ICES/NAFO WGDEC REPORT 2015

ICES ADVISORY COMMITTEE

ICES CM 2015/ACOM:27

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

16–20 February 2015

Horta, Azores, Portugal

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CIEM Conseil International pour l'Exploration de la Mer

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Contents

Executive summary

On 16th February 2015, the joint ICES/NAFO WGDEC, chaired by Neil Golding (UK) and attended by fourteen members (eleven in person, three via WebEx) met in Horta, Faial, Azores to consider the terms of reference (ToR) 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 510 new records were brought to the group this year and appended to the VME database. The new data were from a range of sources including fisheries surveys and seabed imagery surveys. No recommendations were made for the modification of existing, or creation of new bottom fishing closures.

Within the NEAFC regulatory area, the following areas were considered:

- **Rockall Bank:** new VME indicator records from two scientific fish stock assessment surveys were made available. In addition, new information was provided from a commercial fishery but no bycatch was recorded.

Within the EEZs of various countries the following areas were considered:

- **Rockall Bank:** new VME indicator records from two scientific fish stock assessment surveys were made available.
- **Rosemary Bank:** The group considered new VME indicator bycatch records from a scientific trawl survey. Towed video imagery from the same survey also showed evidence of the VME habitat type 'deep-sea sponge aggregations.'
- **Faroe-Shetland Channel:** new VME indicator records from a scientific trawl survey were presented to WGDEC.
- **Bill Baileys Bank and Lousy Bank:** New information on VME indicator bycatch records was provided from a commercial fishery.
- **Greenland:** The group considered a new record of the habitat type 'cold water coral reef', verified by drop down video.
- **Portugal:** WGDEC 2015 was made aware of new VME indicator records from within Azorean waters published in a scientific paper. Data from this scientific paper were not provided to WGDEC and are not currently within the VME database.

Within the Northwest Atlantic (NAFO regulated) the following areas were considered:

- **Flemish Cap Bank, Grand Banks and Flemish Pass Basin:** New information on VME indicator bycatch records was provided from a commercial fishery.

WGDEC used VMS-data for 2014 to analyse the spatial distribution of bottom fishing activity in the NEAFC Regulatory Area. Speed filtering for bottom fishing gear types was improved from last year using vessel speed histograms. WGDEC examined the general data distribution and also looked at some areas in greater detail, such as Hatton and Rockall Banks, Mid-Atlantic Ridge and Josephine seamount.

WGDEC sought to further develop the system developed in 2014 to weight the reliability and significance of VME indicator records. The main advance this year was to move from viewing individual points in the VME indicator database to a spatially gridded data format, which also combined the geographical locations of VMEs in close proximity to each other. The new system captured the fact that not all 'VME indicator species' within the VME database have the same vulnerability to human impacts. Additionally, to account for data quality issues, a 'data uncertainty' index was developed. A proposal for a novel methodology for combining isolated occurrences of VME indicator records into a single bottom fishing closure was submitted to WGDEC 2015; this proposal needs further consideration at WGDEC 2016. WGDEC also recommend that in 2016, the work achieved under this ToR (b) is consolidated with previous work undertaken by WGDEC with respect to buffer zones in order to develop a set of guiding principles for delineating bottom fishing closure boundaries.

WGDEC discussed progress with developing the VME database. This database provides an essential resource for the some of the core work of WGDEC. The large number of 'restricted' records within the database was discussed and proposals made to address this issue. Developments with the ICES VME data portal made since WGDEC 2014 were also discussed. Some clarifications to the VME database guidance were discussed and agreed. Finally, WGDEC discussed and agreed to progress a VME data call pilot, in conjunction with the ICES Data Centre. The VME Data Call would invite ICES Member Countries to submit new data on occurrences of VME indicators or VME habitat types for use in WGDECs work.

WGDEC discussed the potential impacts of deep-sea mining on vulnerable deep-water habitats. WGDEC reassessed the Pressures List developed through the OSPAR Intercessional Correspondence Group on Cumulative Effects (ICG-C), a subgroup of the Environmental Impacts of Human Activities (EIHA) committee, and suggested some modifications to ensure that the pressures associated with deep-sea mining activities were adequately covered. WGDEC noted that as deep-sea mining has not begun and many of the potential impacts, such as extent of plumes and toxicity levels, remain unknown. It is therefore very difficult to predict the sensitivity of vulnerable marine habitats to these potential impacts and so fully address this Terms of Reference at this time.

WGDEC reviewed new evidence of ecosystem functioning on VME indicators in the North Atlantic in relation to the CORALfish project and other research. The group agreed that the scope of this work should be expanded from VME indicators to include VME habitats and VME elements. A set of conclusions from this review are outlined at the end of this section in the report.

Opening of the meeting

WGDEC began discussions at 10:00 on February 16th 2015 at the Department for Oceans and Fisheries, Horta, Azores. Deliberations primarily focused on what was being asked of the group by NEAFC, the EC and ICES. Following introductions, the opening discussion focused on assigning leads to each Terms of Reference, a review of the agenda for the week ahead and the identification of key issues for group discussion.

1 Adoption of the agenda

2014/2/ACOM28 **The Working Group on Deep-water Ecology (WGDEC)**, chaired by Neil Golding, UK will meet in Horta, Azores, Portugal, 16–20 February 2015 to:

a) Provide all available new information on distribution of VMEs in the North Atlantic with a view to advising on any new closures to bottom fisheries or revision of existing closures to bottom fisheries (NEAFC standing request: this may be updated in November 2014). In addition, provide new information on location of habitats sensitive to particular fishing activities (i.e. vulnerable marine ecosystems, VMEs) within EU waters (EC request);

b) In order that advice on closures can be more clearly presented and interpreted, continue the development of a system of weighting the reliability and significance of VME indicator records and consider ways of combining the geographic locations of VMEs through development of a standardised method for recommending closed area boundaries;

c) Maintain the ICES database on VMEs;

d) In light of two deep-sea mining exploration licences that have been granted by the International Seabed Authority (ISA) along the Mid-Atlantic Ridge, review the sensitivity of vulnerable deep-water habitats to these activities and make recommendations for their protection;

e) Review new evidence of ecosystem functioning of VME indicators in the North Atlantic arising from the CORALFISH project and recent scientific literature.

WGDEC will report by 6 March 2015 for the attention of the Advisory Committee.

Supporting Information

<table>
<tr><td>Priority:</td><td>High as a Joint group with NAFO and is essential to providing information to help answer external requests</td></tr>
<tr><td>Scientific justification and relation to action plan:</td><td>a) This information and maps are required to meet part of the European Commission MoU request to “provide any new information regarding the impact of fisheries on ..... sensitive habitats” and the NEAFC request “ 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.” The location of newly discovered/mapped sensitive habitats is critical to these requests. It is essential that ICES/WG chair asks its Member Countries etc. to supply as much relevant information as they may have by one month in advance of the WGDEC meeting;
b) This is an important development of the VME database. Records within the VME database originate from a number of different sources; from specific targeted habitat mapping surveys with a high degree of spatial accuracy through to bycatch records from towed gear/longlining. Through developing a weighting system for these records, the information underpinning any new recommendations on closures, or modifications to existing closures, can be assessed and weighted based on reliability and significance. A clear method of setting boundaries around groups of records would be of considerable help in providing justification for such boundaries;
c) There is a requirement to update the ICES VME database to include new information on the distribution of VMEs (including VME indicator species) submitted under ToR (a);
d) ICES has not considered the effects of deep-sea mining on VMEs previously. This may be of interest in comparing with the effects of bottom-fishing activities;
e) This will provide a useful review of a developing area of science.</td></tr>
<tr><td>Resource requirements:</td><td>The usual helpful support from the Secretariat will be appreciated.</td></tr>
<tr><td>Participants:</td><td>The group is normally attended by some 15–20 members and guests.</td></tr>
<tr><td>Secretariat facilities:</td><td>None, apart from the Sharepoint site</td></tr>
<tr><td>Financial:</td><td>No financial implications.</td></tr>
<tr><td>Linkages to ACOM and its expert groups</td><td>ACOM is parent group. WGDEEP is related, but no explicit overlap in work this year.</td></tr>
<tr><td>Linkages to SCICOM and its expert groups</td><td>No direct linkages, though the work of BEWG is related</td></tr>
<tr><td>Linkages to other organisations:</td><td>OSPAR, NEAFC</td></tr>
</table>

2 Provide all available new information on distribution of VMEs in the North Atlantic with a view to advising on any new closures to bottom fisheries or revision of existing closures to bottom fisheries (NEAFC standing request). In addition, provide new information on location of habitats sensitive to particular fishing activities (i.e. vulnerable marine ecosystems, VMEs) within EU waters (EC request)

2.1 Introduction

New data that indicate the presence of VMEs were submitted to ICES WGDEC in 2015 and these were incorporated into the ICES VME database. A total of 510 new records were added within the NEAFC and NAFO Regulatory Areas (RA) and areas within the EEZs of the EU.

Data on fishing activity within the NEAFC RA from 2006 through to 2014 were provided by NEAFC for use by WGDEC. However, due to time considerations, only data from 2014 was examined and reported on at the end of this section. However, the group noted the potential usefulness of this VMS time-series dataset; Terms of Reference for next year were discussed which could utilise these data.

This chapter is split according to areas within the NEAFC RA, those areas within the EEZs of the EU or other countries and those within the NAFO RA.

Areas considered within the NEAFC RA:

- Rockall Bank

Areas considered within the EEZs of various countries:

- Rockall Bank
- Rosemary Bank
- Faroe-Shetland Channel
- Bill Baileys Bank & Lousy Bank
- Greenland
- Portugal (Azores)

Areas considered within the NAFO RA:

- Flemish Cap and Grand Banks

2.2 Areas within the NEAFC regulatory area

2.2.1 Rockall Bank

Rockall Bank is a large plateau that lies some 250 km to the west of the UK and Ireland surrounded on all sides by deep water. It lies partly in the EU EEZ and partly in international waters where bottom fisheries are regulated by NEAFC. An area in the NW of Rockall Bank has been closed to bottom fishing and fishing with static gear (including bottom-set gillnets and longlines) since 2007. New areas on Rockall Bank called Southwest Rockall Area 1 and 2 were closed to bottom fishing and fishing with static gear (including bottom-set gillnets and longlines) in 2014 (NEAFC, 2014) following ICES advice (ICES, 2013b).

Two fish stock assessment cruises were undertaken in 2014 by Marine Scotland Science over Rockall Bank. Within the NEAFC Regulatory Area, VME indicators were observed from trawl survey bycatch to the south of the NW Rockall closed area and within the Haddock Box closed area (see Figure 1). VME indicators included stony corals, sponges and seapens but were not found in large quantities.

In 2014, a Russian bottom-trawler fishing survey with an observer onboard was also undertaken at Rockall Bank between 56°25'–57°01'N, 15°16'–14°56'W and at a depth range of 210–350 m. No bycatch of VME indicator species were recorded during this survey (Kanishchev and Vinnichenko, 2015).

WGDEC do not recommend a new bottom fishing closure to encompass these new records at this time.

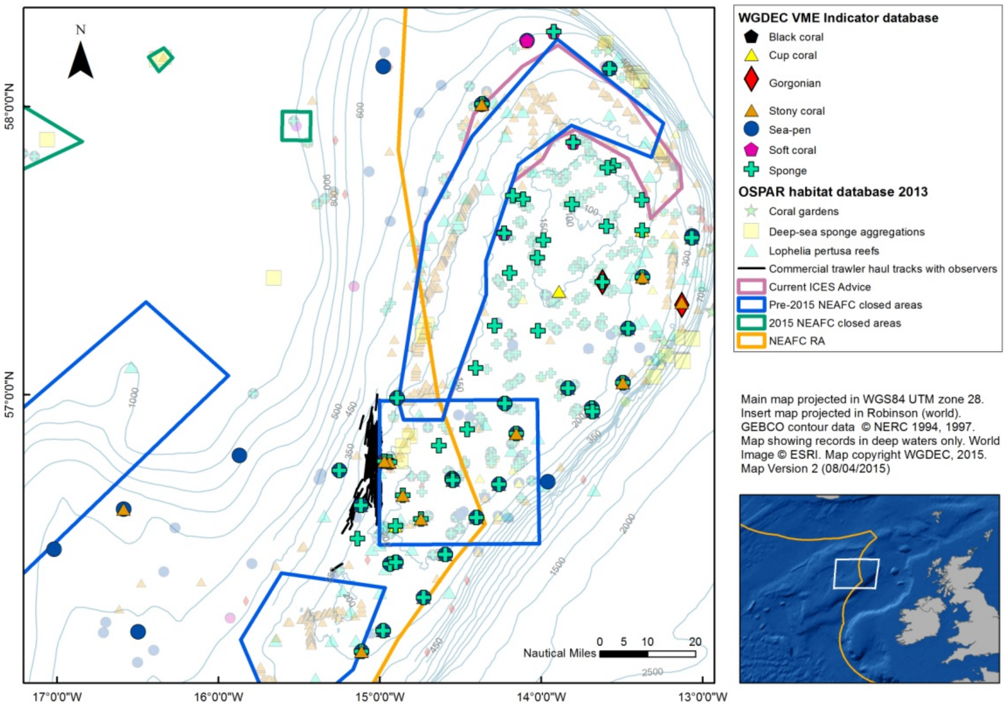

Figure 1. Map of the Rockall Bank showing new VME indicator records presented alongside existing VME indicator data (transparent) and OSPAR habitats submitted to the 2013 OSPAR database. Black lines indicate Russian commercial trawl haul tracks with observers (Kanishchev and Vinnichenko, 2015)

2.3 Areas considered within the EEZs of various countries

2.3.1 Rockall Bank

In the UK EEZ region of the Rockall Bank, two areas, Northwest Rockall Bank and East Rockall Bank, were designated as a Special Areas of Conservation (SACs) and Sites of Community Importance (SCIs) under the Habitats Directive in 2011 and 2013 respectively. Both sites are designated for the protection of reef habitats including biogenic, stony and bedrock subtypes.

An area in the NW of Rockall Bank has been closed to bottom fishing and fishing with static gear, including bottom-set gillnets and longlines since 2007. ICES advised a boundary modification to the NW Rockall bottom fishing closure in 2012, and reiterated this advice in 2013 (ICES, 2013b).

The two fish stock assessment cruises undertaken in 2014 by Marine Scotland Science found VME indicators within the UK EEZ region of Rockall Bank. These were observed from trawl survey bycatch around the NW Rockall closed area and within the Haddock Box closed area (see Figure 2). VME indicators included cup corals, stony corals, sponges and seapens but were not found in large quantities.

WGDEC do not recommend a new bottom fishing closure to encompass new records at this time. However, WGDEC does recommend that ICES advice from 2013 is maintained (ICES, 2013b).

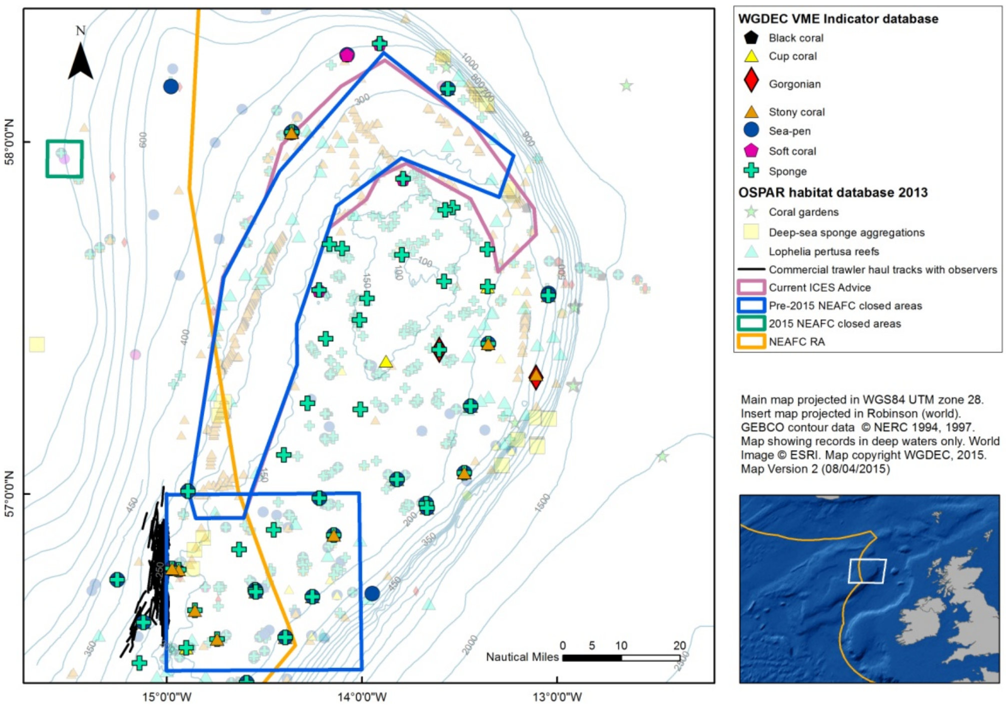

Figure 2. Map of the Rockall Bank showing new VME indicator records presented alongside existing VME indicator data (transparent) and OSPAR habitats submitted to the 2013 OSPAR database. The pre-2015 bottom fishing closures are shown in blue and the ICES 2013 advised boundary modification to the NW Rockall closure is shown in pink.

2.3.2 Rosemary Bank

The Rosemary Bank Seamount lies at the north end of the Rockall Trough. Its summit is around 350 m. Rosemary Bank Seamount was designated as a Nature Conservation Marine Protected Area (NCMPA) by the UK under the Marine and Coastal Access Act (2009) in July 2014 for the features deep-sea sponge aggregations, seamount communities and seamounts (large-scale feature). Fisheries management measures are currently being determined by the Scottish Government.

New data on VME indicator species were collected on a research cruise (survey 1314S) to Rosemary Bank Seamount by Marine Scotland Science in 2014 and presented to WGDEC 2015 (see Figure 3). Data were from a combination of trawl survey bycatch and video tow transects. Trawl bycatch were identified to species level where possible and included small numbers of VME indicators such as stony corals, black corals, gorgonians and seapens, alongside large numbers of sponges such as *Thenea* sp, *Geodia barretti*, and *Radiella* sp. Video tows showed extensive areas of the VME habitat type 'deep-sea sponge aggregations'; potentially the subtype 'Ostur sponge aggregations' (see Figure 4).

