep-water Ecology and the General Fisheries Commission for the Mediterranean (GFCM) Working Group on Vulnerable Marine Ecosystems

Following its establishment, the General Fisheries Commission for the Mediterranean (GFCM) Working Group on Vulnerable Marine Ecosystems (WGVME) met in 2017 to provide the necessary scientific information to the Scientific Advisory Committee on Fisheries (SAC). Sebastian Valanko from the ICES Secretariat was invited to attend this first meeting of WGVME, held in Málaga (3–5 April 2017), and presented work undertaken by the Joint ICES/NAFO WGDEC including the Vulnerable Marine Ecosystem (VME) database and the VME Data Portal[13]. The wish and intention to strengthen this collaboration between WGVME and WGDEC was also highlighted at the most recent WGVME meeting, held in Rome at the end of February 2018.

Despite the idiosyncrasies of the two regions (Atlantic vs. Mediterranean), there are thought to be some similarities in the way science and data may be used to inform management. At the last GFCM WGVME meeting, the recommendation to create a GFCM VME database, containing information on VME Indicator species and habitats, and along the lines of that developed by WGDEC, was highlighted.

WGDEC discussed the benefits of sharing knowledge gained by the group over the past ten years, as it has developed a VME database and VME data portal to help support its work, with the GFCM WGVME group. WGDEC is keen to explore this opportunity, and will look at what may be the best mechanisms to strengthen the cooperation and contact between the two groups. This may be through participation of relevant GFCM WGVME members in WGDEC meetings (and vice versa), as well as the sharing of information and tools (such as the template for VME data submission through the ICES VME Data Call) in order to allow the creation of a **database on VMEs for the Mediterranean.**

13 http://www.ices.dk/marine-data/data-portals/Pages/vulnerable-marine-ecosystems.aspx

Annex 1: List of participants

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Annex 2: Draft WGDEC terms of reference for the next meeting

The Joint ICES/NAFO Working Group on Deep-water Ecology (WGDEC), chaired by Laura Robson, UK, will meet at (TBC) in (TBC) 2019 to:

a) Collate new information on the distribution of vulnerable habitats as well as important benthic species and communities in the North Atlantic and adjacent waters, archive appropriately using the ICES VME Database, and disseminate via the Working Group report and ICES VME Data Portal;

b) Provide all available new information on the distribution of vulnerable habitats (VMEs) in the NEAFC Convention Area. In addition, provide new information on location of habitats sensitive to particular fishing activities (i.e. vulnerable marine ecosystems, VMEs) within EU waters;

c) Continue reviewing how to best define Good Environmental Status (GES) for deep-sea habitats. In particular, continuing a review on spatial and temporal scales and progress with indicator development for the deep sea;

d) Considering work undertaken at WGDEC 2012 to examine NEAFC encounter thresholds as well as criteria used by other RFMOs (such as South Pacific Regional Fisheries Management Organization - SPRFMO) to trigger “move-on “ rules, review current and propose revised thresholds appropriate to each VME indicator type considered in the WGDEC VME weighting algorithm.

WGDEC will report by [date tbc] to the attention of the ACOM Committee.

Supporting Information

Priority	The current activities of this Group will enable ICES to respond to advice requests from a number of clients (NEAFC/EC). Consequently, these activities are considered to have a high priority.
Scientific justification	ToR [a] The Joint ICES/NAFO Working Group on Deep-water Ecology undertake a range of Terms of Reference each year; the scope of these cover the entire North Atlantic, and include aspects such as ocean basin processes. Therefore, collating information on vulnerable habitats (including important benthic species and communities) across this wide geographic area (and adjacent waters) is essential. To this end, a VME data call will be run from September to December 2018, facilitated by the ICES Data Centre. Data will be quality checked/prepared one month in advance of WGDEC 2019. New data will be incorporated into the ICES VME Database and ICES VME Data Portal. This ToR includes any development work on the ICES VME Database and Data Portal, as identified by WGDEC, with support from the ICES Data Centre. ToR [b] This information and associated maps are required to meet the NEAFC request "to continue to provide all available new information on distribution of vulnerable habitats in the NEAFC Convention Area" as well as part of the European Commission MoU request to "provide any new information regarding the impact of fisheries on sensitive habitats". The location of newly discovered/mapped sensitive habitats is critical to these requests. ToR [c] Understanding, defining, and measuring Good Environmental Status is a core concept of the EU Marine Strategy Framework Directive. Work was started on GES at WGDEC 2017 and further work on deep-sea ecosystems is still required. In particular, this ToR will focus on continuing the review of progress made to date with deep-sea spatial and temporal scale definition and indicator development – the focus of a number of European funded projects. ToR [d] Currently, the VME abundance thresholds used within the VME weighting algorithm are based on the NEAFC VME encounter thresholds for corals (30 kg) and half the encounter threshold for sponges (200 kg). These thresholds were based on work undertaken in WGDEC 2012/2013, and were selected during the early deveopmental stages of the weighting algorithm. However, they only specifically examined cold water corals and deep-sea sponge aggregations. Since this time, new information on the life histories and vulnerability/sensitivies of other VME are available, and should be considered in order to develop specific and appropriate thresholds for each VME indicator. As part of this ToR, work undertaken developing VME encounter thresholds for NEAFC in 2012/2013 will be considered alongside work undertaken by other RFMO on criteria, such as the SPRFMO.
Resource requirements	Some support will be required from the ICES Secretariat
Participants	The Group is normally attended by some 15–20 members and guests.
Secretariat facilities	None, apart from WebEx and SharePoint site provision.
Financial	No financial implications.
Linkages to advisory committees	ACOM is the parent committee and specific ToRs from WGDEC provide information for the Advice Committee to respond to specific requests from clients.