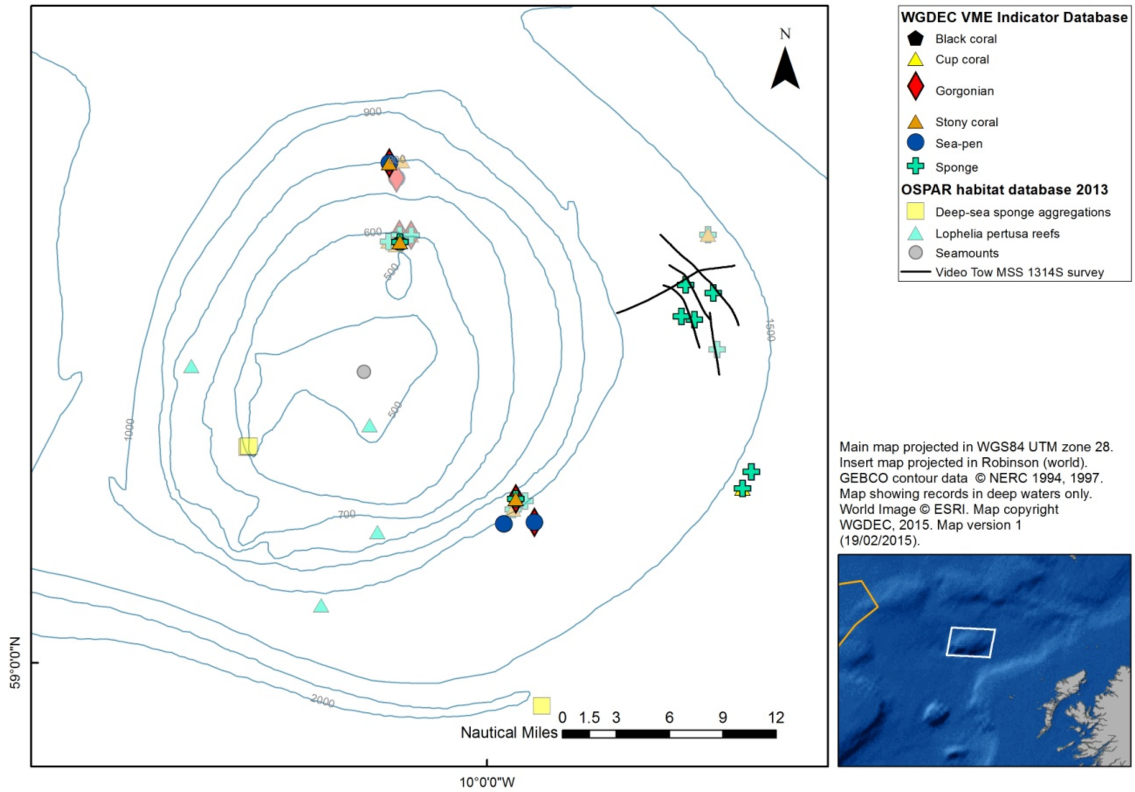

Figure 3. Map of Rosemary Bank Seamount showing new VME indicator records presented alongside existing VME indicator data (transparent) and OSPAR habitats (transparent) submitted to the 2013 OSPAR database. Video tow lines (black) indicate the extent of the 'deep-sea sponge aggregations' VME data collected in 2014.

Figure 4. An image of a deep-sea sponge aggregation VME at Rosemary Bank Seamount at approximately 1200 m depth (survey 1314S). Photo Credit: Marine Scotland Science/Scottish Government.

2.3.3 Faroe-Shetland Channel

The Faroe Shetland Sponge Belt was designated as a NCMPA by the UK under the Marine and Coastal Access Act (2009) in July 2014 for the features deep-sea sponge aggregations, amongst other habitat types and large-scale features. Fisheries management measures are currently being determined by the Scottish Government.

New data on VME indicator species were collected on a research cruise to the Faroe-Shetland Channel by Marine Scotland Science in 2014 (survey 1314S) and presented to WGDEC 2015 (see Figure 5). Data were collected from trawl survey bycatch and video tow transects. Survey bycatch data included the sea-pen *Umbellula encrinus;* various soft coral species, and a large number of sponge species from the orders Poecilosclerida, Hadromerida, Spirophorida and Halichondrida, amongst others, and these were added to the VME database. Please note that the video tow seabed imagery is still in the process of being analysed and will be presented to WGDEC 2016. An example of the sponge communities observed at the Faroe-Shetland Channel on survey 1314S can be seen in Figure 6.

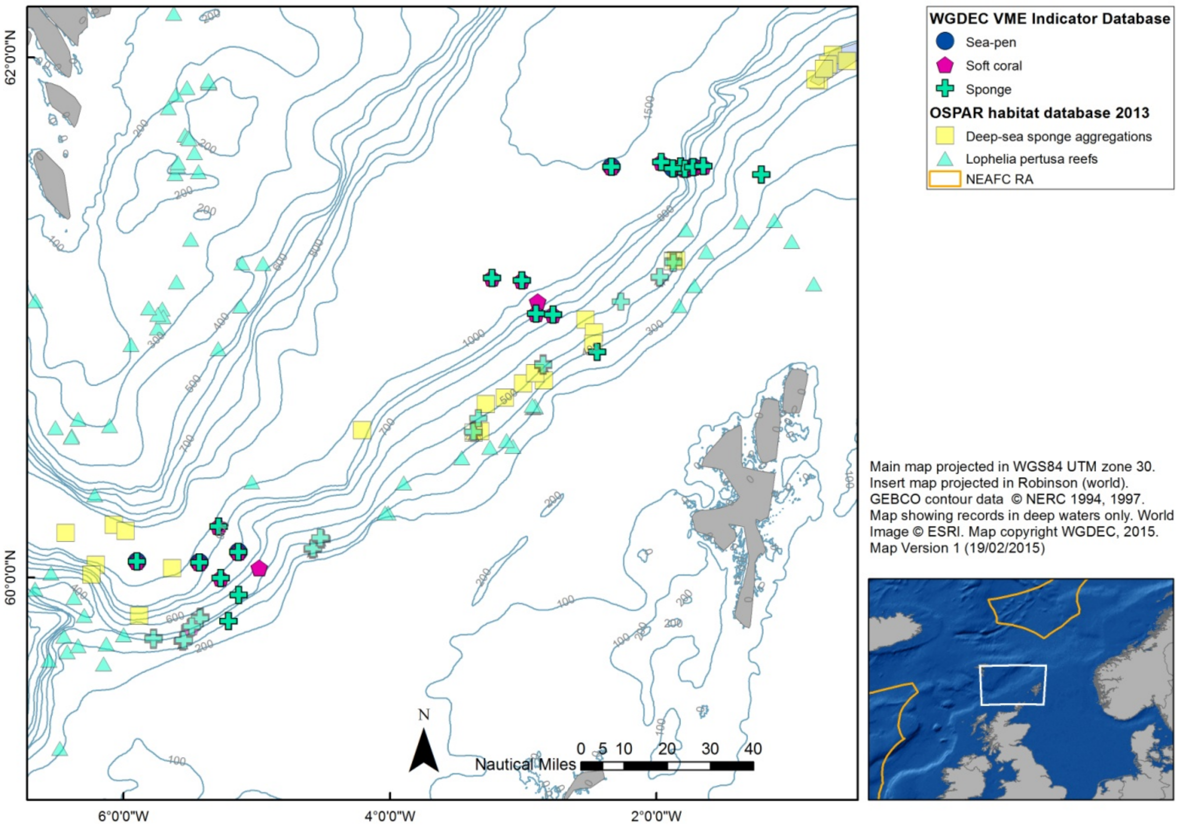

Figure 5. Map of the Faroe Shetland Channel showing new VME indicator records presented alongside existing VME indicator data (transparent) and OSPAR habitats (transparent) submitted to the 2013 OSPAR database.

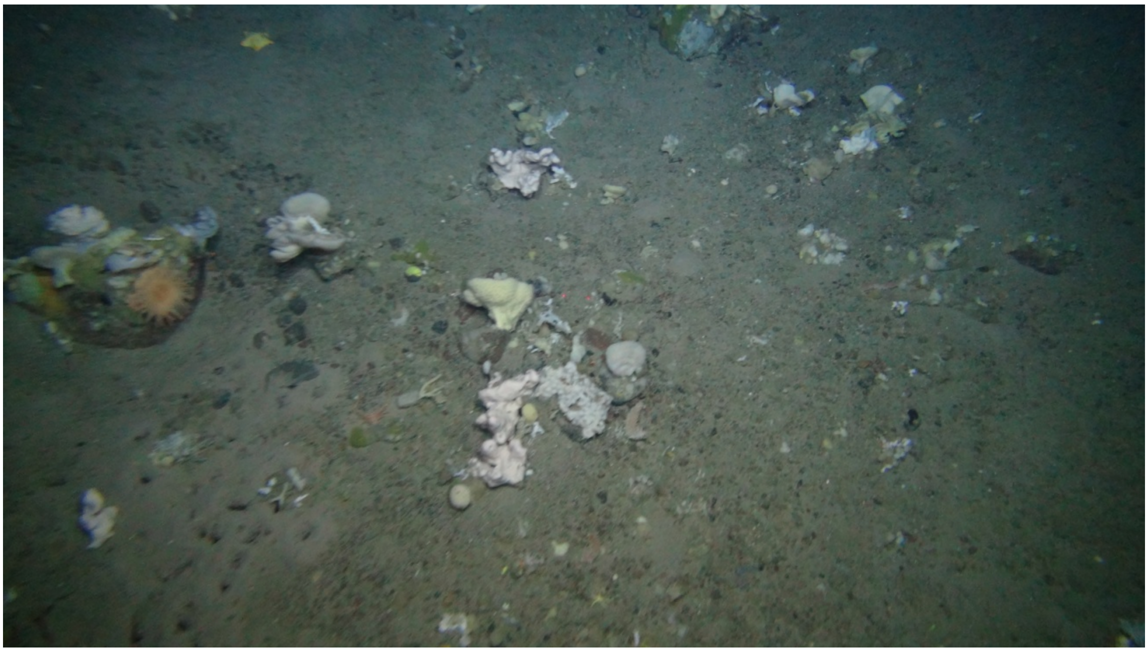

Figure 6. Sponge VME indicator species in the Faroe Shetland Channel at approximately 500 m depth (Survey 13/14S). Photo Credit: Marine Scotland Science/Scottish Government.

2.3.4 Bill Baileys Bank and Lousy Bank

Within the Faroese EEZ a number of observations of VME indicator species were made from a Russian bottom-trawler fishing survey with an observer onboard in May–June 2014 on the slopes of the Bill Baileys Bank and Lousy Bank (Figure 7). Catches of the scleractinian coral *Lophelia pertusa,* the gorgonian coral *Radicipes gracilis* and a number of seapen species including *Funiculina quadrangularis*, *Halipteris finmarchica, Umbellula* sp., and *Anthoptilum* sp. were recorded at depths of 420–630 m (Kanishchev and Vinnichenko, 2015). Generally the total haul catches of VME species indicators did not exceed 10 kg, although one haul between 60°29'N, 12°57'W–60°34'N, 12°44'W, had a total catch of corals weighing 19 kg.

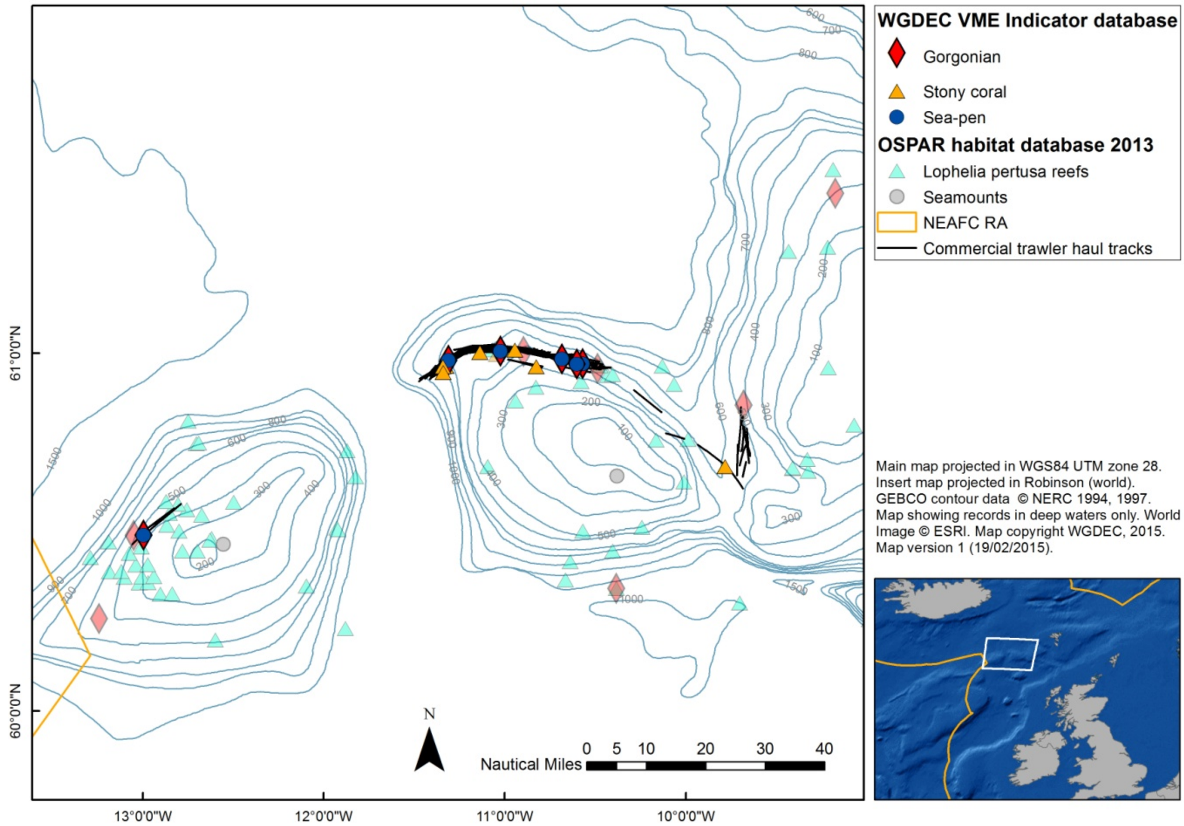

Figure 7. Map of the Bill Baileys Bank and Lousy Bank showing new VME indicator records presented alongside existing VME indicator data (transparent) and OSPAR habitats (transparent) submitted to the 2013 OSPAR database. Black lines indicate the trawl tracks.

2.3.5 Greenland

New data were presented to WGDEC 2015 from Cape Desolation in the Greenland EEZ. Samples of the coral *Lophelia pertusa* and gorgonians *Paragorgia arborea,* and *Primnoa resedaeformis* were found entangled in a CTD wire during a Fisheries and Oceans Canada cruise for the Atlantic Zone Off-Shelf Monitoring Program in June 2012 (see Figures 8 and 9). An international multidisciplinary cruise in September–October 2012 verified these records through a drop down camera survey which confirmed the presence of the VME habitat type 'Cold-water coral reef' at depths of approximately 850–900 m (ICES Insight, 2013)(see Figure 10). The area is a steep, current-swept section of the continental slope, and the reef occurs on a rocky outcrop.

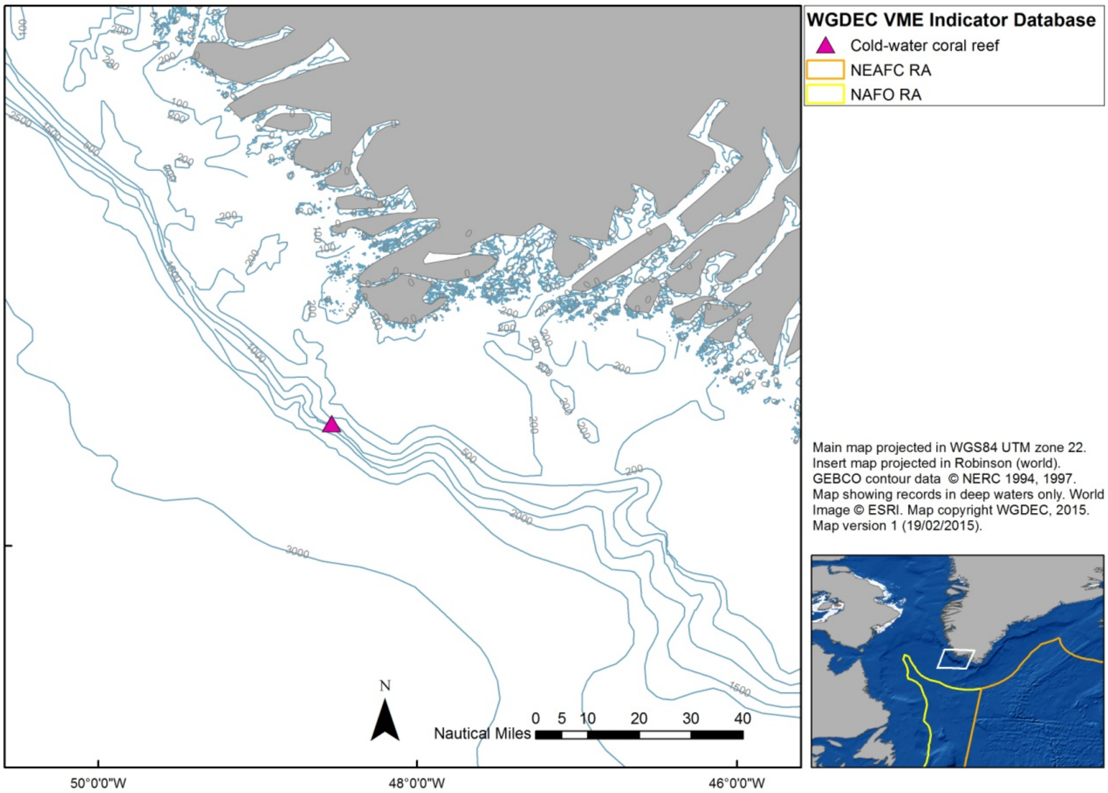

Figure 8. New record of a cold-water coral reef submitted to the VME database at WGDEC 2015 from Cape Desolation within the Greenland EEZ.

Figure 9. The reef forming stone coral *Lophelia Pertusa* found near Cape Desolation at approximately 900 meters depth. Photo credit Bedford Institute of Oceanography.

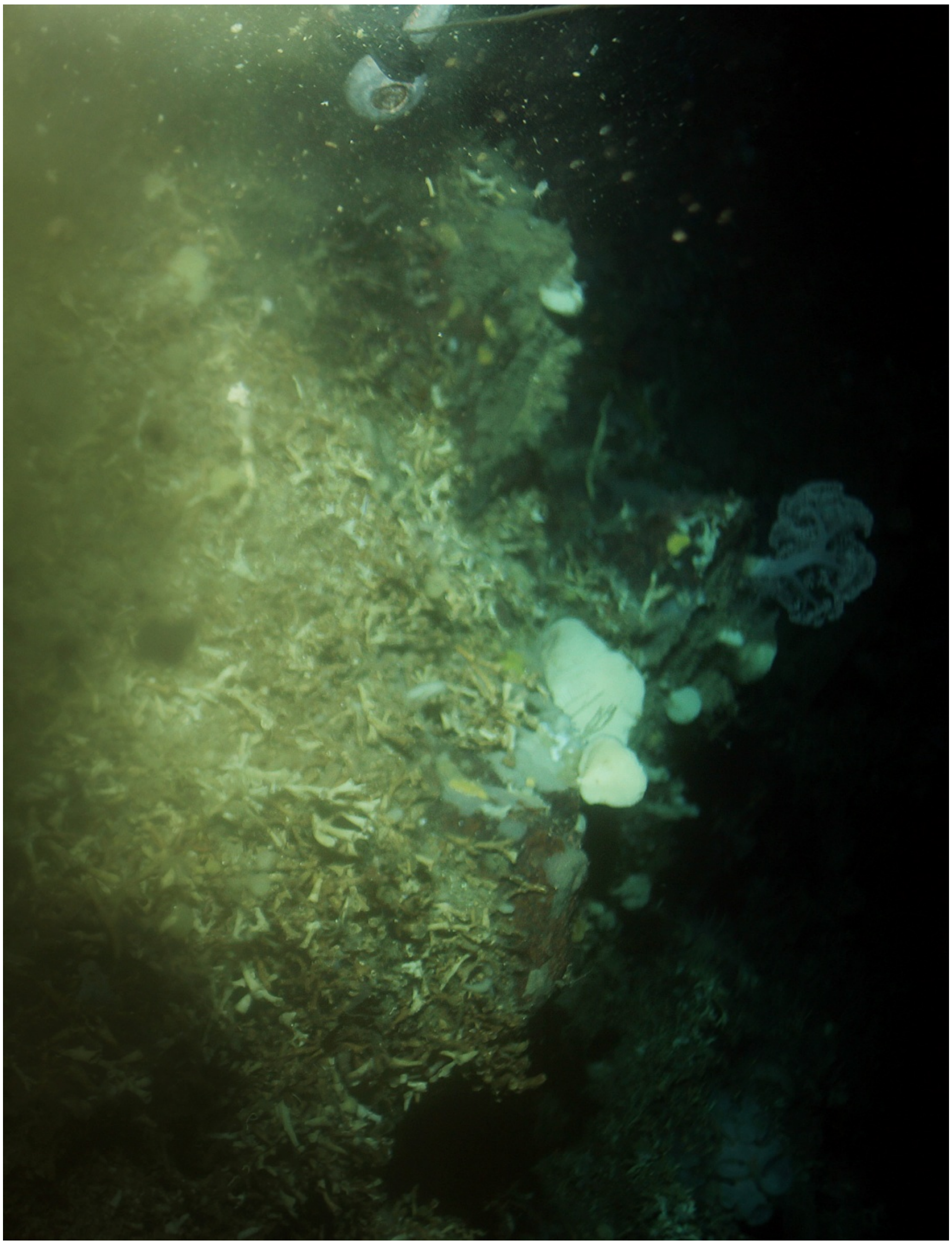

Figure 10. Part of the reef found near Cape Desolation in Southern Greenland. A formation of coral reef framework is seen with sponges, glass sponges and soft coral growing on it. Photo credit: Bedford Institute of Oceanography.