Linkages to other committees or groups	While there are currently no direct linkages to other groups, WGDEC should develop stronger links (ideally through the establishment of joint Terms of Reference) with WGSFD, WGMHM and WGDEEP.
Linkages to other organizations	As a Joint ICES/NAFO group, the work of this group links to work being undertaken by Working Groups under the NAFO Scientific Council; specifically WGESA.

Annex 3: Recommendations

Recommendation	Addressed to
1. WGDEC recommends that a VME data call is undertaken in Autumn 2018. The Data Call will invite ICES Member Countries to submit new data on occurrences of VME indicators or *bona fide* VME; presence and absence data will be requested. The Data Call will be managed by the ICES Data Centre. Similar to last year, the geographic scope of the data call will include all of the North Atlantic.	ICES Data Centre
2. WGDEC recommends that the ICES Data Centre continue to assist in development of the ICES online VME Database Portal and online VME data submission process. Improvements for screening and submitting data were identified during WGDEC 2018 and discussed with the ICES Data Centre representative. Feedback was also provided on recommended updates to the VME Data Portal.	ICES Data Centre
3. WGDEC recommends that a backup copy (snapshot) of the ICES VME database is stored after each WGDEC meeting, ensuring that its is possible to revert back to the database finalised at the end of the last WGDEC meeting if necessary.	ICES Data Centre
4. WGDEC recommends that the ICES Data Centre faciliate the resubmission of VME data; allowing older records in the old VME format to be overwritten with resubmitted data in the new format. This will, through necessity, be more onerous than the automated submission of new data, and will require some technical support from the ICES Data Centre. However, this is an essential process in order to raise the quality of records within the current database.	ICES Data Centre

Annex 4: Catches of cold-water corals and sponges in the North Atlantic as reported in observations obtained by Russian fishing vessels in 2016–2017

Joint ICES/NAFO Working Group on Deep-water Ecology (WGDEC) 2018

Working Document

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Introduction

Targeted research of vulnerable marine ecosystems (VMEs) in the North Atlantic conducted by Russian fishing vessels began in 2007–2008 (Vinnichenko *et al.*, 2009). Afterward, the research was continued on a regular basis (Vinnichenko, 2010; Vinnichenko *et al.*, 2011; Vinnichenko and Sukhangulova, 2012; Vinnichenko and Kanishchev, 2013; Vinnichenko, Kanishchev and Fomin, 2014; Vinnichenko and Kanishchev, 2015; Kanischev and Zavoloka, 2016).

The objective of this Annex is to submit information on results of VME research in Russia conducted in the North Atlantic in 2016–2017 to ICES[14] and NAFO.

Material and methods

Data on VMEs were collected by observers during four fisheries surveys on the Grand Bank of Newfoundland and the Flemish Cap (NAFO Divisions 3LMNO) from March till August 2016 (Table A4.1). In 2017, the data were collected during four surveys on the Grand Bank and the Flemish Cap from January to September and in the international waters of the Rockall Bank (ICES Subarea 6.b) from February to March (Table A4.2).

The observations included:

- records of VME indicator species in catches;
- taxonomic identification of corals and sponges using relevant NAFO indicators (Kenchington *et al.*, 2009; Best *et al.*, 2010);
- photographing of corals and sponges for their identification ashore;
- registration of catch locations of corals and sponges using the GPS system.

Results

In 2016, in the NAFO Regulatory Area (RA) bottom trawling covered the extensive area of the Flemish Cap, the Flemish Pass and the Grand Bank between 43°00'–49°01'N, 43°21'–53°31'W at depths of 230–1260 m (Figure A4.1).

Cold water corals were recorded in small amounts in the northern part of the fishing area (Figure A4.1). The representatives of two orders occurred in the catches: Alcyonacea (soft and dendriform corals) and Scleractinia (*Madrepora* corals), with the genus

[14] Note that these data were submitted after the VME Data Call for WGDEC 2018 had closed and so could not be considered at WGDEC 2018. WGDEC would strongly urge these data be submitted as soon as possible in 2018 for consideration at WGDEC 2019.

Anthoptilum predominating. Single catches of *Lophelia pertusa* and *Polymastia* sponge were also recorded (Table A4.3).

In East Greenland, a single catch of *Geodia* sponges weighing approximately 50 kg was reported between 63°51´–63°85´N and 36°25´–36°41´W (Table A4.4).

In 2017, the research in the NAFO RA was conducted between 42°51'–48°51'N and 42°33'–53°58'W at depths of 234–1200 m (Figure A4.2). Catches consisted of *Anthoptilum* corals, representatives of *Duva florida, Radicipes gracilu*s and Nephtheidae family also occurred. Single catches of *Funiculina quadrangularis* and *Acanella arbuscula* were recorded. Sponges occurred in catches belonged to genera *Geodia, Euplectella* and *Haliclona* (Table A4.5).

In the international waters of the Rockall Bank, fisheries surveys were conducted in the area between 56°02'–59°34'N and 11°21'–16°10'W at depths of 200–330 m (Figure A4.3). VME indicator species were represented by a single catch of *Polymastia thielei* sponge and two catches of the *Flustra bryozoa* (Table A4.6).

The amount of caught VME indicator species throughout the NAFO RA and the Rockall Bank did not exceed 1 kg per haul.

Discussion and conclusion

Data on VME indicator species have been regularly collected by the Russian fishing vessels in the NAFO RA for a decade. Observations covered an extensive area of bottom fisheries in the open part of the Newfoundland area, however there was no evidence of coral and sponge aggregations. Data collected in 2016–2017 have reaffirmed the results of the previous research. In the established fishing areas, catches of cold-water corals and sponges were significantly lower than the threshold established by NAFO Fisheries Commission. The results of long-term Russian research could therefore prove that VMEs were absent in traditional bottom fishing areas of the Newfoundland part within the NAFO RA.