2.3.6 Portugal

WGDEC 2015 was made aware of new VME indicator records (see Figure 11) from within Azorean waters (Braga-Henriques *et al*. (2013)). These records were not provided to WGDEC and are not currently within the VME database.

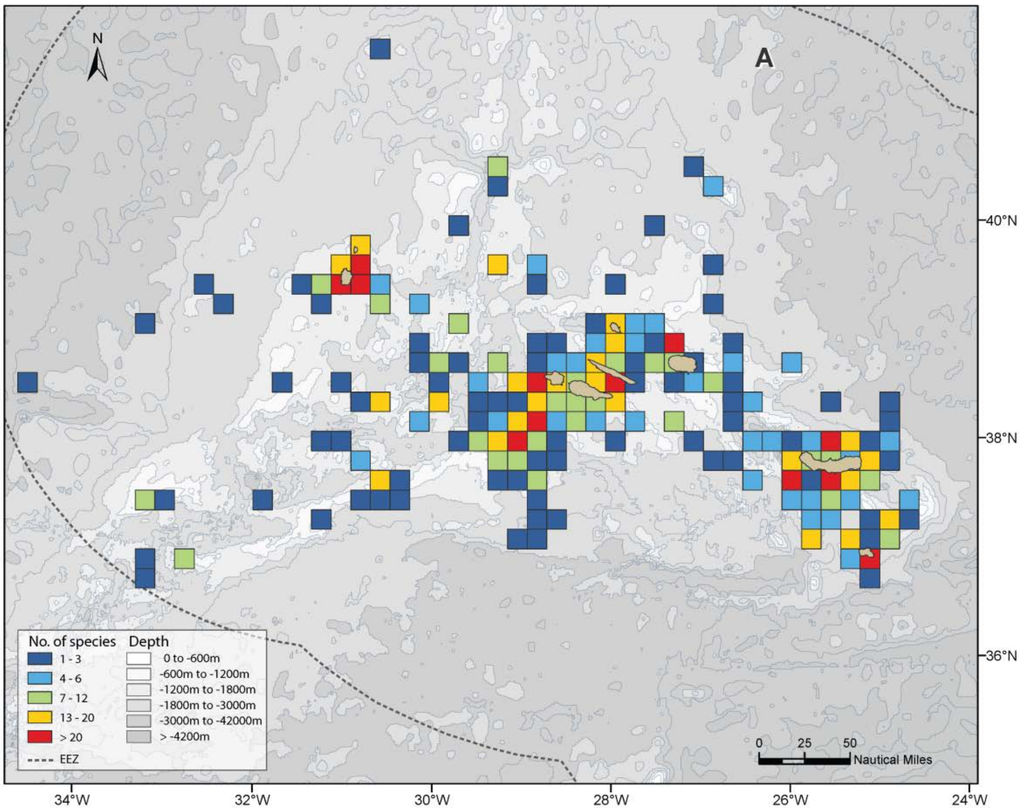

Figure 11. Species diversity of corals in the Azores EEZ per 20 km×20 km cells showing number of species. Samples comprised 164 species belonging to Alcyonacea, Antipatharia, Scleractinia and Stylasteridae. Map extracted from Braga-Henriques *et al*. (2013).

2.4 Areas within the NAFO regulatory area

2.4.1 Flemish Cap Bank, Grand Banks and Flemish Pass Basin

New bycatch data on VME indicator species were submitted to WGDEC 2015 from the Flemish Cap Bank, the Grand Banks of Newfoundland, and the Flemish Pass Basin. These data were recorded during Russian commercial trawling operations in with an observer onboard February-September 2014 at depths between 140–1450 m (see Figure 12).

Small numbers of VME indicator species were recorded in the area including Alcyonacea (soft and branched corals) and seapen species such as *Anthoptilum* sp., *Duva florida* and *Pennatula aculeata*. In addition, small numbers of *Nephtheidae*, *Gersemia* sp. and *Virgularia* sp. were observed. Twenty-one species of sponges were also found among which *Phakellia* sp., *Iophon piceum*, *Geodia* sp., *Chonelasma* sp., and *Haliclona* sp. predominated. The total haul catches of VME indicator species in the area did not exceed 1 kg per haul.

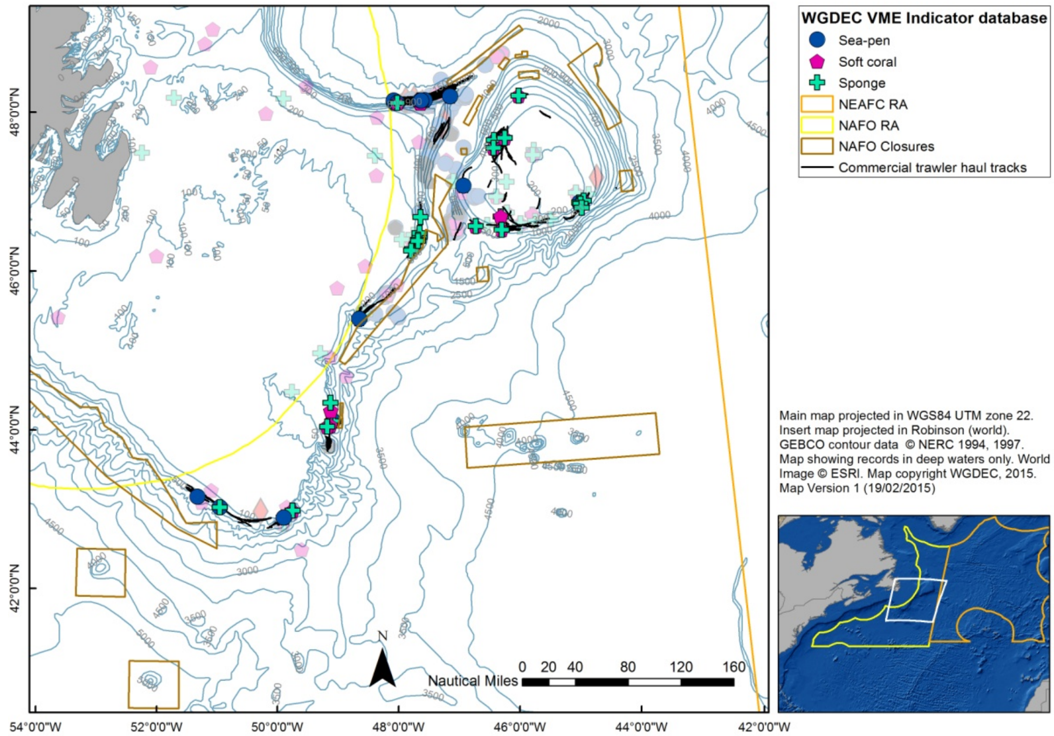

Figure 12. Map of the Flemish Cap Bank, Grand Banks and the Flemish Pass Basin showing new VME indicator records presented alongside existing VME indicator data (transparent). Existing NAFO closures are shown in brown boxes. Black lines indicate the trawl tracks.

2.5 VMS submission from NEAFC for 2014

2.5.1 Background

WGDEC analysed VMS-data for 2014; the data were received by ICES from NEAFC. The dataset comprised raw data, i.e. all records received from all fishing vessels that operated in the Regulatory Area (RA) in 2014, hence filtering was necessary to achieve relevant data for vessel categories conducting fisheries with potentially bottom-touching fishing gear. The following gear codes were selected for bottom trawling (Beam Trawl (TBB), Bottom Otter Trawl (OTB), Bottom Pair Trawl (PTB) and Multi-rig Otter Trawl (OTT)) and longlining (LongLine Set; LLS). These were comparable with the gear code filtering undertaken on 2013 data at WGDEC 2014. To better define the optimum speed filtering for these records to identify when fishing activity was being undertaken, the Chair of the Working Group on Spatial Fisheries Data (WGSFD) was consulted. To this end, histograms showing vessel speeds were calculated (Figures 13, 14, 15, and 16). There was insufficient VMS data for this to be achieved with gear code TBB; a speed filter of 1-4 knots was used.

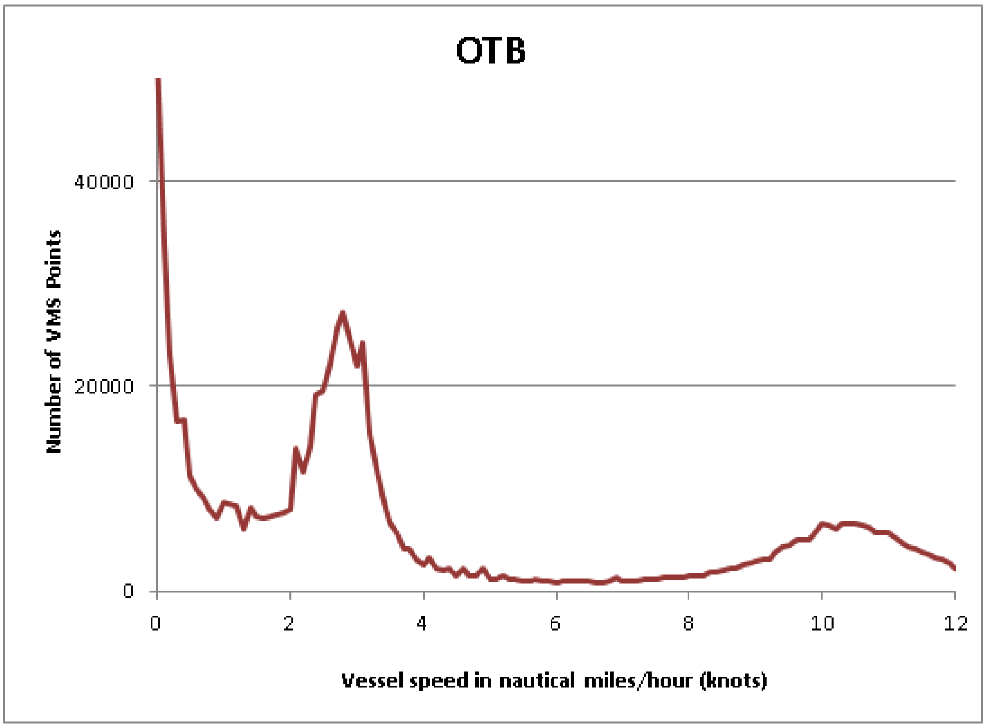

Figure 13. Histogram showing 2014 NEAFC VMS vessel speed data for bottom Otter Trawl (OTB). A speed filter of between 1–4 knots was identified from this plot to identify vessels undertaking 'fishing activity'.

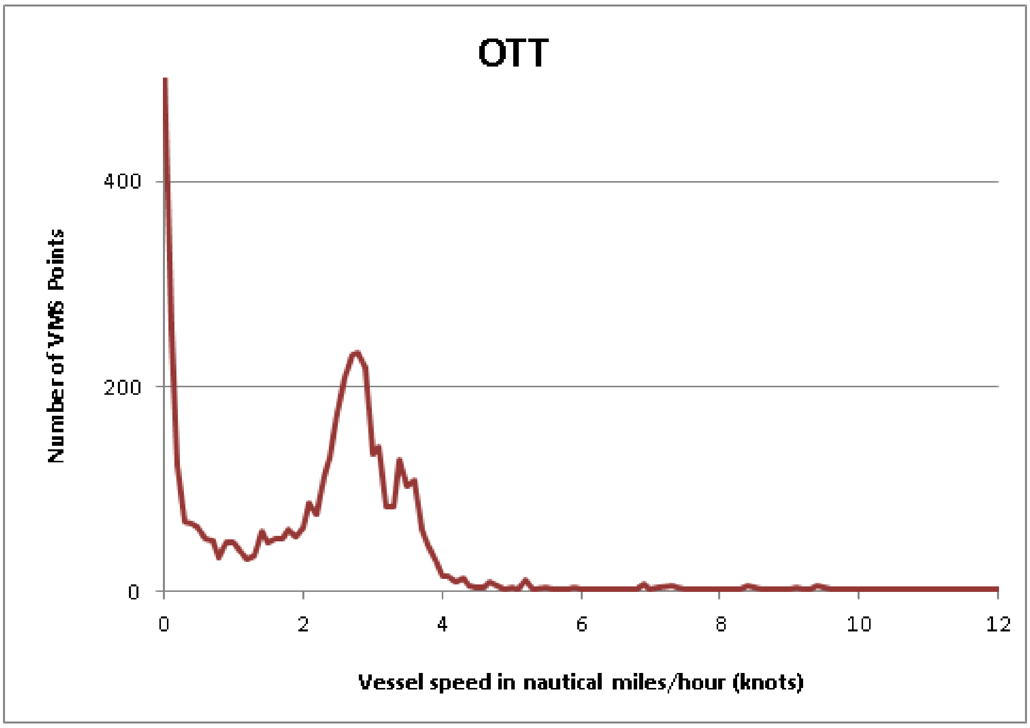

Figure 14. Histogram showing 2014 NEAFC VMS vessel speed data for multi-rig Otter Trawl (OTT). A speed filter of between 1.5–4 knots was identified from this plot to identify vessels undertaking 'fishing activity'.

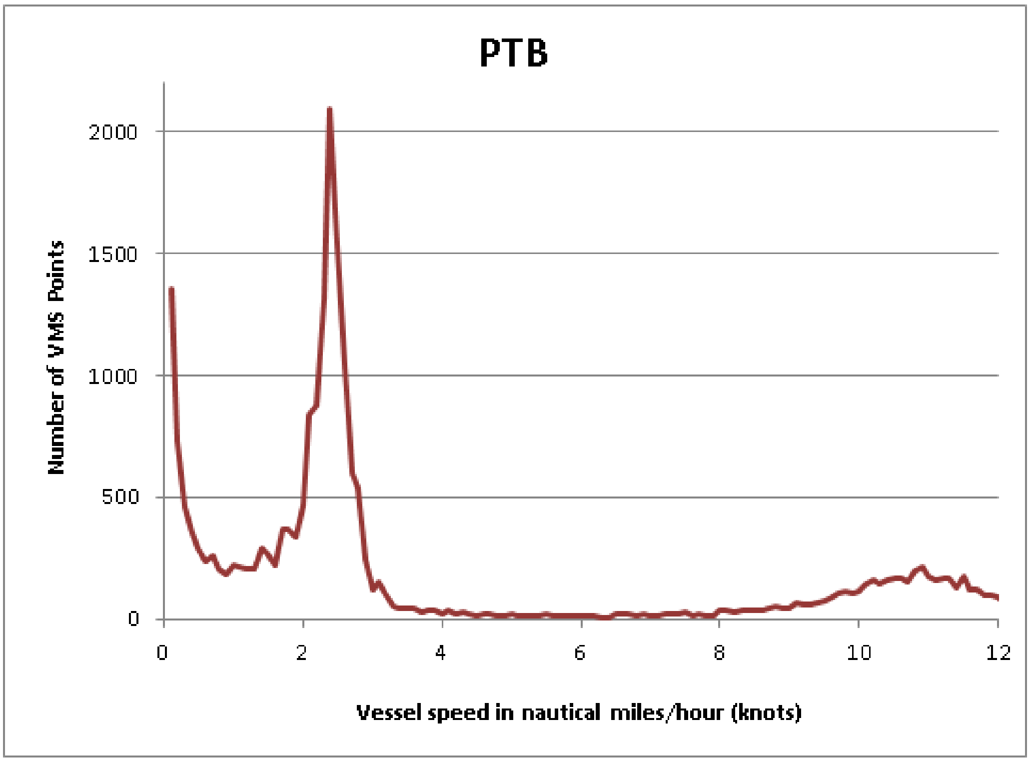

Figure 15. Histogram showing 2014 NEAFC VMS vessel speed data for bottom pair trawl (PTB). A speed filter of 1.5–3 knots was identified from this plot for use as a filter to identify 'fishing activity'.

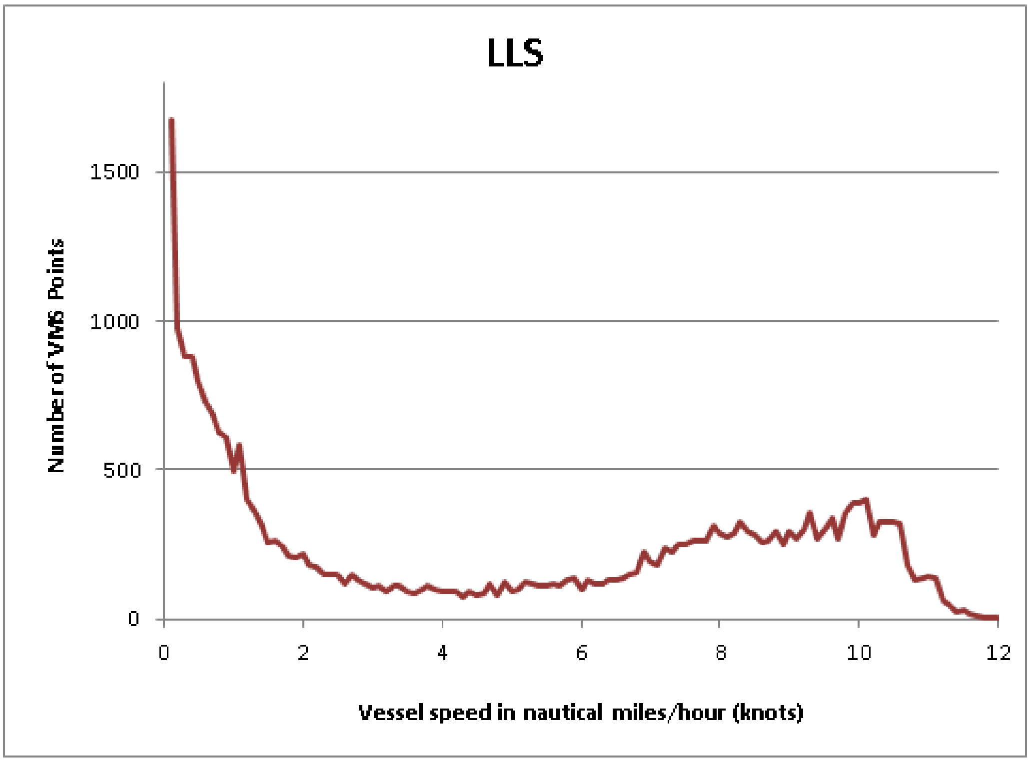

Figure 16. Histogram showing 2014 NEAFC VMS vessel speed data for set longline (LLS). A speed filter of less than 5 knots was identified from this plot for use as a filter to identify 'fishing activity'.