Although the scope of the Russian research was quite limited, a certain amount of new data obtained in 2017 on the Rockall Bank have enabled an update on the coral distribution and species composition in the Northeast Atlantic.

Table A4.1. Areas of North Atlantic VMEs research covered by Russian fishing vessels in 2016.

Area	Coordinates		Depth, m	Target species	Number of hauls
	N	**W**			
Newfoundland area	43°00'–49°01'	43°21'–53°31'	230–1260	Greenland halibut, redfish	456

Table A4.2. Areas of North Atlantic VMEs research covered by Russian fishing vessels in 2017.

Areas	Coordinates		Depth, m	Target species	Number of hauls
	N	W			
Newfoundland area	42°51'–48°51'	42°33'–53°58'	234–1200	Greenland halibut, redfish	430
Rockall Bank	56°02'–59°34'	11°21'–16°10'	200–330	Haddock	98

Table A4.3. Composition and amount of cold-water corals and sponges caught by Russian trawlers in NAFO RA in 2016.

Coordinates of hauls				Depth, m	Species	Amount of specimen	Length, cm	Condition	Mass, kg
Start position		End position							
N	W	N	W						
48°08′	47°02′	48°16′	46°32′	860	*Anthoptilum* sp.	1	40		0.020
48°52′	45°07′	48°42′	45°39′	1280	*Anthoptilum* sp.	1	40		0.020
48º07′	47º00′	48º16′	46º31′	840–900	*Anthoptilum* sp.	1–2	15–25		0.054
48°17′	46°32′	47°55′	46°45′	920–820	*Anthoptilum* sp.	1–3	17–21		0.049
48°08′	47°09′	48°08′	47°36′	980–970	*Lophelia pertusa*	1	2		0.011
48°08′	47°37′	48°07′	47°06′	920–930	*Anthoptilum* sp.	1–2	19–24		0.077
47°28′	47°17′	47°33′	47°15′	300–320	*Polymastia* sp.	1	7		0.059

Table A4.4. Composition and amount of sponges caught by Russian trawlers in East Greenland area in 2016.

Coordinates of hauls				Depth, m	Species	Amount of specimen	Length, cm	Condition	Mass, kg
Start position		End position							
N	W	N	W						
63°51′	36°25′	63°85′	36°41′	1030	*Geodia* sp.	20	8–20		50.0

Table A4.5. Composition and amount of cold-water corals and sponges caught by Russian trawlers in NAFO RA in 2017.

Coordinates of hauls				Depth, m	Species	Amount of specimen	Length, cm	Condition	Mass, kg
Start position		End position							
N	W	N	W						
46°34′	45°48′	46°28′	45°36′	380–390	*Nephtheidae*	3	3–5		<1
46°34′	45°48′	46°28′	45°36′	380–390	*Duva florida*	8	10–15		<1
46°34′	45°48′	46°28′	45°36′	380–390	*Anthoptilum* spp.	3	30		<1
46°30′	45°44′	46°38′	45°54′	370–390	*Geodia* spp.	2	6		<1
46°30′	45°44′	46°38′	45°54′	370–390	*Duva florida*	7	8–10		<1
46°30′	45°44′	46°38′	45°54′	370–390	*Anthoptilum* spp.	3	30		<1
46°35′	45°52′	46°28′	45°40′	370–390	*Nephtheidae*	3	5–10		<1
46°35′	45°52′	46°28′	45°40′	370–390	*Duva florida*	8	10–15		<1
46°35′	45°52′	46°28′	45°40′	370–390	*Anthoptilum*	3	30		<1
46°28′	45°38′	46°36′	45°51′	350–360	*Geodia* spp.	6	6–10		<1
46°28′	45°38′	46°36′	5°51′	350–360	*Eeuplectella* spp.	1	13		<1
46°28′	45°38′	46°36′	45°51′	350–360	*Duva florida*	10	10–15		<1
46°28′	45°38′	46°36′	45°51′	350–360	*Anthoptilum*	3	30		<1
46°28′	45°38′	46°36′	45°51′	350–360	*Haliclona* sp.	3	5–10		<1
46°28′	45°38′	46°36′	45°51′	350–360	*Funiculina quadrangularis*	2	40		<1
46°37′	45°53′	46°28′	45°43′	350–360	*Acanella arbuscula*	3	12–21		<1
46°37′	45°53′	46°28′	45°43′	350–360	*Duva florida*	3	10–15		<1
46°37′	45°53′	46°28′	45°43′	350–360	*Anthoptilum* spp.	5	30–35		<1
46°37′	45°53′	46°28′	45°43′	350–360	*Nephtheidae*	3	3–5		<1
43°00′	49°42′	43°00′	49°42′	315	*Anthoptilum* spp.	3	24–30		0.084
48°10′	47°39′	48°10′	47°07′	1100–1170	*Radicipes gracilus*	1	20		0.010
48°18′	46°32′	48°09′	47°02′	950–980	*Radicipes gracilus*	1	26		0.010

Table A4.6. Composition and amount of cold-water sponges and bryozoa caught by Russian trawlers on the Rockall Bank in 2017.

Coordinates of hauls				Depth, m	Species	Amount of specimen	Length, cm	Condition	Mass, kg
Start position		End position							
N	W	N	W						
56°44′	15°01′	56°55′	15°01′	260–270	*Flustra* sp.	1	6		<1
56°43′	15°04′	56°32′	15°17′	250	*Polymastia thielei*	5	6–10		<1
56°43′	15°04′	56°32′	15°17′	250	*Flustra* sp.	1	6		<1

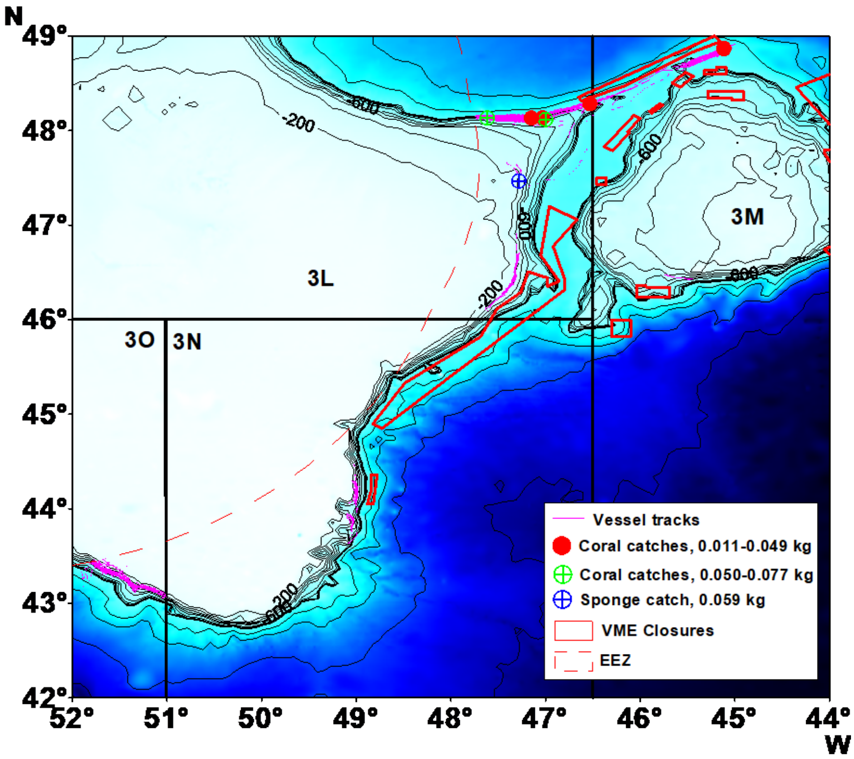

Figure A4.1. Tracks of Russian vessels with observers onboard (according to satellite monitoring data) and occurrence of cold-water corals and sponges in NAFO RA in 2016. Weight of caught VME indicator species reached 0.011–0.077 kg.

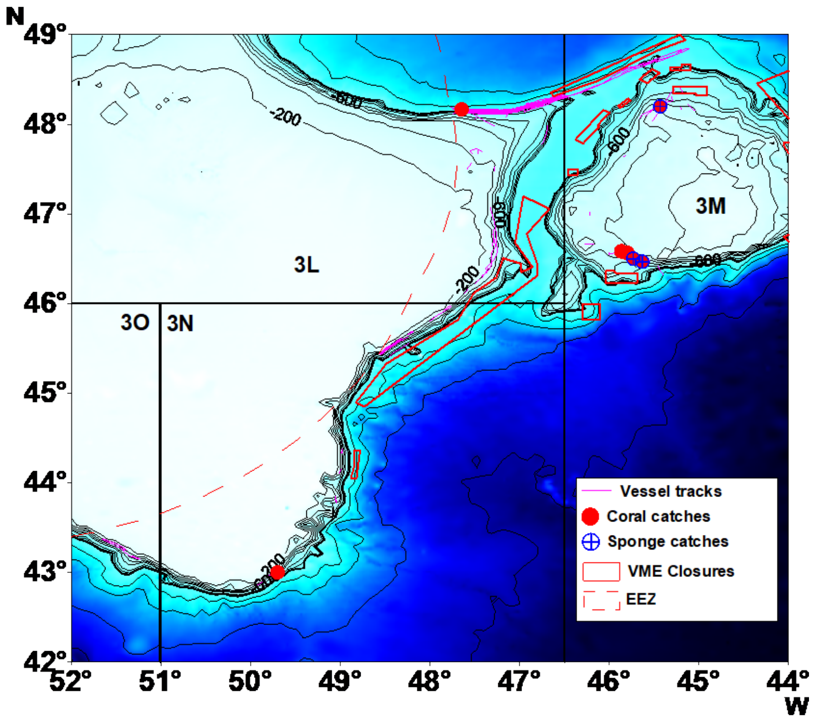

Figure A4.2. Tracks of Russian vessels with observers onboard (according to satellite monitoring data) and occurrence of cold-water corals and sponges in NAFO RA in 2017. Weight of caught VME indicator species did not exceed 1 kg per haul.