Following the examination of vessel speed histograms, the following speed filters were applied to TBB, OTB, PTB and OTT; 1–4 knots, 1–4 knots, 1.5–3 knots and 1.5–4 knots respectively. These speed filters differ slightly from the filters applied during WGDEC 2014. For longliners, VMS data were filtered for speeds of less than 5 knots. Records from areas with bottom depth exceeding 2000 m, i.e. the current maximum depth of bottom fishing, were also excluded using the GEBCO 2000m isobath.

For the bottom-trawling gear types selected (above), prior to filtering, there were 78 725 VMS pings in the 2014 dataset. Following filtering by the speeds discussed above, 42 373 VMS pings remained. For static longline gear types, prior to filtering, there were 7707 VMS pings in the 2014 dataset. Following filtering by the speeds discussed above, 4904 VMS pings remained.

Similarly to the 2013 data, the vast majority of records were from trawlers of various categories, and it was a concern that once again, filtering by gear using trawl gear codes given in the dataset did not seem to provide a fully reliable dataset. The dataset is updated twice a year and each vessel is assigned a gear-code. The vessel can potentially change fishing gear in this period and it seems that some vessels do not send positions on a one hour basis.

Fishing activity is unevenly distributed. The overall Northeast Atlantic map for potential bottom trawling can be seen in Figure 17 and static longlining in Figure 18. WGDEC also considered certain subareas of interest where bottom fishing closures have been established or proposed to protect VMEs; these subareas were Hatton and Rockall Banks, Mid-Atlantic Ridge and Josephine Seamount.

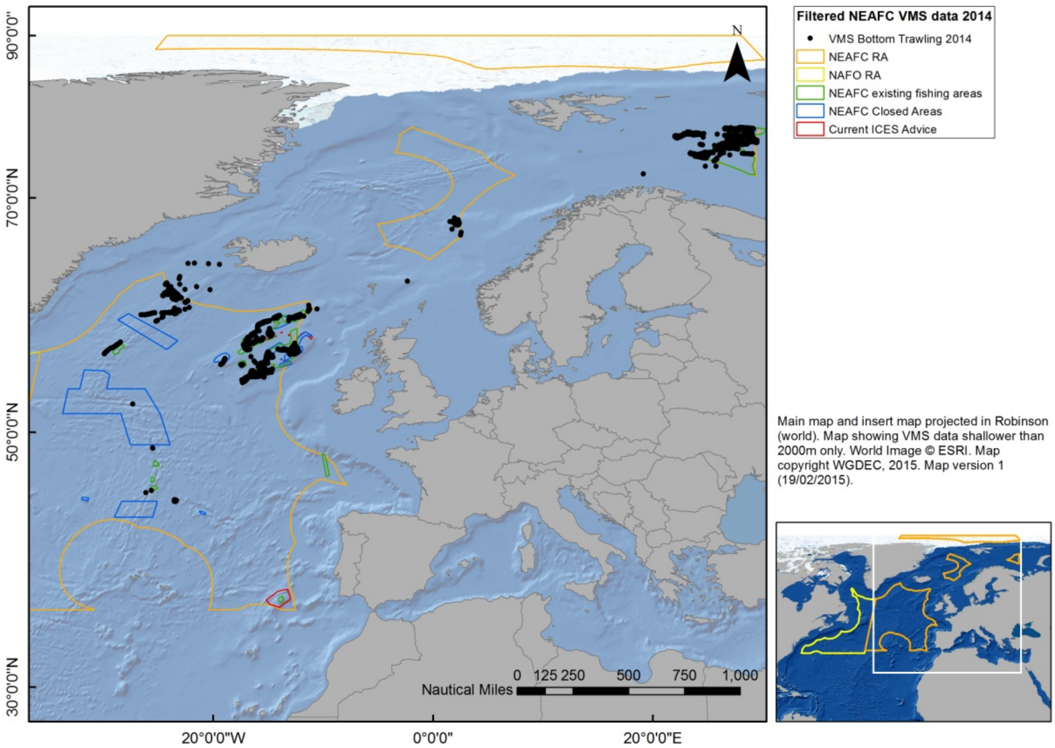

Figure 17. Map showing 2014 NEAFC VMS data for potential bottom-trawling gear types (TBB, OTB, PTB and OTT) across the NEAFC area (note that records deeper than 2000 m have been excluded).

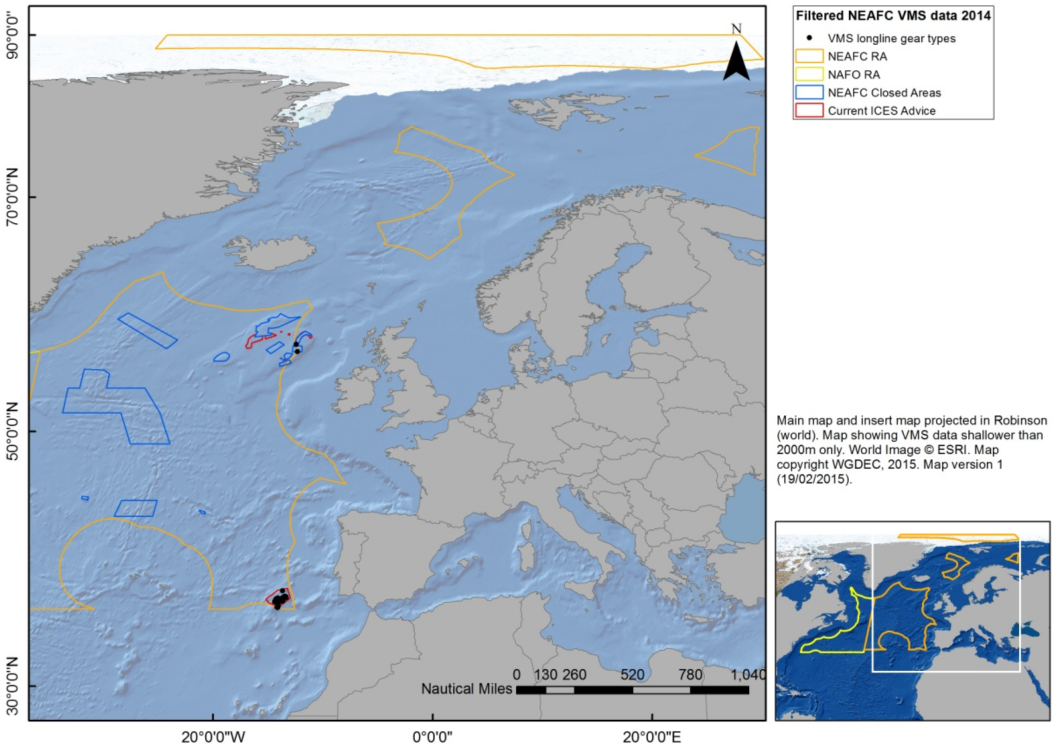

Figure 18. Map showing 2014 NEAFC VMS data for set longline gear types (LLS) across the NEAFC area (note that records deeper than 2000 m have been excluded).

2.5.2 Hatton and Rockall Banks

The NEAFC VMS data in Figure 19 show fishing activity around the features that are closed. Most of the activity appears to be restricted to 'existing fishing areas', but in some areas there also appears to be fishing between such areas, especially between the areas HAR3 and HAR4. It should be noted that a few isolated lines of single points in closed areas probably represent a vessel reducing speed whilst steaming and not actually undertaking fishing activity.

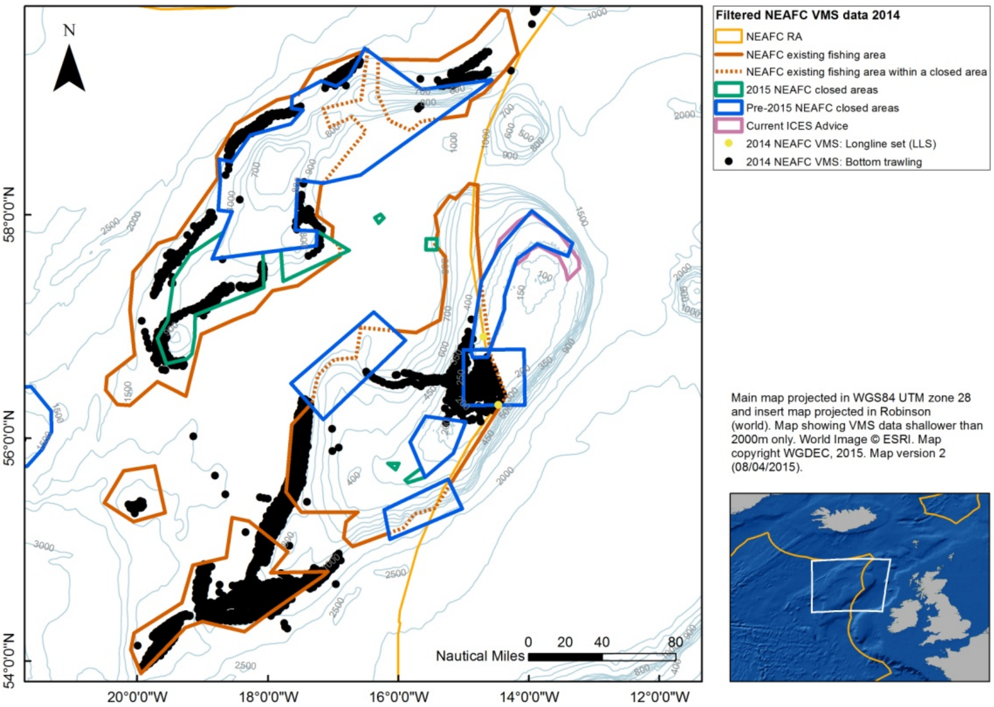

Figure 19. More detailed map showing 2014 NEAFC VMS data (filtered for potential bottom-trawl gears and excluding points deeper than 2000 m) across Hatton and Rockall Bank. Existing NEAFC fishing areas are delineated in orange. Where these fishing areas intersect closed areas, the lines are hatched. Pre-2015 NEAFC fishing closures are outlined in blue, while new NEAFC fishing closures brought into force in 2015 are outlined in green.

2.5.3 Mid-Atlantic Ridge (Reykjanes Ridge)

Similarly reported in WGDEC 2014, the data (Figure 20) suggest that extensive trawling occurs in two areas on the Reykjanes Ridge. Once again, the Group could not determine if these records are valid bottom fishing records, but were concerned that they might represent miscoded records of midwater trawling for redfish and roundnose grenadier. ICES is certainly aware of the redfish fisheries with midwater trawls on the western flank of the Reykjanes Ridge, and also the development of a midwater trawl fishery for roundnose grenadier in the Reykjanes Ridge to the southeast of Iceland (ICES, 2013a).

All this activity is recorded in 'new fishing areas'. The Mid-Atlantic Ridge is regarded by ICES as having VME elements; hence extensive bottom fishing in the area may cause significant adverse impacts on likely VMEs.

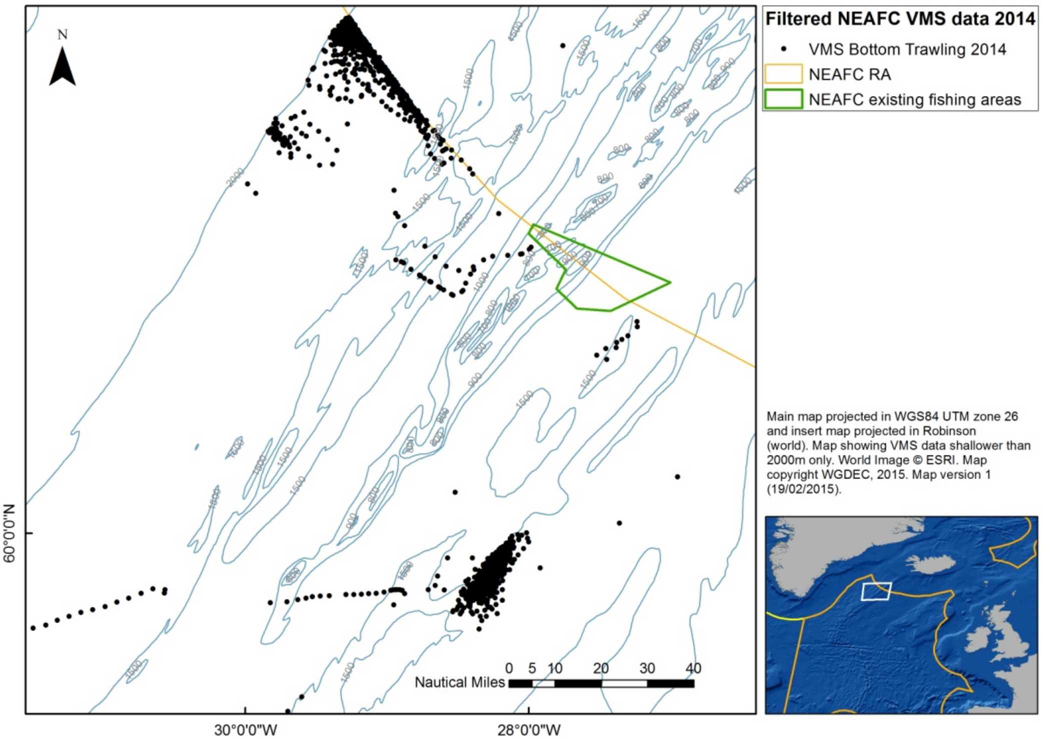

Figure 20 More detailed map showing 2014 NEAFC VMS data (filtered for bottom-trawl gears and excluding points deeper than 2000 m) across the northern section of the Mid-Atlantic Ridge.

2.5.4 Josephine Seamount

A subarea of the Josephine Seamount is currently a NEAFC 'existing fishing area', i.e. open to bottom fishing. In 2013 ICES advised that the entire seamount and adjacent areas be closed to bottom fishing (ICES, 2013b). The basis of this advice was documented records of VME indicator organisms, primarily gorgonian corals.

While NEAFC VMS data from 2013 showed no records of trawling activity within the proposed closure area on Josephine Seamount, there is evidence of a longline fishery from 2014 VMS data (see Figure 21).

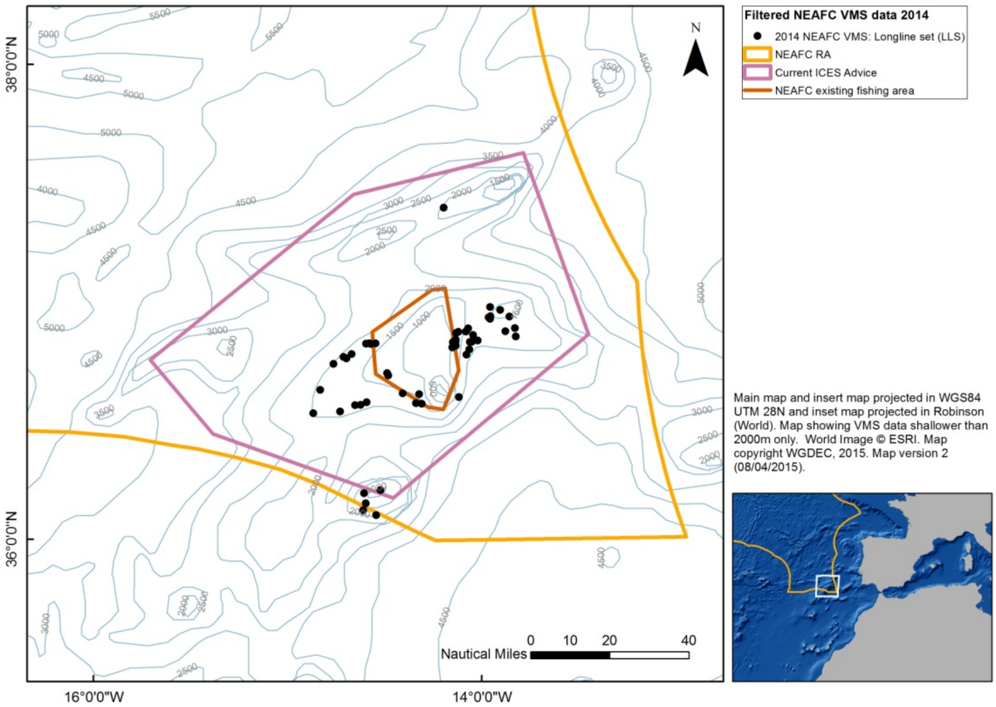

Figure 21 More detailed map showing the 2014 longline fishery on Josephine Seamount (VMS points are filtered by gear type (LongLine Set, LLS)). Note that points deeper than 2000m are excluded. The NEAFC existing fishing area is delineated in orange whilst the bottom fishing closure proposed in ICES Advice (ICES, 2013b) is shown in pink.

2.6 References

Braga-Henriques A, Porteiro F.M, Ribeiro P.A, de Matos V, Sampaio I, Ocana O and Santos R.S. 2013. Diversity, distribution and spatial structure of the cold-water coral fauna of the Azores (NE Atlantic). Biogeosciences, 10, 4009–4036.

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 Insight. Issue No. 50. 2013. http://ices.dk/sites/pub/Publication%20Reports/ICES%20Insight/Insight%20Issue%2050.pdf.

ICES. 2013a. Report of the Working Group on Biology and Assessment of Deep-sea Fisheries Resources (WGDEEP), 14–20 March 2013, Copenhagen, Denmark. ICES CM 2013/ACOM:17. 963 pp.

ICES. 2013b. Special Request. Advice June 2013. Section 1.5.5.1. Vulnerable deep-water habitats in the NEAFC Regulatory Area. ICES CM 2013/ACOM: 28. 10 pp.

NEAFC. 2009. Report of the 28th Annual Meeting of the North East Atlantic Fisheries Commission. 9–13 November 2009. Volume I, Report.

NEAFC. 2014. Recommendation 19 2014: Recommendation on the protection of vulnerable marine ecosystems in the NEAFC Regulatory Area. This text will be amended by Recommendation 09 2015. http://www.neafc.org/rec/2014/19.

Vinnichenko V.I. and Kanishchev A.A. 2015. Russian catches of cold-water corals and sponges in the North Atlantic based on the data of observations aboard fishing vessels in 2014. WGDEC 2015 Working Document.

3 In order that advice on closures can be more clearly presented and interpreted, continue the development of a system of weighting the reliability and significance of VME indicator records and consider ways of combining the geographic locations of VMEs through development of a standardised method for recommending closed area boundaries

3.1 Background

In 2014 WGDEC proposed a system of weighting the reliability and significance of Vulnerable Marine Ecosystem (VME) indicator records (ICES, 2014). This system was intended to formalise expert opinion and utilize as much relevant information as possible from the ICES VME database. A multi-criteria approach (MCA) to the weighting index was developed, the purpose of which was to evaluate the likelihood of how representative a datapoint was of the presence of an actual VME. The approach was moderately successful, yielding maps that were more readily interpreted with respect to those data that determined WGDEC's assessment that VMEs were present in an area.

There were, however, problems with the approach such as incorporating (in the same score) measures of the likelihood of a VME indicator record being an actual VME (e.g. based on the abundance) with measures of the uncertainty of that likelihood (e.g. survey method). There were also problems with the approach that resulted in conflicting values for certain records. For example, visual survey data could not be assigned a value for the amount of material observed meaning that it scored low in this respect, even if it was clear the record was indicating presence of a VME. In addition, the system did not take into account the taxonomy of the VME indicator records and their likelihood of forming a VME (e.g. seapen vs. stony coral).

A principal issue with the MCA system of 2014 was the scoring of individual records rather than providing an aggregate score for an area, taking into account all of the records present in that area. For example, one short (500 m) ROV transect was producing multiple scores while one long (several kilometres) fisheries trawl was producing one single value, therefore potentially biasing the representation of likelihood of a VME being present in one area. In other words, the MCA system was not taking into account other records that were in close proximity when informing the potential presence of a VME. This year WGDEC sought to resolve such issues and redeveloped the approach to provide a single measure evaluating the likelihood of a grid cell to represent an actual VME and an additional measure of the uncertainty associated with that former score.