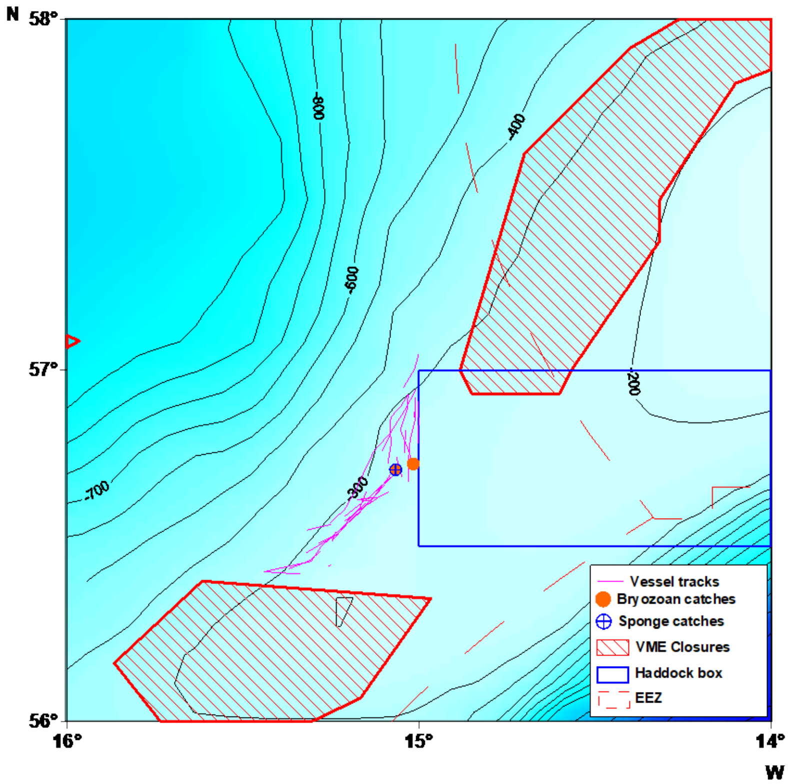

Figure A4.3. Tracks of Russian vessels with observers on board (according to satellite monitoring data) and occurrence of cold-water sponges and bryozoa on the Rockall Bank in 2017. Weight of caught VME indicator species did not exceed 1 kg per haul.

References

Best, M., Kenchington, E., MacIsaac, K., Wareham, V.E., Fuller, S.D. and Thompson, A.B. 2010. Sponge Identification Guide: NAFO Area. NAFO Scientific Council Studies, 43:1–49. doi:10.2960/S.v43.m1.

Kanishchev, A.A. and Zavoloka, P.A. 2016. Russian catches of coldwater corals and sponges in the North Atlantic based on the data of observations by fishing vessels in 2015. Working Document to the ICES/NAFO WGDEC 2016. Copenhagen, Denmark, 2016.

Kenchington, E., Best, M., Cogswell, A., MacIsaac, K., Murillo-Perez, J., MacDonald, B., Wareham, V., Fuller, S.D., Jørgensbye, H. I. Ø., Sklyar, A. and Thompson, A.B. 2009. Coral Identification Guide NAFO Area. Scientific Council Studies, 42: 1–23. doi:10.2960/S.v42.m1.

Vinnichenko, V.I., Sklyar, V.V., Zhivov, B.D. and Mashkov, V.N. 2009. Encounter of coldwater corals in the Iceland and Faeroe Islands areas (by the results on Russian researches in 2007–2008). Working Document to the ICES WGDEC 2009 Copenhagen, Denmark, 9–13 March 2009.

Vinnichenko, V.I. 2010. Russian investigations of Vulnerable Marine Ecosystems in the Newfoundland area. Unreviewed Working Document to the ICES WGDEC 2010. Copenhagen, Denmark, 22–26 March 2010.

Vinnichenko, V.I., Zelinsky, V.N. and Fomin, K. Yu. 2011. Russian catches of cold-water corals and sponges in the Northwest Atlantic in 2010. Working Document to the ICES/NAFO WGDEC 2011. Copenhagen, Denmark, 28 February–4 March 2011.

Vinnichenko,V.I. and Sukhangulova, K.O. 2012. Russian catches of coldwater corals and sponges in the North Atlantic based on the data of observations by fishing vessels in 2011. Working Document to the ICES/NAFO WGDEC 2012. Copenhagen, Denmark, 2012.

Vinnichenko, V.I. and Kanishchev, A.A. 2013. Russian catches of coldwater corals and sponges in the North Atlantic based on the data of observations by fishing vessels in 2012. Working Document to the ICES/NAFO WGDEC 2013. Floedevigen, Norway, 2013.

Vinnichenko, V.I., Kanishchev, A.A. and Fomin, K. Yu. 2014. Russian catches of coldwater corals and sponges in the North Atlantic based on the data of observations by fishing vessels in 2013. Working Document to the ICES/NAFO WGDEC 2014. Copenhagen, Denmark, 2014.

Vinnichenko, V.I. and Kanishchev, A.A. 2015. Russian catches of coldwater corals and sponges in the North Atlantic based on the data of observations by fishing vessels in 2014. Working Document to the ICES/NAFO WGDEC 2015. Horta, the Azores, 2015.

Annex 5: Schedule 6 sensitive environments

Schedule 6
Sensitive environments

r 3

Sensitive environment	Indicator of existence of sensitive environment
Stony coral thickets or reefs	A stony coral reef or thicket exists if— • a colony of a structure-forming species (ie, *Madrepora oculata*, *Solenosmilia variabilis*, *Goniocorella dumosa*, *Enallopsammia rostrata*, *Oculina virgosa*) covers 15% or more of the seabed in a visual imaging survey of 100 m^2 or more; or • a specimen of a thicket-forming species is found in 2 successive point samples; or • a specimen of a structure-forming species is found in a sample collected using towed gear.
Xenophyophores (sessile protozoan) beds	A xenophyophore bed exists if average densities of all species of xenophyophore found (including fragments) equal or exceed 1 specimen per m^2 sampled.
Bryozoan thickets	A bryozoan thicket exists if— • colonies of large frame-building bryozoan species cover at least 50% of the of an area between 10 m^2 and 100 m^2; or • colonies of large frame-building bryozoan species cover at least 40% of an area that exceeds 10 km^2; or • a specimen of a large frame-building bryozoan species is found in a sample collected using towed gear; or • 1 or more large frame-building bryozoan species is found in successive point samples.
Calcareous tube worm thickets	A sensitive tube worm thicket exists if— • 1 or more tube worm mounds per 250 m^2 are visible in a seabed imaging survey; or • 2 or more specimens of a mound-forming species of tube worm are found in a point sample; or • mound-forming species of tube worm comprise 10% or more by weight or volume of a towed sample.
Chaetopteridae worm fields	A sensitive chaetopteridae worm field exists if worm tubes or epifaunal species— • cover 25% or more of the seabed in a visual imaging survey of 500 m^2 or more; or • make up 25% or more of the volume of a sample collected using towed gear; or • are found in 2 successive point samples.
Sea pen field	A sea pen field exists if— • a specimen of sea pen is found in successive point samples; or • 2 or more specimens of sea pen per m^2 are found in a visual imaging survey or a survey collected using towed gear.
Rhodolith (maerl) beds	A rhodolith bed— • exists if living coralline thalli are found to cover more than 10% of an area in a visual imaging survey:

Sensitive environment	Indicator of existence of sensitive environment
	• is to be taken to exist if a single specimen of a rhodolith species is found in any sample.
Sponge gardens	A sponge garden exists if metazoans of classes Demospongiae, Hexactinellida, Calcerea, or Homoscleromorpha— • comprise 25% or more by volume of successive point samples; or • comprise 20% or more by volume of any sample collected using towed gear; or • cover 25% or more of the seabed over an area of 100 m^2 or more in a visual imaging survey.
Beds of large bivalve molluscs	A bed of large bivalve molluscs exists if living and dead specimens— • cover 30% or more of the seabed in a visual imaging survey; or • comprise 30% or more by weight or volume of the catch in a sample collected using towed gear; or • comprise 30% or more by weight or volume in successive point samples.
Macro-algae beds	A macro-algae bed exists if a specimen of a red, green, or brown macro-algae is found in a visual imaging survey or any sample.
Brachiopods	A brachiopod bed exists if 1 or more live brachiopods— • are found per m^2 sampled using towed gear; or • are found in successive point samples.
Deep-sea hydrothermal vents	A sensitive hydrothermal vent exists if a live specimen of a known vent species is found in a visual imaging survey or any sample. The following vent species are known to exist in New Zealand waters: • *Vulcanolepis osheai*: • *Ashinkailepas kermadecensis*: • *Gigantidas gladius*: • *Vulcanidas insolatus*: • *Alvinocaris niwa*: • *A. longirostris*: • *A. alexander*: • *Lebbeus wera*: • *Nautilocaris saintlaurentae*: • *Gandalfus puia*: • *Xenograpsus ngatama*: • *Paralomis hirtella*: • *Bathyaustriella thionipta*: • *Siboglinum* sp: • *Oasisia fujikurai*: • *Lamellibrachia juni*: • *Sclerasterias eructans*: • *Parachnoidea rowdeni*: • *Pyrolycus moelleri*:

Annex 6: Technical minutes from the Vulnerable Marine Ecosystems Review Group

- RGVME
- By correspondence 27 May–7 June 2018
- Participants: James Asa Strong (Chair), Rabea Kiekmann, Emanuela Fanelli and Sebastian Valanko (ICES Secretariat)
- Working Group: WGDEC

Overview

In response to the three advice requests (DGMARE, EU, NEAFC), this report (i) reviews the spatial data, provided by the Working Group on Deep-water Ecology (WGDEC), on the distribution, vulnerability and abundance (VME index) of VMEs in the Northeast Atlantic; (ii) examines the methods used to derive the VME distribution (method behind the VME Index); (iii) reviews the processing and presentation of VMS (Vessel Monitoring System) data within the NEAFC (North-East Atlantic Fisheries Commission) regulatory area; and (iv) comments on the potential issues surrounding the overlap analysis of VME and NEAFC VMS data. The Working Group on Deep-water Ecology (WGDEC) and Neil Campbell (Working Group on Spatial Fisheries Data (WGSFD)), analysing fishing activities in the NEAFC regulatory area, provided the reports for review. The review document is structured according to the three requests.

The review group worked by correspondence during the period indicated. Two teleconference meetings were held during the review; one on the 1st June 2018 to agree on (i) the approach to the review; (ii) request any additional documentation or clarification from the ICES Secretariat; and (iii) identify the main advice points for the report. A second meeting was held on the 6th June, 2018, to ratify the final advice provided in this report.

1 DGMARE request – “advice on a prioritised list of bottom fisheries closures areas where VMEs are likely to occur, taking into account the current fishing footprint”

1.1 Representation of the distribution of VMEs

VME information was sourced from the WGDEC 2018 report and the RGVME commend the group for collating this enormous amount of information consolidating data from visual and catch survey as well as from the literature. It is noted that the WGDEC have included a significant volume of new observations through the ICES VME Data Call in 2017/2018. However, the vast majority of these observations are not relevant to the EU area.

Based on the general scarcity of observations, the RGVME support the use of the VME Index (for combining VME indicators) for estimating the distribution of VMEs. The Review Group did share the concerns of the WGDEC (WGDEC 2018) on how abundance data are included and weighted in the calculation of the VME Index; without consistent and considered thresholds supported by field observations, it was felt that this information currently offered little additional information.

Within the calculations for the VME Index, it was not clear to the RGVME whether OSPAR habitat observations had been included in the Index as *bona fide* habitat records. Also, it wasn’t clear as to how multiple indicator observations within a c-square, if any, were merged or averaged to produce a final Index value. One assumes that multiple indicators within a c-square should increase the VME Index.

The Review Group noted that the distribution of VME observations is extremely patchy and sparse. The reporting of absence data will aid in the interpretation of the VME presence records (e.g. if there are lots of absences, one can assume a patch distribution or, when few absences are reported, that the scatter observed is the product of undersampling). It is noted that WGDEC makes the recommendation (addressed to the ICES Data Centre) that absence information should be recorded. Having absence information will further allow using a broad array of geo-statistical modelling techniques, which is a recommendation for a future WGDEC ToR (see below).