Alongside the work undertaken by the group developing the weighting system, a proposal was submitted by Russia investigating a method of combining the isolated geographic locations of VMEs. This proposal is summarised in Section 4.3 and expanded in more detail in Annex 5.

3.2 A new weighting system for VME indicator data

The main advance this year was to move from viewing individual points in the VME indicator database to a spatially gridded data format, i.e. multiple individual points contributed to the likelihood that a grid cell contained a VME. A grid cell size of

0.05 degrees was used (approximately 3 km x 5 km). Additionally, the new system captured the fact that not all 'VME indicator species' within the VME database have the same vulnerability to human impacts, and thus they should have different VME scores, e.g. WGDEC considered that stony coral reefs should score higher than seapens. Therefore, the new weighting system for VME indicator data was built on a taxa-dependent spatial method. Additionally, to account for data quality issues, a 'data uncertainty' index was developed.

The term 'vulnerability' was based on the FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO, 2009). These guidelines state: "A marine ecosystem should be classified as vulnerable based on the characteristics that it possesses. The following list of characteristics should be used as criteria in the identification of VMEs:

- Uniqueness or rarity;
- Functional significance of the habitat;
- Fragility;
- Life-history traits of the component species that make recovery difficult;
- Structural complexity".

As such, for the purposes of the weighting system exercise, the term 'vulnerability' was deemed to include all of the above criteria. The term did not, however, include an assessment of 'exposure' of the VME indicator or habitat to a human-induced pressure.

For each grid cell, two values needed to be generated that reflected:

i) How intrinsically vulnerable to human impacts the VME indicator was deemed to be (assuming that different VMEs vary in their vulnerability), and how abundant the VME indicator was (for example, an aggregation or reef as opposed to a record of a single individual). This index combining these two measures was termed the 'VME index'.

ii) The uncertainty associated with (i) above. This was an uncertainty (or confidence) estimate based upon; a) how well sampled the grid cell was, b) the provenance of the records in that cell (e.g. visual survey, fisheries data, or inferred from other methods), c) the time frame of the data, and d) how recent the last survey was.

3.2.1 Step 1; 'VME index' scoring procedure

The likelihood of a grid cell to represent an actual VME was evaluated based on the presence of particular VME indicators and their abundance. The presence of such indicators could be assessed by using both real data, coming from sampled features, or from global models which could complement data deficient sites. The latter was however not included in the present version of the framework.

3.2.1.1 Step 1a; Assigning a VME 'vulnerability' score to VME indicators

Nine VME indicator types were assigned a score of between 1–5 for each of the five FAO criteria mentioned above (see Table 1). Hydrothermal vents and cold seeps were not considered to be appropriate to weighting as they represent known VME habitats. The FAO criteria are defined as:

- Uniqueness or rareness: An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems.
- Functional significance of the habitat: Discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species.
- Fragility: An ecosystem that is highly susceptible to degradation by anthropogenic activities.
- Life history of species make recovery difficult: Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: slow growth rates, late age of maturity, low or unpredictable recruitment, or long-lived.
- Structural complexity: An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features.

Table 1. Showing how each VME indicator was ranked according to the FAO criteria for VMEs (FAO, 2009).

	FAO criteria for VMEs						
VME indicator	Unique	Functional	Fragility	Life History	Structural	Value	rank
Stony coral	3	4	5	5	5	5.00	1
Sponge	2	4	5	3	4	4.09	2
Black coral	5	2	4	5	2	4.09	2
Gorgonian	4	3	3	5	2	3.86	4
Lace coral	4	1	4	2.5	2	3.07	5
Seapen	2	3	3	2	2	2.73	6
Cup coral	2	1	2	4	1	2.27	7
Soft coral	1	1	2	2	2	1.82	8
Hydroid	1	1	2	1	1	1.36	9

The values in Table 1 were agreed by members of WGDEC using expert judgement. It should however be noted that these scores could readily change if new data were to become available, for example on the life history of seapens or lace corals.

The sum of these scores was then calculated per VME indicator, and this was rescaled from 1 to 5, where 5 was used for the maximum value (FAO criteria for each VME indicator were summed, divided by 22 (the maximum score for stony coral) and then multiplied by 5). This was then used to produce the VME indicator 'vulnerability' score.

3.2.1.2 Step 1b; Defining abundance thresholds to different VME indicators

For each record in the database, the abundance recorded was evaluated against the VME thresholds for corals (30 kg) or sponges (200 kg). Readers should note that these were thresholds agreed for the purposes of trialling the weighting system, but can be updated to align with existing fishing regulations (for example the NEAFC VME thresholds). If the data indicated the record was over the threshold, a value of five was assigned, while if it was below threshold, a value of one was assigned. If no data for abundance was available, the weighting was set to 0 and thus has no effect on the final "VME index". As there are no agreed thresholds for VME indicators such as gorgonians, black corals or seapens, the same value for corals (30 kg) was used. This was almost certainly too high a threshold for such VME indicators, but without agreed thresholds, this was considered the most appropriate option.

3.2.1.3 Step 1c; Defining the final 'VME index' for each grid cell

The final 'VME index' value was calculated based on the VME indicator 'vulnerability' score and the abundance score. These two scores were weighted based on the relevance they had in the assessment of the VME but mostly on the quality of information available in the current version of the ICES VME database. In the current report, 90% weight was given to the 'VME index' and 10% weight to the abundance score:

$$\text{VME index} = \text{VME indicator score} * 0.9 + \text{abundance score} * 0.1$$

A low weighting was assigned to the abundance score because in the past WGDEC has raised much doubt about the relevance of thresholds when little is known about how VMEs are retained in fishing nets, etc. The results of the VME index were then aggregated to a 0.05 degree grid cell (approximately 3 km x 5 km). For each cell, the maximum VME index score was taken as the overall value for that cell. This was to prevent down-weighting of important records by less important records as would happen if, for example, the mean value of a cell was used. It was therefore acknowledged that some cells would have high scores even if many low VME indicator score records were present in that cell.

The final outcome was presented as three nominal categories of 'VME index' scores, indicating the likelihood of encountering a VME in the assessed grid cells. These categories were:

- Low: for total scores <2.9;
- Medium: for total scores between 2.9 and 3.9;
- High: for total scores >3.9.

These thresholds were selected by inspecting the data distribution and then cross-checking that important records were being assigned to appropriate values. This ensured that the high 'VME index' scores would pick out stony corals at any abundance, and black corals, sponges and gorgonians only when above the VME threshold. The medium 'VME index' scores would pick out black corals, sponges and gorgonians when below the VME threshold, and seapens and lace corals when above the threshold.

When applied to the ICES database, the resulting distribution of the VME index was approximately normal with a small dip at around 3 (Figure 22).

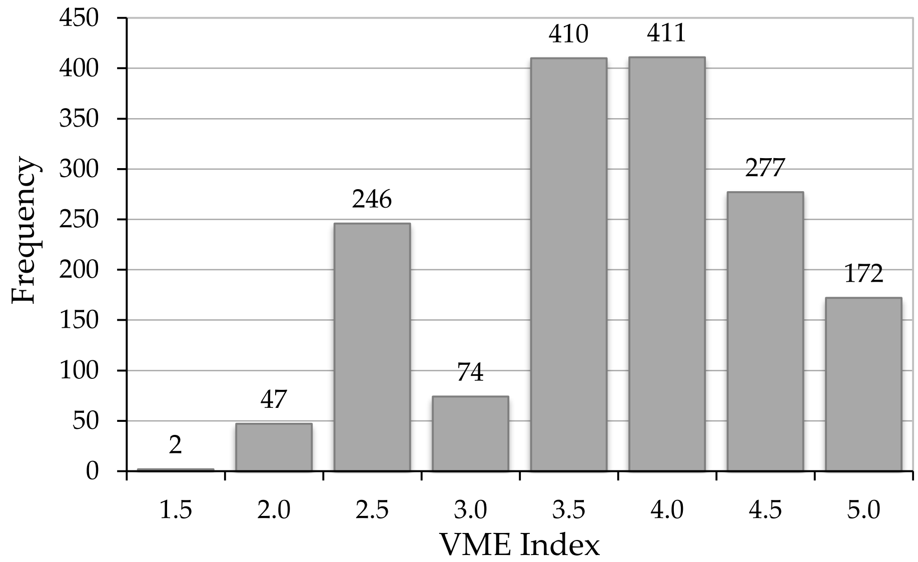

Figure 22. Resulting distribution of the VME index when applied to the ICES database. Each value represents one grid cell (approximately 3 km x 5 km).

3.2.2 Step 2; Data 'Uncertainty Index' scoring procedure

To account for data uncertainty such as data quality issues and the varying degree of knowledge regarding each geographical area (how well it has been surveyed), a data uncertainty index similar to the one elaborated in Wallace *et al*. (2010) was developed. This index served as a measure of confidence in the VME index scores assigned to individual grid cells. This index was calculated independently of the VME index.

Two measures are usually incorporated in such indices: data quality and data deficiency. Data uncertainty reflects origin and nature of the collected data and was divided into three categories: low (scored as 1), medium (scored as 0.5), and high (scored as 0) data quality. The high data quality category will highlight cells with information derived from scientific visual surveys, sampled by many independent surveys, during a long time period, and where the most recent record is within the last ten years (thus giving some indication that the VME may still be present). Low quality data referred to a VME index derived from a poorly sampled grid cell, where the presence of a VME had been somehow inferred, sampled for only a short period and from a long time ago. Four 'measures' were considered in estimating the data Uncertainty Index:

1) The type of survey method used. If a visual survey: score = 0. If fisheries data or any scientific data without visual information: score = 0.5. If inferred from indirect methods scores, e.g. acoustic methods: score = 1. The final uncertainty value related to the survey method used is that associated with the record producing the highest scoring VME index (or the mean of highest scoring VME index if there was more than 1 record of maximum value).
2) Number of surveys. If greater than five surveys in that cell scores 0, between 3–5 scores 0.5, and less than 3 scores 1.
3) The time span or range of surveys undertaken in years. If greater than 20 years scores 0, between 10–20 years scores 0.5, and less than ten years scores 1.

4) How recent the last survey was. If less than ten years scores 0, between 10–30 years scores 0.5, and greater than 30 years scores 1.

The resulting data Uncertainty Index for each grid cell was calculated as the average of these scores and had a minimum value approaching 0 (all 'measures' scored with high data quality) and a maximum value approaching 1.

When applied to the ICES VME database, the resulting distribution of the Uncertainty index was mostly grouped around three values (Figure 23). As in the VME Index, the final outcome was presented as three nominal categories of 'Uncertainty index' scores, indicating the degree of confidence that a VME was present in a particular grid cell. These categories were derived from Figure 23: low uncertainty, for scores smaller than 0.51; medium uncertainty, for score between 0.51 and 0.70; and high uncertainty for scores greater than 0.70.

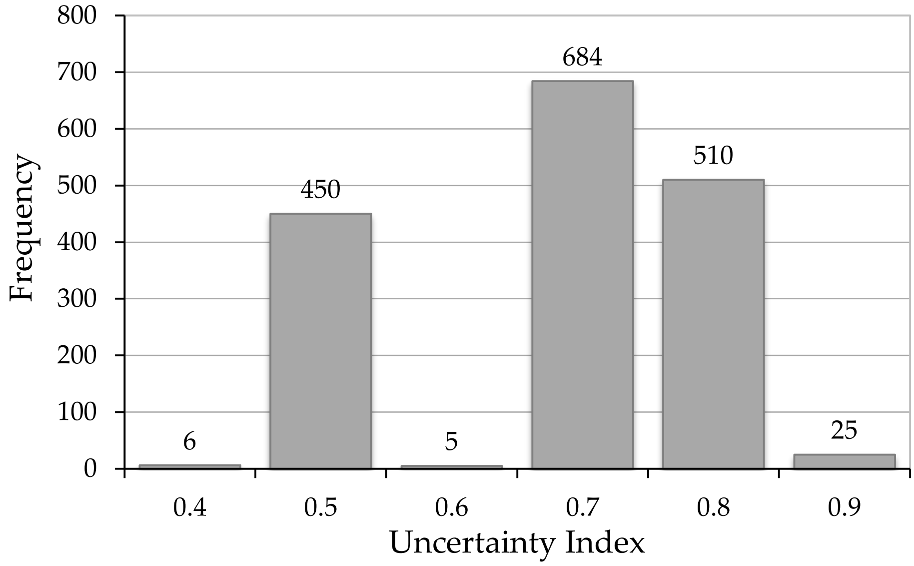

Figure 23. Resulting distribution of the Uncertainty Index when applied to the ICES database. Each value represents one grid cell of 0.05 degree (approximately 3 km x 5 km).

Implementation of the framework was done through the application of an SQL algorithm in the ICES VME database.

3.2.3 Schematic representation of the application of the new weighting system

3.2.3.1 Step 1; building spatial grids of VME index and Uncertainty index

The implementation of this approach was illustrated schematically by creating maps of the VME index and Uncertainty index. The VME index map contained cells with high VME index scores in red, medium in yellow, and low in green. The Uncertainty index map contained cells with low uncertainty score in light grey, medium in mid-grey, and high uncertainty in dark grey (Figure 24).

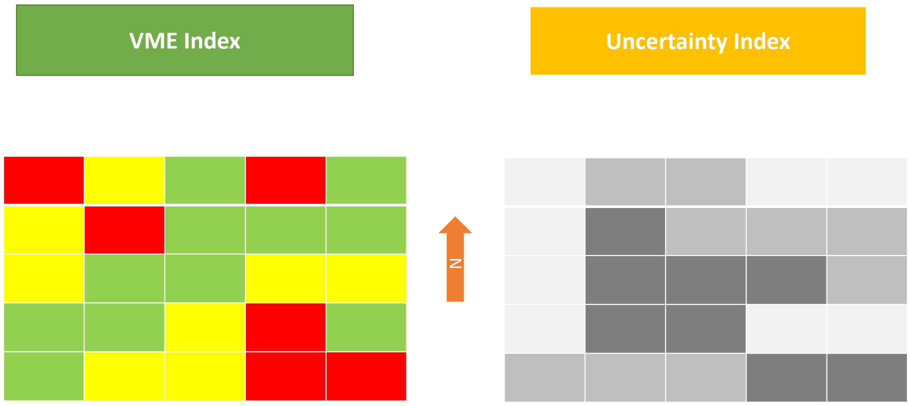

Figure 24. Schematic representation of VME and Uncertainty indices outputs. The VME index (left) contains cells with high VME index scores in red, medium in yellow, and low in green. The Uncertainty index (right) contains cells with low uncertainty score in light grey, medium in mid-grey, and high uncertainty in dark grey.

3.2.3.2 Step 2; Using the VME and Uncertainty maps

The second step was to then combine the information of the VME map with that of the Uncertainty map in order to highlight cells with high VME index scores with different uncertainties. In the top panel of Figure 25, we highlight those grid cells scoring 'high' in the VME index but with all uncertainty categories. In the mid panel of Figure 25, we highlight grid cells scoring 'high' in the VME index but excluding those cells with a 'high' uncertainty index. In the bottom panel of Figure 25, we highlight only those grid cells scoring 'high' in the VME index and 'low' uncertainty.

It should be stated that with this approach we are not stating that cells with high and medium uncertainty are not important, but rather the degree of uncertainty means they require additional sampling.

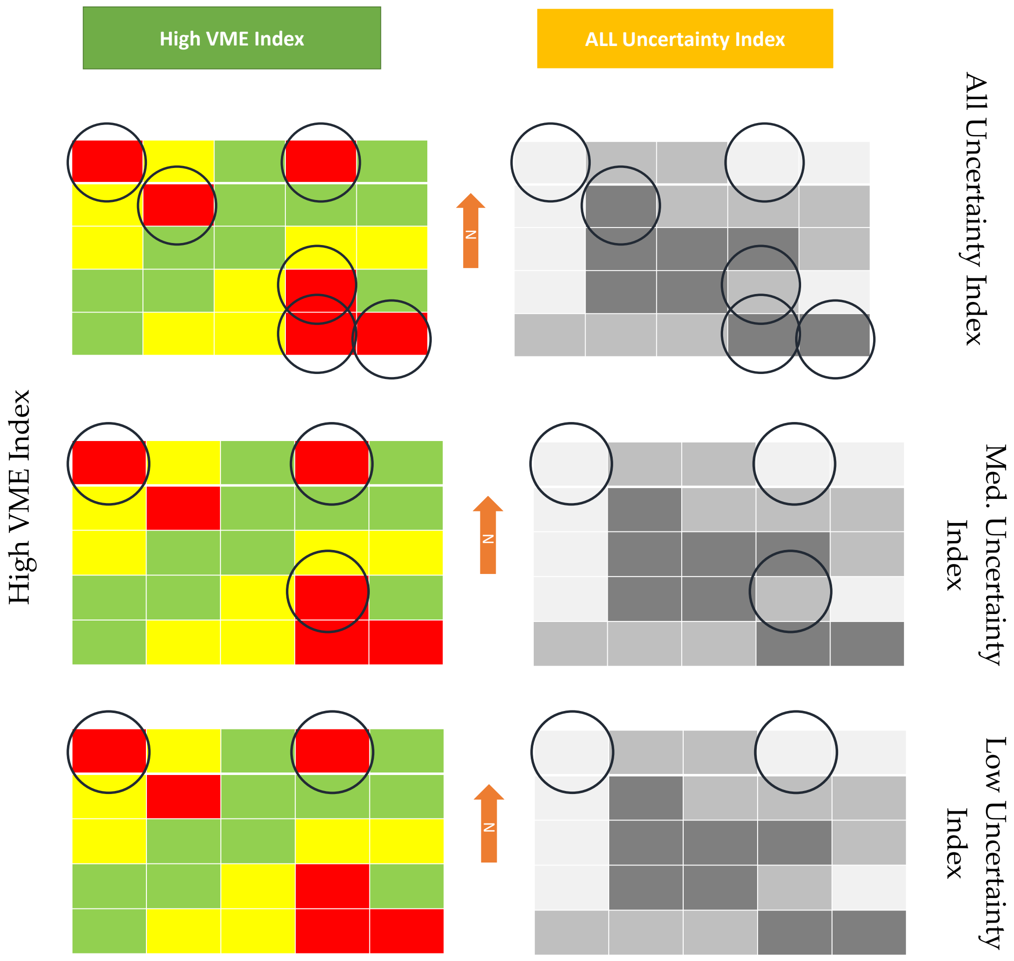

Figure 25. Schematic representation of how the VME index could be influenced by the associated Uncertainty index.

3.2.4 Results and outputs

For illustrative purposes a series of maps were produced for three different regions in the NE Atlantic; the Rockall-Hatton Bank area, the Bay of Biscay and the western shelf area of Norway.

3.2.4.1 Hatton-Rockall

The data outputs for this area illustrate several important aspects of the method. Firstly, there are some very obvious high value 'VME index' areas; inside the NW and SW Rockall NEAFC Closures for example (Figure 26 A). Secondly, there are large areas of medium value VME index across Rockall and Hatton that reflect the many records of VME indicators that are below the threshold. Third, in Figure 26 B, it is obvious that the intensive sampling on the Rockall plateau yields high confidence, whereas the less-well sampled Hatton bank yields a lower overall confidence. This can then be seen particularly clearly in Figure 26 C and Figure 26 D where only the cells with medium (C) and high (D) confidence are plotted. It is important to emphasize that this does not mean Rockall bank is more important from a VME perspective than other areas, only that we have greater confidence that Rockall Bank is an important VME area. There is good evidence that VMEs are present at Hatton, but the certainty of these records is not as high as it is at the Rockall Bank.

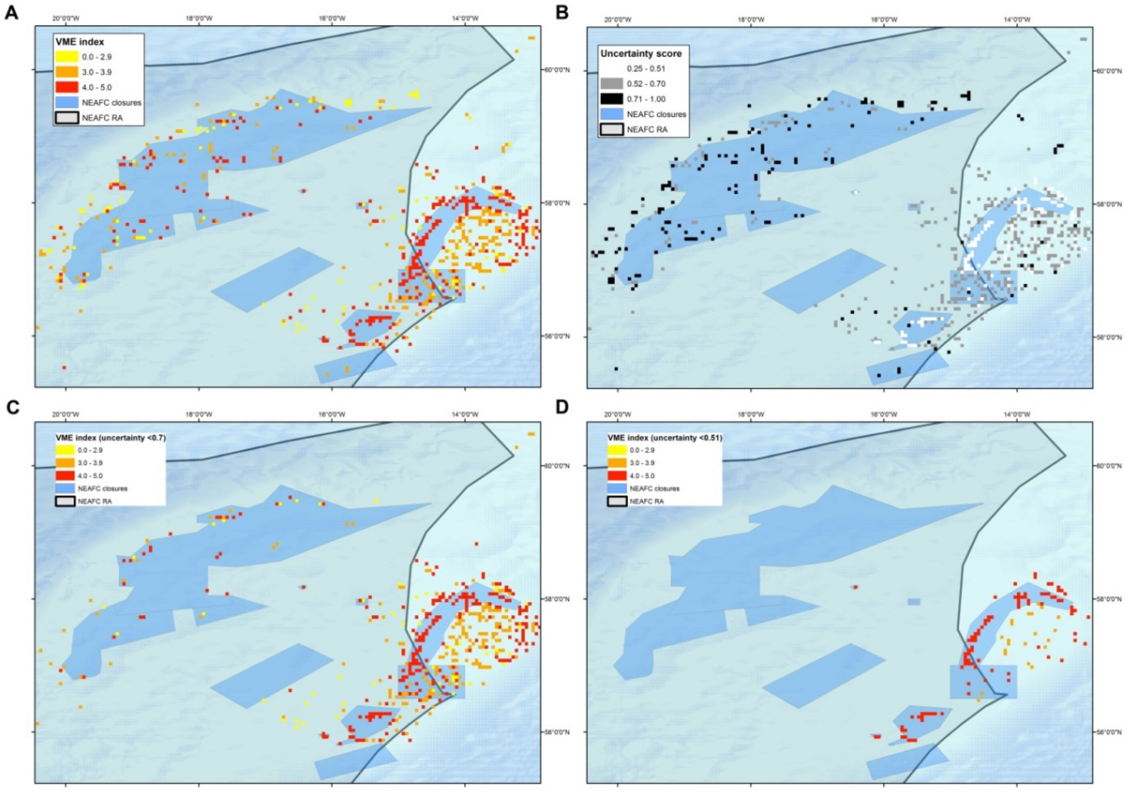

Figure 26. Applying the VME Index and Uncertainty Index to the VME database: Rockall and Hatton Bank.

3.2.4.2 Bay of Biscay

The Bay of Biscay is an interesting case study for different reasons (Figure 27). Here we have a strong indication of VME presence, but because the data are either from very recent highly specific ROV studies, or historical records that we have little information on, we have a bimodal confidence with some areas very high and other very low.

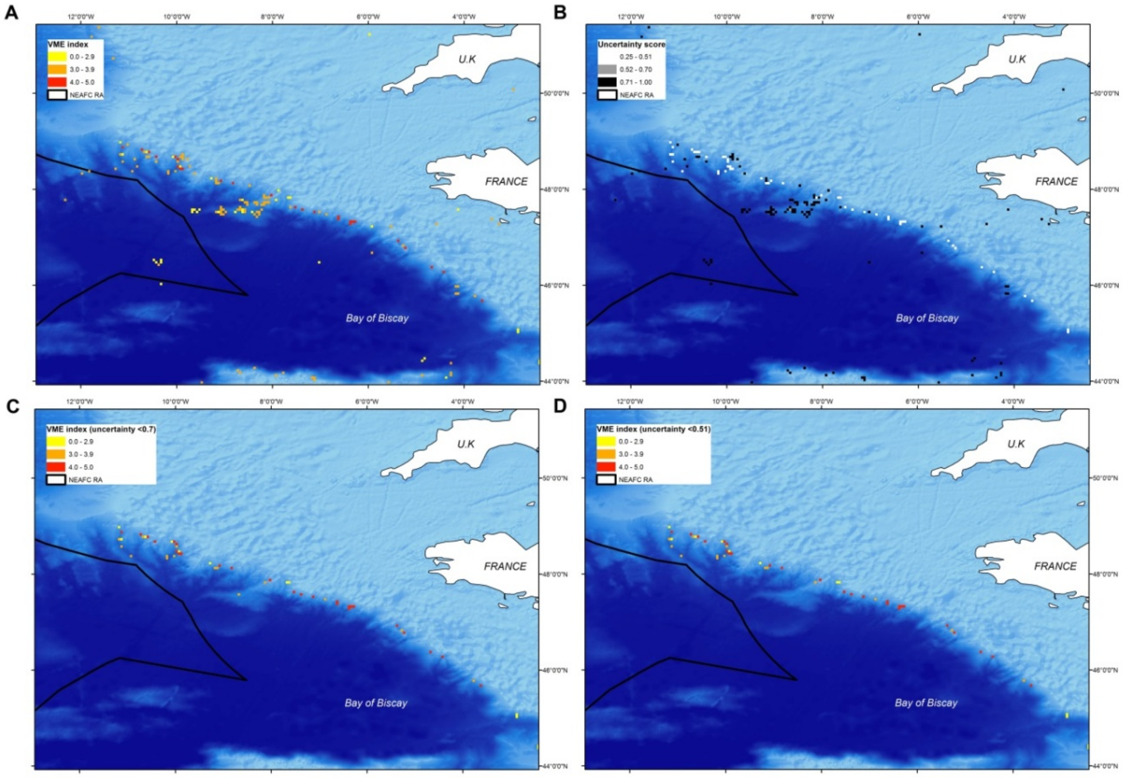

Figure 27. Applying the VME Index and Uncertainty Index to the VME database: Bay of Biscay.

3.2.4.3 Western shelf of Norway

Norway has some of the most extensive coral reefs in the NE Atlantic and they have been studied in exceptionally fine detail using ROVs (Figure 28). This is reflected in the data where nearly all the points have a high VME index and high confidence.

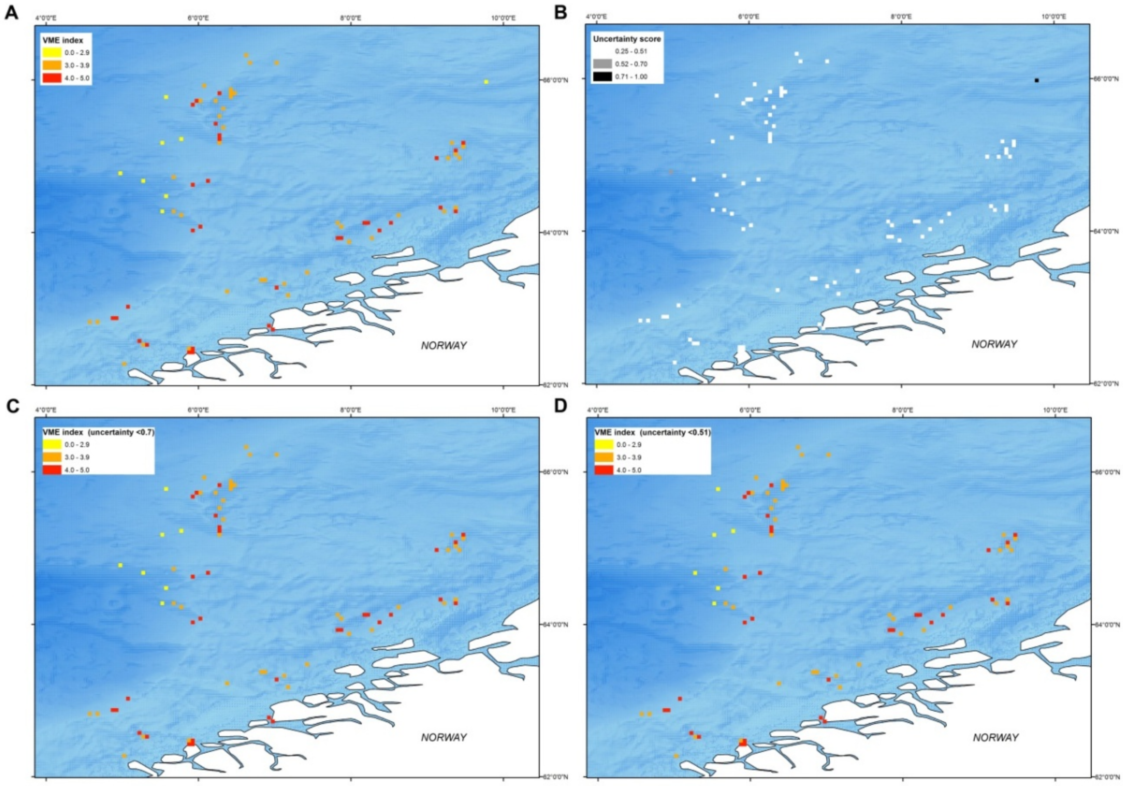

Figure 28. Applying the VME Index and Uncertainty Index to the VME database: Norwegian shelf.

3.2.5 Concluding remarks on the new weighted VME index

Overall the new weighting system appears to capture most of the important elements of the data that are used by WGDEC to assess VME likelihood. One remaining problem is that the database contains some records that are actual *bona fidae* records of VME habitats (not VME indicators). These are for example, ROV surveys of Lophelia reefs, sponge fields, coral gardens. Since such records are known VMEs, the weighting system developed here is not necessary and should not be applied. Applying the weighting system can only act to unnecessarily increase the uncertainty associated with such records. A solution to this is to modify the database to include a 'known VME' category that will exclude such records from the weighting process. This is further discussed under ToR (c) in Section 4.

The new weighting system resolved many of the problems encountered in 2014 and provides a simplified, aggregated and weighted estimate of the likelihood of a VME being present in a specific area. The VME index clearly highlights areas where VME is more likely to occur. The associated estimate of uncertainty gives an indication of how confident WGDEC is with that assessment. The methodology is transparent and the aggregate cells can be explored in greater detail to reveal the individual datapoints that have contributed to the assessment. It uses far more of the information in the ICES VME database than previous methods and as such better captures the underlying reasoning behind much of WGDEC's past advice. As noted, there is a minor problem with actual records of VMEs in the database for which this method is simply not required. Once this modification to the database has been made, the method can be repeated with the output layers being updated each year to provide an automated, dynamic revision of advice as new information is received.

3.3 Toward standardising the method for recommending closed area boundaries

Often, VME indicators are separated by varying distances and there is currently no standardised method for deciding whether to unite the encountered VMEs under a single larger closure or multiple smaller closures. Depending on the experts' position, the number and area of proposed closures may vary greatly. A methodology for when to/not to combine the isolated occurrences of VME indicator records into a single bottom fishing closure was submitted to WGDEC 2015 by Russia (Annex 5). WGDEC did not have time to fully review this work and thus it is suggested to fully develop this work as term of reference for 2016.

The suggested method allows closures to be established under the precautionary approach and is based on the spatial proximity of VME indicator records, the relief features of the seabed and ease the drawing of the closure. This will simplify the monitoring of closure violation and increase the precision of vessel location in relation to the closures.

It may be useful to use the distance travelled by the vessel between two observed locations according to the VMS system. Currently there is usually no more than an hour between these observations. Considering the vessel speed during bottom fishery can equal 3–3.5 knots, the vessel will travel no more than 3.5 nautical miles in one hour. Thus, that distance (3.5 nm) may be used as the criterion for when to unite VME occurrences into one closure. The aforementioned distance (3.5 nm) is sufficient for controlling the vessels' trajectories, preserving the potential VME distribution areas and considers the bottom relief. Distances greater than this may lead to the unjustified expansion of closures between the VME encounter locations, even if those have different bathymetric conditions (depth shifts, canyons, valleys, seamounts, etc.) which present changes in habitat and the absence of VMEs. Details of the set of rules for establishing the boundaries of closures can be found in Annex 5. These will be considered in full at WGDEC 2016 and integrated with the weighted VME system.

3.4 Further work

One of the main advantages of deriving a gridded VME index is that it can be directly compared to other gridded data, for example fishing effort. Some further exploratory work was undertaken linking the outputs from the VME Index with NEAFC VMS data. This should be considered a work in progress, but the methodology used and outputs developed to date can be seen in Annex 4.

Several concerns were raised by members of WGDEC about the weighting system developed at WGDEC 2015 which will need to be addressed before the next meeting. These included:

1) Simplifying the description of the calculation procedure and making it more transparent and accessible for understanding. It is advisable to show the calculation algorithm in the form of mathematical formulas. This will eliminate the issues with practical application of the method.

2) It was noted that it would be desirable to have information in the database in which the VME indicator species were absent and that this should be factored into the weighting system.

3) Include in some way information on total number of observations per grid cell (ideally including surveys in which the VME indicator species were not found).

4) Explore the optimal resolution of the grid cells and whether a variable grid size can be used depending upon the quantity and quality of the data available.

5) Explore if there is likely to be a problem of assigning VME indicators to a fixed cell grid, i.e. whether this captures the most probable position of the VME.

Further development of the methodology for combining the geographic locations of VMEs is also recommended.

3.5 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. 2014. Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC), 24–28 February 2014, Copenhagen, Denmark. ICES CM 2014/ACOM:29. 70 pp.

Wallace BP, DiMatteo AD, Bolten AB, Chaloupka MY, Hutchinson BJ, *et al*. 2011. Global Conservation Priorities for Marine Turtles. PLoS ONE 6(9):e24510.

4 Maintenance and development of the ICES VME database

510 new records that indicate the presence of Vulnerable Marine Ecosystems (VMEs) were submitted to ICES WGDEC in 2015 and these were incorporated into the ICES VME database.

Following the WGDEC 2014 meeting, it was noted that there were a large number of records within the VME database classed as 'restricted;' almost 95%. This was a result of data being submitted to the group whilst research papers were being prepared for publication. This issue was discussed in the group and WGDEC members who had brought VME data to the group previously were requested to check back with the data owners in order to make these data public. At the close of WGDEC 2015, the situation had improved, with approximately 51% of data within the VME database classed as 'restricted'. Efforts will continue in 2015 to reduce this number further.

Since WGDEC 2014, significant work has been undertaken to develop a central portal (hosted by the ICES DataCentre) to disseminate data on the distribution, abundance and quality of habitats and species considered to be indicators of VMEs across the North Atlantic. This portal is planned to be part-operational in 2015, with further development anticipated throughout the year. Part of this development work will see all VME indicator data being gridded using a 0.05 degree grid (an identical grid to that used in ToR (b)), and presented via a map displayed on the web portal. This will show the distribution of all VME indicator records being considered by WGDEC. For those records that are 'restricted', this grid will not reveal the exact location of the record, but will show metadata including the data owner contact point so that users of the portal can directly contact the data owner to request the data. However, all records marked as public will be available for download through the portal. Displaying all VME data being used by the group in this way will ensure that all data underpinning WGDEC recommendations (such as bottom fishing closures) will be visible, improving the transparency of the group's actions and recommendations.

While the number of restricted records within the VME database is a legacy issue, WGDEC discussed ways this could be avoided in future. One option could be to recommend that all data submitted to the group are made public after a fixed period of time has elapsed (for example one year). This acknowledges that data access sometimes needs to be restricted while papers reporting on scientific research are drafted. However, this option was not agreed by all group members and requires further consultation before implementation.

The group discussed other improvements to the VME database. It was noticed that some records had an entry both in the 'VME indicator' field and also the 'VME habitat type'. Clearer database guidance was agreed which states that only one of these fields should be completed (see Annex 6). The 'VME indicator' field should be completed if the record is of a VME indicator species, such as from a longline or trawl bycatch. These records would be the type considered in the weighting system developed under ToR (b). However, for *bona fidae* records of VME habitats, such as from a ROV transect surveying a cold-water coral reef, the 'VME indicator' field should not be completed and should be left blank. Instead, the 'VME habitat type' field should be completed. These records should be considered in their own right as records of VMEs, and would not need further consideration in a VME indicator record weighting system.

The group also discussed undertaking a dedicated VME Data Call, which would be managed by the ICES DataCentre. The Data Call would invite ICES Member Countries to submit new data on occurrences of VME indicators or VME habitat types. This would further streamline the VME data submission process, and further ensure that new data are submitted well in advance of WGDEC to allow for QA checks. The group agreed that this 'VME Data Call' should be taken forward as a recommendation from WGDEC.

Some other minor revisions were made to the VME database format, and these are outlined in Table 2 (Annex 6).

Finally, to improve the utility of the VME database following a trial of the weighting system (Section 3), and to ensure that the database is fully populated with new VME data submissions prior to WGDEC 2016, a short VME database workshop was discussed and proposed. A set of draft Terms of Reference for the workshop are included in Annex 9. This could be held around August 2015 and could be hosted by JNCC, in Peterborough, UK.

5 In light of two deep-sea mining exploration licences that have been granted by the International Seabed Authority (ISA) along the Mid-Atlantic Ridge, review the sensitivity of vulnerable deep-water habitats to these activities and make recommendations for their protection

5.1 Background

Deep-sea mining relates to the potential mining of manganese nodules, cobalt crusts and seafloor massive sulphides. In seas areas beyond national jurisdiction ("The Area") licensing of the exploration and exploitation of these minerals is carried out though the International Seabed Authority. All state parties to the UN Convention on the Law of the Sea are also parties to the ISA and are expected to adopt regulations that are at least as comprehensive as those of the ISA. As of February 2015, the ISA has not developed its regulations to manage exploitation of deep-sea minerals, but it has committed to do so during the 2015–2016 meeting cycle. Regulations are in place to control exploration for deep-sea minerals (International Seabed Authority, 2013). To date no deep-sea mining has taken place in The Area with the exception of some test mining activities for nodules that were carried out in the 1970s and 1980s in the central Pacific. There are no accounts of deep-sea mining having taken place in national waters although Nautilus Minerals has an exploitation licence to mine within the State of Papua New Guinea, and mining is expected to begin there in 2018.

The three mineral types are found in quite different environments. Manganese nodules are limited to areas with very low sedimentation; typically deep seafloors between 4000 and 6500 metres water depth, and they are more common in the Pacific than other oceans. The commercial potential of known nodules fields in the Atlantic is low; however, much has not been surveyed, as evidenced by a recent discovery of nodules in January 2015 in the North Atlantic several hundred miles east of Barbados by the research team aboard the RV Sonne.

Cobalt crusts are formed on bare rock surfaces in the ocean by the precipitation of minerals from seawater. The thickest and most economically interesting crusts form on the outer rims of the summits of seamounts and on saddles on the summits, in water depths ranging from 800–2500 metres (Hein *et al*., 2008). The largest number of potentially mineable crusts are found in the Pacific, but the Rio Grande Rise, in the South Atlantic, and the New England Seamounts, that extend from 37–40°N and 59.5–67.5W in the North Atlantic, also have potential resources. Brazil has applied to the ISA for an exploration licence for an area on the Rio Grande Rise.

Seafloor massive sulphides (SMS) form on ocean ridges where hydrothermal fluids are expelled through black smokers. They can potentially occur on any ridge system but many potential sulphide sites are either too small, too deep for metals to precipitate, or of too low grade to be mineable. Nevertheless, a small number of sites have been identified including off Papua New Guinea as mentioned above. In the Atlantic, the ISA has issued exploration licences to Ifremer, France and the Government of the Russian Federation for areas lying between approximately 14 and 26°N on the Mid-Atlantic Ridge (Figure 29). In addition Nautilus has asked for some prospection areas in Portuguese waters around the Azores and adjacent areas, and Norway is investigating the Mid-Atlantic Ridge between Norway and Greenland (Cruz *et al*., 2013).