The RGVME caution against the exclusion of VME Index c-squares, based on the filtration method detailed in Section 4 of WGDEC (2018), before the overlap analysis. The exclusion of low, medium and high (low confidence only) vulnerability index c-squares in Section 4 is a significant modification of the underlying VME indicator data. It is evident that the exclusion step results in a significant change in the density and distribution of VME vulnerability index c-squares, as demonstrated between sections three and four of the WGDEC report. The RGVME do not question that in order to indicate where “VMEs are likely to occur”, many of the c-squares with lower vulnerability indices should be excluded. However, the review group believe that the removal of lower index c-squares should be done after the overlap analysis. The inclusion of all of the VME c-squares may provide interesting insights into the relationship between VME vulnerability, VMS-derived effort and depth bands. For example, although not providing any information on cause or effect, it might be informative for the advisory phase to understand the correspondence between the VME vulnerability index and fishing intensity, e.g. only low vulnerability index c-squares are found in areas with the highest fishing effort.

At some point in the overlap analysis, it will be necessary to filter VME Index c-squares to to represent better where VMEs are likely to occur. The review group note that little justification was provided for the filtration method detailed in Section 4 of the WGDEC (2018) i.e. the exclusion of low, medium and high (low confidence only) vulnerability index c-squares. Based on the importance of these exclusions for the density and distribution of VMEs, it would seem prudent and transparent to provide a thorough justification for the choice of exclusion rules applied.

The RGVME suggest that overview maps and tables are provided for the VME observations and c-squares (with a clear link to the ICES VME data portal). Once again, the inclusion of absence observations or some estimate of sampling effort within a regional would assist greatly in the interpretation of large expanses of no data. It is also noted that VME observations of both habitats and indicators come from point sampling with cameras and grabs as well as from prolonged trawling tows; WGDEC needs to carefully consider how to standardise and represent these very different sources of information in a comparable manner. It is also likely that the ability to sample, and therefore detect, certain VME indicators might be different between sampling methods; this may also require consideration within the WGDEC report.

By using the full VME index and habitats observations, the RGVME are content that the surfaces provided do represent the best available evidence of estimating the distribution of VMEs. It is clear that the VMEs are often associated with bathymetric and geomorphological features. As such, they are amenable to geo-statistical modelling techniques (as we are sure WGDEC have also realised). Based on the sparsity of observations, the RGVME suggest that predictive modelling techniques will be a useful method for providing a fuller representation of 'suitable habitat' or potential VME distribution. By using confidence intervals, priority areas for fisheries closures should be identifiable even in areas that are currently underrepresented in the ICES VME database.

1.2 Advice on the overlap analysis based on the review of the input datasets

Vessel Monitoring System data, collated by ICES, will be used to establish the fisheries footprint in the Northeast Atlantic. The RGVME notes that the WGSFD are reviewing ICES-based VMS data for the overlap analysis.

The RGVME highlight that the VME Index and habitat observations are very scattered and sparse, which might complicate the overlap analysis. To overcome the issues of poor coverage, it is recommended that geo-statistical modelling techniques that produce predicted probability surfaces for VMEs are investigated in future by WGDEC.

In the absence of modelled VME surfaces and considering the scattered nature of the VME vulnerability index c-squares, steps to spatially buffer the VME observations can be considered. Given that sampling effort is likely to be generating much of the scatter within the VME observation, it might seem appropriated to apply neighbourhood buffers. However, buffering without considering any environmental information could be problematic. Many VMEs are found along strong environmental (depth) gradients and simply extrapolating VMEs to neighbouring grid cells may be an oversimplification of the actual configuration. As an interim solution, it might be more prudent to apply expert judgement when buffering points and by this delineating VMEs.

Fisheries intensity information will be provided by ICES as surface and subsurface swept-area ratio (SAR) per grid cell (0.05°*0.05° C-square). Due to the high sensitivity of VMEs to trawling activities, RGVME suggest to overlap VME information with surface SAR estimates rather than with subsurface SAR.

RGVME suggests plotting the frequency of occurrence of VMEs and average fishing intensities vs. water depth/depth bands in order to inform decision-making. This will provide context on the value for VMEs of closed areas vs. *de facto* closed areas that are too deep (or steep/with natural constraints) for current fishing practices.

It is worthwhile considering that areas with a high fishing effort potentially provide high revenues. If high-effort areas are closed, fisheries might be displaced to other areas with, so far, modest or no fishing activity. Therefore, the decision needs to be made if either all VMEs with a certain characteristic/threshold should be closed for fisheries or if not, which percentage. In the latter case, it is possible to close the areas which currently experience only a modest/no fishing activity and preserve the respective habitats that have not been historically fished and therefore damaged.

Based on this review, RGVME are content that the 'VME vulnerability index and habitat observations' represents the best available evidence of representing the likely distribution of VMEs, and is a suitable evidence base for ICES to provide the requested advice to DGMARE.

2 EU - As part of the MoU with the European Commission, ICES is requested to: Provide any new information regarding the impact of fisheries on other components of the ecosystem including small cetaceans and other marine mammals, seabirds and habitats. This should include any new information on the location of habitats sensitive to particular fishing activities

2.1 Occurrence of VMEs

VME information was sourced from the WGDEC 2018 report. It is noted that the WGDEC have included a significant volume of new habitat observations (n = 3118) through the ICES VME Data Call in 2017/2018. The vast majority of these observations are outside European waters and 99 new habitat observations were reported within European waters (mostly within UK waters). It was not clear to the RGVME whether OSPAR habitat observations had been included as VME occurrences within the WGDEC report.

Use of the VME vulnerability index, which is the basis of VME reporting under the DGMARE and NEAFC requests, greatly increases the density and distribution of relevant VME observations.

The Review Group noted that the distribution of VME observations is extremely patchy and sparse. The reporting of absence data will aid in the interpretation of the VME presence records (e.g. if there are lots of absences, one can assume a patch distribution or, when few absences are reported, that the scatter observed is the product of undersampling). It is noted that WGDEC makes the recommendation (addressed to the ICES Data Centre) that absence information should also recorded. Also, should WGDEC investigate the use of geo-statistical modelling to delineate VMEs, having absence information will allow a broad array of geospatial modelling techniques to be used. The latter issue should also be an important recommendation for WGDEC.