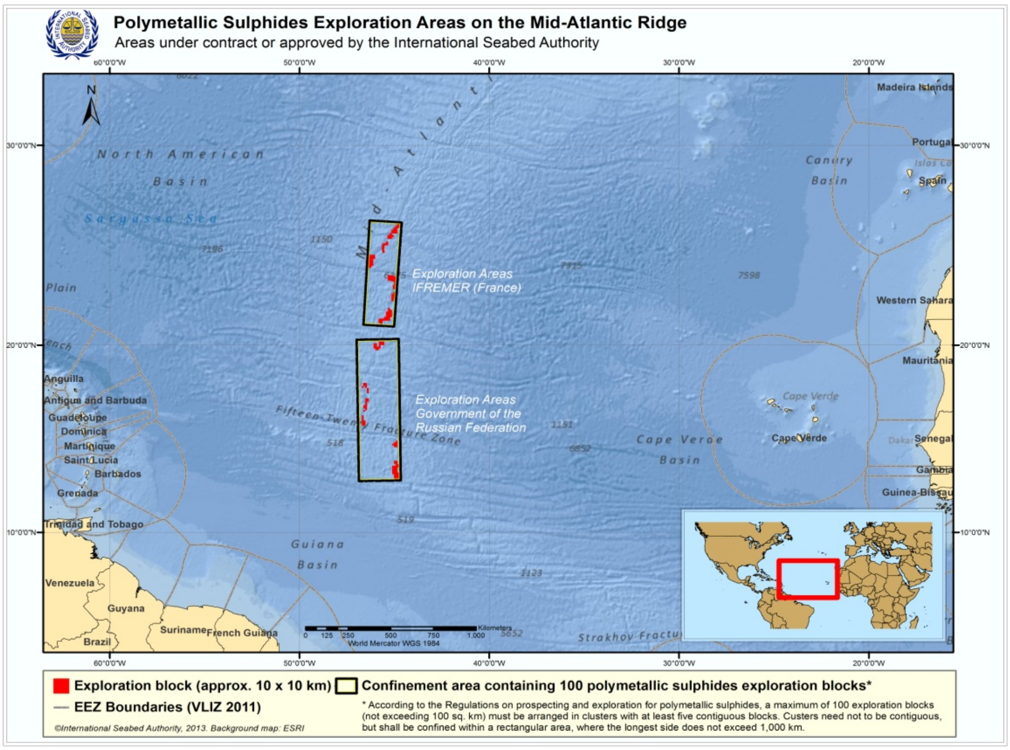

Figure 29. Polymetalic sulphide exploration areas in the North Atlantic as approved by the International Seabed Authority.

5.2 Review of ICG-C Pressures List.

In light of the increased interest in exploration for deep-sea minerals in the Atlantic Ocean, WGDEC reassessed the Pressures List developed through the OSPAR Intercessional Correspondence Group on Cumulative Effects (ICG-C), a subgroup of the Environmental Impacts of Human Activities (EIHA) committee. This list details those pressures considered by ICG-C to impact marine habitats and species across the Northeast Atlantic, and includes associated definitions. The Pressures List was reviewed to ensure they adequately cover the pressures associated with deep-sea mining activities. Many of the issues are adequately covered but it is recommended that some of the wording be modified to include references to deep-sea mining with examples where appropriate. Recommended changes are included in Table 3 (Annex 7) and should be considered alongside the two additions below.

In addition to the modifications, we identified a number of pressures that were not adequately covered in the ICG-C Pressures List. These could all be included under the section on Biological Pressures and include:

- Removal or destruction of key areas used in the life history of a species. The removal of habitat by seabed mining can cause connectivity issues and is particularly applicable to linear features such as ocean ridges or chains of seamounts. Identifying specific areas that support critical life-history stages of individual species requires an understanding of movements or migratory patterns of individual species, which are often related to feeding, breeding or caring for young.
- Removal or destruction of large areas of seafloor. In some cases removal or destruction of habitat may cover such large areas that recolonisation may be impossible or extremely slow. Refer to L2 if part of an ecosystem is re-

moved permanently e.g. nodules or D1 when whole habitat is destroyed and must be recolonised.

5.3 Potential impact of deep-sea mining on vulnerable deep-water habitats

The impacts of deep-sea mining are discussed at length in the DG Mare ECORYS report (in press). These are summarised below and described in detail in Tables 3 and 4 (Annex 7), which are based on Table 6.2 in the DG Mare Ecorys report. We did not include the table related to nodules since nodule mining is not regarded as being likely in the North Atlantic. The main potential impacts are:

- The removal of substrate (and habitat) by the seabed mining activity. Both nodules and crusts form essentially two-dimensional deposits and so the mining activity will need to cover large areas removing the upper few centimetres to tens of centimetres. For each mining operation this could represent the loss of several tens of square kilometres per year. Seafloor massive sulphides, on the other hand, are relatively small three-dimensional deposits extending several metres into the seabed. Considerable information is available for the planned Solwara 1 mine site off Papua New Guinea. The area to be mined there extends to 0.11 km^2 and the mining will last approximately 24 months to extract up to an inferred 1.3 million tonnes (Golder Associates, 2008); a modest amount by commercial mining standards.
- The generation of bottom plumes caused by the mining activity. These can spread away from the mined area affecting adjacent habitats. The distances such plumes will travel is unknown.
- Toxicity. For SMS deposits the mining process will release toxic chemicals into the water column and these will be incorporated into the near seabed plume. We do not know the impact of this toxicity. Some species may be able to tolerate high levels of toxicity, but species living away from the active hydrothermal areas may be affected. It is not known whether toxic chemicals will be released by the mining of cobalt crusts or the crushing of nodules during their transport to the surface.
- The generation of plumes from returned water following the pumping process to bring ore to the sea surface. Such plumes may have a high density of small particles and may also contain toxic chemicals. They may cause changes in pH and temperature. Their potential impact on midwater organisms is unknown. If this retuned water is warmer than the ambient water, the plumes may rise in the water column and potentially affect the plankton by reducing light levels. Alternatively, the presence of iron in the plume may enhance plankton growth and change the nature of the planktonic communities.
- Impact from the operation of the mining equipment. This includes noise and light (although very little is known about their effects on deep-sea organisms the negative impacts of noise on marine mammals living closer to the surface are well documented), oil spills and leaks from hydraulic equipment, sewage and other contaminants from the ore carriers and support vessels. Noise generated by riser systems could be of particular concern because the riser would pass through all depths, thus potentially

affecting cetacean communications that rely upon audio "channels" between thermoclines.

5.4 Response to the ToR

It must be stressed that deep-sea mining has not begun and so many of the potential impacts, such as extent of plumes and toxicity levels, remain unknown. It is therefore very difficult to predict the sensitivity of vulnerable marine habitats to these potential impacts and so fully address this Terms of Reference. Certainly the excavation of areas of seafloor will impact a number of habitats, especially where mining takes place on seamounts and hydrothermal vents. It is expected that once a licence is granted, a large amount of environmental survey will be carried out during the exploration phase and this should lead to the identification of all habitats to be affected. It is a requirement of any licence that this information be reported to the ISA on an annual basis. The commitment to collect environmental information only extends to the license area, however, and it is not clear how the potential impact of plumes or other pollution, including noise, that travel outside the licensed area will be dealt with. It is also not clear how any overlap of activities, such as between bottom trawling and mining, would be resolved.

Bearing in mind the impacts that deep-sea mining will cause together with the uncertainties and the interests of many stakeholders, including a number of conservation minded organisations, the ISA has adopted a spatial management approach for one of its main areas of licensing activity (Lodge *et al.*, 2014). Conflicts between areas licensed for exploitation and areas of conservation such as VMEs and MPAs have not yet arisen but would be identified at the early stages if regional spatial plans were produced for all areas where deep-sea mining is likely to occur.

5.5 Regional Environmental Planning – an example from the central Pacific

One approach to dealing with multiple stressors including those from new activities such as deep-sea mining is to develop a regional environment plan in which all new activities can be planned so as to minimise impacts and provide refuges for organisms and habitats. One example has been developed for the Clarion Clipperton Zone (CCZ) in the central Pacific in response to the potentially large amount of mining in this area (see Lodge *et al.*, 2014). The ISA has licensed 14 contractors to carry out exploration for manganese nodules in the CCZ. The CCZ-EMP is the first regional-scale environmental management plan for the deep seabed. Its genesis was a proposal drawing upon the results of the Kaplan Project (2002–2007), a collaborative project undertaken by the ISA with the aim of assessing levels of biodiversity, species range and gene flow in the abyssal nodule provinces using molecular and morphological methods (Smith *et al.*, 2008). An international workshop in 2010 brought together representatives of the scientific community and seabed mining industry to further refine the Authority's proposals for the CCZ and draw up the basis of the EMP.

The EMP established nine Areas of Potential Environmental Interest (APEIs) to the north and south of the licence blocks and partially overlapping the fracture zones. Each of the APEIs covers a core area of 200 x 200 km plus a buffer zone of 100 km on each side making the total area of each APEI 400 x 400 km. In some cases the APEIs abut the licence blocks whilst in other areas there are gaps. Reasonable assumptions concerning mining impacts, in terms of direct disturbance, likely mining patterns and sediment plumes, underpinned the design of the EMP. The 100 km buffer zones around APEI core areas were established as a precautionary measure to ensure that mining activity adjacent to an APEI would not impact the core area. It is generally agreed that near-seabed plumes generated by the mining would not travel more than 100 km, although midwater plumes can travel very long distances (Rolinski *et al.*, 2001; Wedding *et al.*, 2013). The nine APEIs were chosen to reflect the biological variability of the area (Smith *et al.*, 2007), which is driven by strong north–south and east–west gradients in productivity across the Clarion-Clipperton Zone (Smith *et al.*, 1997; Hannides and Smith, 2003). Between them the APEIs cover the typical geomorphology in the CCZ including abyssal plains, abyssal hills, seamounts and fracture zones. The distribution of the APEIs in relation to the licence blocks for the CCZ is shown in Figure 30.

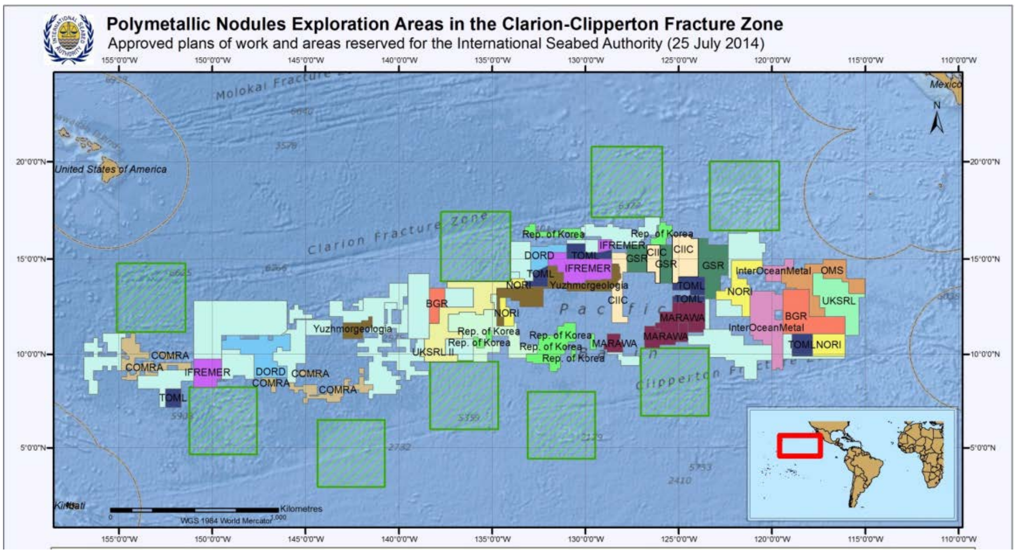

Figure 30. Polymetallic nodule exploration areas in the CCZ with Areas of Potential Environmental Interest (APEIs) indicated as green hatched boxes.

5.6 Strategic /Regional planning on the Mid-Atlantic Ridge

Mineral mining on the Mid-Atlantic Ridge (MAR) is expected to impact different ecosystems with contrasting ecological properties. Massive sulphide mining will primarily target inactive vents but may also directly or indirectly impact active hydrothermal vents. Active vents support a chemosynthetically based ecosystem. Many species are endemic to the vents and for many their distribution is thought to be restricted to the Mid-Atlantic Ridge, which forms a consistent biogeographic unit. Benthic communities at inactive vents and cobalt crusts remain poorly understood. They are likely more diverse than at active vents and may well host VMEs. The distribution of those species inhabiting inactive vents and cobalt crusts is expected to be widespread and continuous rather than island-like but species composition and the biogeography of these species are mostly unknown.

The occurrence along the Mid-Atlantic Ridge of Vulnerable Marine Ecosystems (VMEs, as defined by the FAO International Guidelines for deep-sea fisheries in the high seas) or threatened and/or declining species and habitats (as defined by OSPAR) has already prompted the closure of five areas to bottom fishing by NEAFC and the creation of a network of Marine Protected Areas by OSPAR in 2010 and 2012. Management recommendations for these MPA's have been agreed, based upon their conservation objectives, but management plans are not yet in place. OSPAR has also initiated a 'Collective Arrangement' between the Northeast Atlantic competent authorities (including NEAFC, ISA and IMO). The CBD Regional EBSA Workshop for the Northwest Atlantic (24–28 March 2014) also described an Ecologically or Biologically Significant Area (EBSA) for a group of hydrothermal vents on the MAR. In the Azores region, based on OSPAR and IUCN Guidelines for the management of MPAs, the Azores government created the plans for deep-sea MPAs including the hydrothermal vent fields Lucky Strike and Menez Gwen as well as the seamounts Dom João de Castro and Sedlo. In view of its outer continental shelf claim, Portugal will be responsible for four additional deep-sea protected areas: the Rainbow hydrothermal vent field, the Mid-Atlantic Ridge north of Azores, and the Altair and Antialtair seamounts.

A Strategic Environmental Plan and a Regional Management Plan for mineral mining along the Mid-Atlantic Ridge would have to consider cumulative impacts and existing management rules from the coastal states for their jurisdictional areas and from ISA for the Area. A workshop is already planned to start this process for the Area, to be held in Horta, Azores, 1–3 June 2015 (TBC) gathering the main stakeholders together with scientists from different disciplines in order to discuss the two main issues:

1) Socio-economics: with a focus on unintended negative social and macroeconomic effects of natural resource development and how these can be avoided.
2) Environment: identifying elements of an environmental plan for chemosynthetic and non-chemosynthetic ecosystems along the Mid-Atlantic Ridge.

5.7 Availability of information for Strategic environmental planning in the North Atlantic

As described above there are many gaps in our knowledge of deep-sea ecosystems and only limited knowledge of potential mining practices. Some of the key issues are being addressed in the EU FP7 project MIDAS (Managing Impacts of Deep-seA reSource exploitation, http://www.eu-midas.net/) that runs for three years from 2013–2016. These include 1) physical destruction of the seabed by mining and the creation of mine tailings; 2) the potential effects of particle-laden plumes in the water column, and 3) the possible toxic chemicals that might be released by the mining process. Key biological unknowns to be addressed include connectivity between populations, impacts of the loss of biological diversity on ecosystem functioning, and how quickly the ecosystems will recover. The plan is to use this information to develop recommendations for best practice in the mining industry. A key component is the involvement of industry within the project and through stakeholder engagements to find feasible solutions. The project will also work closely with European and international regulatory organisations to take these recommendations forward into legislation and regulations. A major element of MIDAS will be to develop methods and technologies for 1) preparing baseline assessments of biodiversity, and 2) monitoring activities remotely in the deep sea during and after exploitation, including ecosystem recovery.

Although MIDAS may make some progress on the above issues it cannot fill all the data gaps in only three years and it does not cover issues such as noise and light pollution. It does not cover issues related to multiple stressors such as mining and fisheries and, although the project will support the development of a regional environmental plan for the MAR, it does cover specific research in this area.

5.8 References

Cruz, M.I.F.S.; Marques, Ana Filipa Alfaia; Dias, A.; Pedersen, Rolf B.; Relvas, Jorge MRS; Barriga, Fernando JAS. 2013. Sulfide Sites in the Arctic Ocean: Jan Mayen and Loki's Castle. Mineralogical magazine. 77:929.

ECORYS. In press. Study to investigate state of knowledge of Deep Sea Mining. DG MARE/2012/06 - SC E1/2013/04. Interim text available at https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/FGP96656%20DSM%20Interim%20report%20280314.pdf.

Golder Associates. 2008. Mineral Resource Estimate Solwara 1 Project Bismarck Sea Papua New Guinea for Nautilus Minerals Inc. Accessed February 2015: http://www.nautilusminerals.com/i/pdf/2008-02-01_Solwara1_43-101.pdf.

Hein, J.R. 2008. Geologic characteristics and geographic distribution of potential cobalt-rich ferromanganese crusts deposits in the Area. In Mining cobalt-rich ferromanganese crusts and polymetallic sulphides deposits: Technological and economic considerations. Proceedings of the International Seabed Authority's Workshop held in Kingston, Jamaica, 31 July–4 August 2006, p. 59–90.

Hannides, A., Smith, C. R. 2003. The northeast abyssal Pacific plain. In *Biogeochemistry of Marine Systems*, K. B. Black and G. B. Shimmield. Eds., CRC Press, Boca Raton, Florida, 208–237.

International Seabed Authority. 2013. Consolidated regulations and recommendations on prospecting and exploration 212 pages. Create Space Independent Publishing Platform ISBN-10: 1494296578.

Lodge, M., Johnson, D., Le Gurun, G., Wengler, M., Weaver, P. and Gunn, V. 2014. Seabed mining: International Seabed Authority environmental management plan for the Clarion-Clipperton Zone. A partnership approach. Marine Policy 49, 66–72. DOI 10.1016/j.marpol.2014.04.006.

Rolinski S, Segschneider J, Sundermann J. 2001. Long-term propagation of tailings from deep-sea mining under variable conditions by means of numerical simulations. Deep-Sea Res. II 48, 3469–3485. (doi:10.1016/S0967-0645(01)00053-4).

Smith, C. R., Berelson, W., DeMaster, D. J., Dobbs, F. C., Hammond, D., Hoover, D. J., Pope, R. H., Stephens, M. 1997. Latitudinal variations in benthic processes in the abyssal equatorial Pacific: Controls by biogenic particle flux. *Deep-Sea Research* II (44), 2295–2317.

Smith, C. R., Galeron, J., Gooday, A., Glover, A., Kitazato, H., Menot, L., Paterson, G., Lambshead, J., Rogers, A., Sibuet, M., Nozawa, F., Ohkawara, N., Lunt, D., Floyd, R., Elce, B., Altamira, I., Dyal, P. 2007. Final report: Biodiversity, species ranges, and gene flow in the abyssal Pacific nodule province: predicting and managing the impacts of deep seabed mining. J. M. Kaplan Fund and the International Seabed Authority, 41 pp.

Smith, C.R., Galéron, J., Glover, A., Gooday, A., Kitazato, H., Lambshead, J., Menot, L., Paterson, G., Rogers, A. and Sibuet, M. 2008. Biodiversity, species ranges, and gene flow in the abyssal Pacific nodule province: Predicting and managing the impacts of deep seabed mining. ISA Technical Study no. 3, International Seabed Authority, Kingston, Jamaica.