It is also noted that VME observations of habitats come from point sampling with cameras and grabs as well as from prolonged trawling tows; WGDEC needs to carefully consider how to standardise and represent these very different sources of information in a comparable manner. It is also likely that the ability to sample, and therefore detect, certain VME habitats might be different between the differing sampling methods; this may also require consideration within the WGDEC report.

The RGVME are content that the information provided by WGDEC is the best available evidence of representing the occurrence of VMEs. It is likely that the occurrence of VMEs is substantially undersampled and it is, therefore, wise to consider the information provided as a mere indication of the likely distribution of VMEs. As stated earlier, it is possible that the use of the VME vulnerability index (i.e. use of indicator species) may provide useful supporting data for interpreting the distribution of VMEs. Furthermore, it is clear that the VMEs are often associated with bathymetric and geomorphological features. As such, may be amenable to geo-statistical modelling techniques (as we are sure WGDEC have also realised). Based on the sparsity of observations, the RGVME highlight the value of predictive modelling techniques for providing a fuller representation of 'suitable habitat' or potential VME distribution. By using confidence intervals, it should be possible to identify habitats that are sensitive to fishing activities and that are currently missing or underrepresented in the ICES VME database.

Based on this review, RGVME are content that the VME habitat occurrence observations represents a suitable evidence base for representing the known distribution of VMEs, and is a suitable evidence base for ICES to provide the requested advice to the EU.

3 NEAFC – NEAFC requests ICES to continue to provide all available new information on distribution of vulnerable habitats in the NEAFC Convention Area and fisheries activities in and in the vicinity of such habitats, and provide advice relevant to the Regulatory Area and the above-mentioned objectives

A review of the information representing vulnerable habitat (VME habitats and VME indicator species as presented by the VME vulnerability index) is provided in Section 1.1 (1 DGMARE request – 1.1 Representation of the distribution of VMEs).

The RGVME was asked to review information about the fisheries footprint in relation to VMEs. The VMS data provided by NEAFC and were processed by Neil Campbell. The supporting report describes the data, the limitations and potential errors, and provides raster layers of fishing effort covering the NEAFC regulatory area with specific maps for five areas with spatial measures for the protection of VMEs.

The analysis generally follows the workflow described by WGSFD (ICES, 2016). However, the data from the NEAFC area partly differ from the data that are submitted according to the ICES data call in relation to VMS/Logbook data for fishing activities in the Northeast Atlantic and the Baltic Sea. These differences include: (i) catch records don't have date information and can be linked to VMS data only on a six-monthly basis; (ii) minimum interval between two consecutive VMS polls is four hours instead of two; (iii) the analysis of speed profiles is based on all vessels registered as using trawl gears rather than by each specific gear type or vessel and resulted in an overall definition that vessels are fishing at a speed of 0–5 knots; (iv) fishing effort is given in hours rather than as swept-area, which is due to the fact that gear width cannot be estimated appropriately. Further, the report mentions problems with the quality of speed data. The RGVME evaluates that the data issues and problems were addressed adequately and the output of the analyses was representative. Some misinterpretations, e.g. of gear type or vessel's activity cannot be completely avoided with the currently available information, but, when relevant, were mentioned in the text accordingly.

The presentation of four different maps for each area is appreciated, as it gives additional information according to the quality of the assessment. The spatial layer that is important for an overlay with VME records is the gridded effort of vessels using mobile bottom contacting gears. The spatial resolution of the grid cells (0.05°*0.05° C-square) may be slightly too high (due to 4 h ping intervals) creating artefacts especially at low fishing intensities but is in accordance to the WGSFD workflow (ICES, 2016) and corresponds to the resolution used in the WGDEC report. The maps with putative tows illustrate that trawling seems to concentrate at the border of closed areas, and vessels usually comply with measures. The maps further provided credence to the underlying data and the processing method. However, RGVME caution against the use of interpolated tow lines for producing raster layers as long as the minimum transmission interval is 4 h.

Generally, the analysis of fishing effort could be improved by (i) a higher polling frequency, (ii) the provision of detailed logbook information (including catch data and the gear type used), and (iii) the improvement of speed reports. Nevertheless, the currently available information on the intensity of fishing with bottom contacting and static gears were produced adequately allowing an overlay with VME layers.

For the future, RGVME note that in addition to an annual analysis of fishing effort:

1) information about the area-specific interannual variation in fishing intensity should be provided to assess if fishing happens only sporadically or chronically;
2) a spatial layer representing the multiannual fishing effort (e.g. 2012–2017) should be produced; and
3) an analysis of the amount of overlap between fishing activities and area closures for each (potential) spatial measure would be informative.

These data products could then assist in defining a prioritised list of fisheries closure areas. Fishing intensity maps, such as Figure 21 of the report, could further help identifying particular areas of interest to bottom trawling and providing guidance to potential features associated to VMEs.

Based on this review, RGVME are content that the VME vulnerability index and habitat observations represent the best available evidence of representing the likely distribution of VMEs, and are a suitable evidence base for ICES to provide the requested advice to NEAFC. Equally, RGVME are content that the NEAFC VMS data are also sufficient to indicate the intensity and distribution of fishing effort with the NEAFC area.

4 References

ICES. 2016. Interim Report of the Working Group on Spatial Fisheries Data (WGSFD), 17–20 May 2016, Brest, France. ICES CM 2016/SSGEPI: 18. 244 pp.

ICES. 2018. Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC), 5–9 March 2018, Dartmouth, Nova Scotia, Canada. ICES CM 2018/ACOM:26. 123 pp.