Wedding LM, Friedlander JN, Kittinger L, Watling L, Gaines SD, Bennett M, Hardy SM and Smith C.R. 2013. From principles to practice: a spatial approach to systematic conservation planning in the deep sea. Proceedings of the Royal Society B: Biological Sciences, 280, 20131684, published 6 November 2013 doi:10.1098/rspb.2013.1684 1471-2954.

6 Review new evidence of ecosystem functioning and services of VME indicators in the North Atlantic arising from the CORALFISH project and recent scientific literature

6.1 Background

In the context of ecosystem functioning (EF), the group agreed that aside from vulnerable marine ecosystem (VME) indicators, VME habitats and elements should also be considered since published research often focuses on EF in more general terms, with direct application to VME habitats and elements, such as seamounts for instance. 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.

The definition of EF in marine ecosystems has seen much debate and a range of definitions are spread across literature comprising multiple aspects of ecosystem ecology, usually dependent on the type of marine ecosystem that is considered. In addition, functions (and processes) associated with Ecosystem Services (ES) are defined in several frameworks such as the Millennium Assessment (MA, 2005), The Economics of Ecosystems and Biodiversity (TEEB, 2010), and Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2013) and reviews specifically applied to the marine environment (e.g. Beaumont *et al*., 2007) to enable valuating the benefits (goods and services) that marine ecosystems bring to the human population. Functions and processes can be treated as synonyms providing appropriate definitions (Wallace, 2007). These processes and functions comprise the interactions that occur between abiotic and biotic elements of ecosystems and habitats, whilst the services are the benefits to humans provided by the functions and processes. In a recent review, Thurber *et al*. (2014) proposed a comprehensive synthesis on ecosystem function and services of the deep sea. This review explains the complexity and the interrelatedness of functions and services, and the great range of temporal and spatial scales on which they occur. Important to note is that the biological, physical, and chemical properties of the ecosystem combine to form complex processes that result in globally important services in the case of the deep sea.

Thurber *et al*. (2014) proposes the following categories which group functions and services:

Deep-sea supporting and regulating functions and services

- Water circulation and CO_2 exchange
- Nutrient cycling and the biological pump
- *In situ* primary and secondary production
- Waste absorption and detoxification

Deep-sea provisioning functions and services

- Fisheries/nutrition (nursery function, habitat provision, trophic support)
- Oil and gas/energy
- Mining/non-nutritional materials
- Waste disposal

- Biodiversity-Bioprospecting potential
- Others (military; human infrastructure-cables, oil/gas derricks with land-based refineries)
- Cultural services (scientific, education, literature, arts and entertainment)

Evidence of EF associated with VMEs is reviewed here, focusing on the most important EFs that are applicable to VMEs; these are highlighted in bold in the above list, and are based on the available results of the CoralFISH project and other recent literature. The group notes, however, that a comprehensive review of all the literature could not be performed within the time frame of the WGDEC meeting. That being said, the evidence that can be drawn from literature indicates that VME indicators perform significant EFs that contribute to total EF of habitats and ecosystems.

6.2 CoralFISH

CoralFISH is an FP7 EU project that brought together deep-sea fisheries biologists, ecosystem researchers/modellers, oceanographers, economists and a fishing industry Small to Medium Enterprise to (1) develop essential methodologies and indicators for baseline and subsequent monitoring of closed areas, (2) integrate fish into coral ecosystem models to better understand coral fish-carrying capacity, (3) evaluate the distribution of deep-water bottom fishing effort to identify areas of potential interaction and impact upon coral habitat, (4) use genetic fingerprinting to assess the potential erosion of genetic fitness of corals due to long-term exposure to fishing impacts, (5) construct bioeconomic models to assess management effects on corals and fisheries to provide policy options, and (6) produce habitat suitability maps both regionally and for the OSPAR Region V to identify areas likely to contain vulnerable habitat, all in an effort to provide the EU with tools to address the issues raised by the UNGA 61/105 resolution.

A Special Issue of Deep-Sea Research II, dedicated to CoralFISH results, addressing: "Ecosystem based management and monitoring in the deep Mediterranean and North Atlantic" (Guest Editors: Anthony Grehan, Alessandra Savini, Chris Yesson, Sophie Arnaud-Haond, Gianfranco D'Onghia), is in preparation, and due for publication by the end of 2015, early 2016. Adopting Thurber *et al*. (2014) categories, CoralFISH research relating to ecosystem functioning was mainly concerned with:

- Nutrient cycling and the biological pump
- Fisheries/nutrition (nursery function, habitat provision, trophic support)

Some preliminary results from this work are included here. CoralFISH showed that cold-water corals (CWCs) are hot spots of carbon processing along continental margins. Their high organic carbon-processing rate, previously unaccounted for in regional carbon budgets, indicate that CWCs make a significant (~25%) contribution to the annual organic carbon processing of the entire Norwegian Shelf (CoralFISH, 2013). A coupled hydrographic-ecosystem model describing a NE Atlantic coral mound province on Rockall Bank indicated that direct benthic-pelagic coupling exists between CWC habitats occurring at depths of 600 m and surface productivity, due to a tidal-induced down welling of fresh organic matter from the ocean surface towards the coral mound (Mohn *et al*., 2014). Strong inter-regional differences are apparent in the functioning of CWC reefs. Carbon cycling is dominated by corals at Traena

(Norway) where there is a strong contribution from zooplankton in their diet. At the Belgica Mounds (Ireland) in contrast, a larger diversity of groups constitutes the foodweb, with zooplankton being of minor importance in coral diets. Fish abundance on cold-water coral reefs, assessed by measuring arrival times of fish to bait dispersed from baited landers, showed that the fish density on corals could be up to seven times higher than at non-coral reference stations (CoralFISH, 2013). Moving more to ESs than EFs, CoralFISH bioeconomic analysis focused on incorporating ecosystem processes into traditional fisheries bioeconomic models and provided indications of the potential economic importance of cold-water coral. Managing fisheries without taking into account this larger ecosystem perspective may potentially cost fisheries economically. It also suggests that the focus on closing areas driven by VME existence values where resistance from fishermen is low, should be expanded to include a more comprehensive set of mechanisms (Armstrong *et al.*, 2014).

6.3 Other scientific literature

The recent scientific literature indicates that VMEs play important roles in many of the EF categories, and VMEs often contribute to more than one category as many of the EFs result in interrelated regulating and provisioning services. Arguably the most important EF is supporting secondary production, the formation of biomass fuelled by organic carbon degradation and assimilation, the primary function resulting in the provision of biomass for human consumption, most notably finfish, shellfish, and cetaceans, supporting fisheries and therefore of immediate importance within the NEAFC context. Additionally, secondary production is the result of respiration - where CO_2 is released and oxygen consumed –and thus is involved in the functional regulation of gas cycling and carbon regulation in the deep sea. Habitat provision for different life-history stages of marine vertebrate and invertebrate species and trophic support to these species are some of the main EFs of VMEs indicators and habitats.

6.3.1 Habitat provision and biodiversity support by VMEs

The majority of studies suggest that the presence of VMEs and especially CWCs supports high-abundance and high diversity of fish assemblages although some studies report such a relation is not clear (Biber *et al.*, 2014). Reasons as to why this discrepancy is observed remain unresolved, but the general consensus is that VME presence supports rich and abundant fish assemblages by providing habitat (refuge and nursery functions; linked to complexity and size of framework structures) and trophic support (provision of diverse and abundant food sources). VMEs and in particular coral frameworks act as habitat for many fish, including those of commercial value, but also invertebrates such as brittlestars, sea stars, crinoids, polychaetes and other smaller invertebrates which are closely associated with branches and skeletons of these corals.

It is generally acknowledged that more fish are located in coral areas than adjacent areas (Foley *et al.*, 2010; Puglise *et al.*, 2005). NE Atlantic coral reefs provide biodiversity hot spots within the deep sea, often with aggregations of commercially important species of fish (e.g. cod, saithe, ling, tusk, redfish) that provide valuable fishing grounds on and around the reefs (Söffker *et al.*, 2011; Purser *et al.*, 2013). Table 6 (Annex 8) provides a list of fish species associated with deep-water corals and sponge habitats (based on Buhl-Mortensen *et al.*, 2010). Redfish (*Sebastes*) are found in high abundance in Lophelia reef areas (Fosså *et al.*, 2005). Aggregations of orange roughy are also found in cold-water coral environments (Koslow, 2003). Demersal species such as ling and tusk appear to be more common around corals than on the surrounding seabed (Costello *et al*., 2005; Husebø *et al*., 2002). The ivory tree coral, *Oculina varicosa*, located off the coast of Florida was found to be associated with grouper, snapper and amberjack (Reed, 2002) and Koenig (2001) observed a relationship between grouper, snapper, sea bass, and amberjack and the health (dead, sparse and intact) of *Oculina* colonies. Foley *et al*. (2010) reports that *Oculina* reefs off Florida have been identified as essential fish habitat for federally managed species, as have gorgonian-dominated deep coral communities off Alaska (Stone, 2006; Heifetz, 2000). Studies by Fosså *et al*. (2002; 2005) and Husebø *et al*. (2002) found that there was a greater abundance of fish species in coral areas than in non-coral areas. There are possibilities that coral grounds act as spawning grounds and nurseries to juvenile fish; Costello *et al*. (2005) and Fosså *et al*. (2002) reported gravid female *Sebastes norvegicus* and *Sebastes viviparus* in close association with corals at the Sula reef in Norway. However, the lack of additional observations of gravid female red-fish within *Lophelia* ecosystems since the studies of Fosså *et al*. (2002) and Costello *et al*. (2005) indicates that *Lophelia* reefs are not extensively used as nursery area for red-fish in Norway although they might be locally important. Pham *et al*. (2015) demonstrated using General Additive Models that total fish catch was higher inside Azorean VMEs but the relationship between fish and VMEs varied among fish species. Species-specific models showed that catch was strongly influenced by environmental factors, whilst the presence of VMEs was only important for two rockfish species; juvenile and adult *P. kuhlii* and juvenile *H. dactylopterus*. A recent study from the Canadian shelf (Baillon *et al*., 2012) documented larvae of two other red-fish species, i.e. *Sebastes fasciatus* and *Sebastes mentella*, within the beds of seapens suggesting that seapen fields may serve as an essential habitat for these species.

Similar observations are reported for elasmobranch species (Figure. 31), providing indications that *Lophelia* reefs may be used as nursery areas for local populations of other fish species. Kutti *et al*. (2014) for instance suggested that the positive correlation between *Galeus melastomus* and *Chimaera monstrosa* abundance and the density of *Lophelia* reefs within the Træna region of the Norwegian shelf could be that these species are using the complex structure of the coral framework as a shelter and protection against predators for its egg and young. Mortensen and Buhl-Mortensen (2005) found a colony of *Paragorgia arborea* with 26 eggs of the deep-sea catshark (*Apristurus profundurum*) at around 500 m depth in the Northeast Channel, Nova Scotia (Figure 31). Henry *et al*. (2013) reported that coral VME (Mingulay reef complex off western Scotland) helps maintain key life stages of shark populations (presence of egg cases of *G. melastomus* in coral complex provide evidence of spawning grounds; Figure 31) and provides socio-economic benefits through supporting recreational fishing industry and tourist-driven economy. Elasmobranch egg cases have also been reported in association with the framework-forming scleractinians at the Hebrides Terrace Seamount (Henry *et al*., 2014). Henry *et al*. (2014) further reports that seamounts support a rich fauna (including VME indicators: xenophyophores, geodiid sponges (known to contain bio-active anti-cancer compounds) and reef framework-forming scleractinian coral *Solenosmilia variabilis*) whereby the *Solenosmilia* frameworks were inhabited by black corals (*Stichopathes*), glass sponges, encrusting sponges, ophiuroids and crinoids similar to the fauna that can be found in association with Lophelia frameworks. Some deep-sea skates and rays are not associated with corals (Costello *et al*., 2005; Ross and Quattrini, 2007; Sulak *et al*., 2007), but their egg cases co-occur with Lophelia (Costello *et al*., 2005; Quattrini *et al*., 2009), suggesting changes in habitat use through life history of elasmobranchs. However, all chondrichthyans (that produce relatively few numbers of eggs or young) are considered to be particularly vulnerable to exploitation (Gordon, 1999). Therefore further investigation of the use of *Lophelia* reefs as nurseries by targeted sampling of live coral framework and surrounding unstructured sediment at the time of spawning should be carried out.

Despite the notion that more fish and more diverse fish assemblages are associated with coral VMEs, the characteristics for the association are not necessarily unique for live coral. Söffker *et al*. (2011) recorded 30 fish taxa with three species of scleractinians (*Lophelia pertusa, Madrepora oculata, Desmophyllum cristagalli*) and a diverse range of other corals (Antipatharia, Alcyonacea, and Stylasteridae), with some fish species only found in stands of live coral, whilst others were mainly found in structural habitats provided by dead coral. Significantly more fish were found on structurally complex coral rubble habitats than on flatter areas where coral rubble was clogged with sand. Mortensen *et al*. (2005) reports higher probability for the commonly targeted redfish (*Sebastes* sp.) occurrence in habitats with coral present (0.45) compared to habitats with coral absent (0.10–0.12), but the presence of boulders also had an effect on the occurrence probability, with values of 0.25 for boulder habitats vs. 0.10 when boulders were absent. A recent study using a tethered video platform (video and stills) reports that trawl-impacted *Lophelia* reefs (which equates to loss of structural complexity of the habitat) had lower fish abundance and diversity compared to non-impacted reefs, whilst trawl impacts resulted in high-abundance low-diversity invertebrate assemblages with particularly high-abundance of opportunistic species (Buhl-Mortensen, in prep.). In addition to the observation of different types of coral habitat resulting in different types of fish assemblages, there has been much interest in distinguishing between essential and facultative fish habitats (Foley *et al*., 2010; Anon, 1996; Peterson *et al*., 2000; Rosenberg *et al*., 2000). Preliminary results indicate that deep-water corals may not be essential habitat for fish, but there are indications that it may be a preferred habitat for many life processes of fish. This infers that the destruction of such preferred habitat may result in losses connected with fish having to settle for second-best, leading to lower growth or reproduction, reducing the potential economic value.

These results indicate that the structural complexity of the habitat is likely the main driver for enriched and abundant invertebrate and fish assemblages and that the range of niches occurring both within and adjacent to the live reef structure are utilised by different assemblages.

Aside from the increased biodiversity of fish assemblages associated with VMEs, micro-, meio-, macro and megafauna diversity in and around VMEs is also enhanced (Van Gaever *et al*., 2004; Van Oevelen *et al*., 2009; Buhl-Mortensen *et al*., 2010; Mortensen and Fosså, 2006; Buhl-Mortensen and Mortensen, 2005; D'Onghia *et al*., 2012). In a comprehensive study investigating biodiversity associated with different types of *Lophelia pertusa* reefs in Norway, highest diversity was found in samples with a small proportion of live coral (>20%) and lowest for samples from the coral rubble zone surrounding the reefs (Mortensen and Fosså, 2006). When comparing several similar studies, the same authors reported a total of 769 species associated with *Lophelia pertusa* reef structures, but only 21 were common for all studies (Mortensen and Fosså, 2006), indicating unique invertebrate assemblages are associated with *Lophelia pertusa* reefs, generating a high turnover between *Lophelia* areas.

Prokaryotic and viral abundance and turnover rate are enhanced in the presence of *Lophelia pertusa* and *Madrepora oculata* (Maier *et al*., 2011), whilst living specimens of *L. pertusa* seem to possess a specific microbial community different from that of dead coral and sediment samples (Yakimov *et al*., 2006).

Information on diversity and the functional role of sponges in the deep sea is fragmentary. Based on ROV image analysis, Bo *et al*. (2012) characterized the population structure of the sponge assemblages in the Mediterranean deep sea and tested their structuring role, mainly focusing on the demosponges *Pachastrella monilifera* and *Poecillastra compressa*. Due to their erect growth habit, these sponges contribute to the creation of complex three-dimensional habitats in otherwise homogenous environments exposed to high sedimentation rates and attract numerous species of mobile invertebrates (mainly echinoderms) and fish. Sponges themselves may represent a secondary substrate for a specialized associated fauna, such as zoanthids. As demonstrated in oceanic environments, sponge beds also support locally rich biodiversity levels in the Mediterranean Sea. Sponges emerge as important elements of benthic–pelagic coupling in these deep-sea habitats. Hence, in deep-sea ecosystems, not only the coral habitats, but also the grounds of massive sponges represent important biodiversity reservoirs and contribute to the trophic recycling of organic matter. From an ecological point of view, these sponge species may play the same engineering role held by colonial, arborescent corals in deep environments (Klitgaard and Tendal, 2004; Hogg *et al*., 2010; Bo *et al*., 2011). Klitgaard and Tendal (2004) report that the presence of large-sized astrophorid sponges increase the physical heterogeneity of the local area and the number of available microhabitats, leading to high biodiversity assemblages associated with the sponge areas.

Buhl-Mortensen *et al*. (2010) reviewed the structural attributes and biotic effects of the habitats that corals, seapens, sponges and xenophyophores offer other organisms. The importance of VME indicators as substrata seemed to increase with depth as the complexity of the surrounding geological substrate and food supply decline. There are marked differences in the degree of mutualistic relationships between habitat-forming taxa. This is especially evident for scleractinian corals, which have large numbers of facultative associates (commensals) and few obligate associates (mutualists), and gorgonians, with their few commensals and many obligate associates. Size, flexibility and architectural complexity of the habitat-forming organism are positively related to species diversity for both sessile and mobile species.

Cold-water coral ecosystems are thought to offer new opportunities for pharmaceutical, engineering, medical and food research (Grehan *et al*., 2003; McAllister and Alfonso, 2001; Witherell and Coon, 2001). Although it is difficult to identify the specific ecosystem functions providing this type of service, it can be argued that the processes of specification and diversification and biodiversity enhancement are important EFs contributing to the presence of unique natural compounds. There is historical evidence of some medicinal effects resulting from CWC (Wilson, 2001). Recently, the lace coral perforating *Thoosa armata*, found within *Errina dabneyi* from the Princess Alice Seamount nearby the Azorean islands, was found to have anticancer properties evidenced by cancer cell essays (Lino *et al*., 2015). The coral species *Sarcodictyon roseum* is being used in clinical trials for the cure of various strains of cancer and bamboo corals are being used for bone grafting (Ehrlich, 2006; Foley *et al*., 2010). Future use of compounds from CWC as described above may be discovered by harvesting CWC, but scientists have also used the natural coral structure to successfully synthesise bone analogues thereby reducing further destruction of corals for this purpose (Foley *et al*., 2010).

The last decade has brought substantial progress in determining the abundance and diversity of micro-organisms associated with corals (Rosenberg *et al*., 2007); Kellog *et al*. (2009), for instance, showed that unique microbial communities are associated with *Lophelia pertusa* (Gulf of Mexico). Further evidence is provided by Yakimov *et al*.

(2006) who show on the basis of a phylogenetic survey of metabolically active microbial communities associated with *Lophelia pertusa* found in the central Mediterranean Sea, that these deep-sea corals are harbouring specific microbial populations, which may allow the existence of these corals in such an extreme environment.

In many studies, the nature of the relationship between the associated species and CWCs is uncertain because direct observations of the location of mobile species on deep-water corals are few and samples of deep-water corals often contain a mixture of sediments and broken corals. Buhl-Mortensen and Mortensen (2004) compiled all available records of invertebrates associated with alcyonarian, antipatharian, gorgonian, and scleractinian deep-water corals and reported that more than 980 species were recorded on deep-water coral, of these 112 can be characterised as symbionts, of which 30 species are obligate to various cnidarian taxa. The obligate symbionts are rarer than their hosts, which implies that reduced coral abundance and distribution may be critical to the symbionts' ecology. Buhl-Mortensen and Mortensen (2004) also reported that scleractinian corals support higher diversity than octocorals do.

6.3.2 Nutrient recycling, C sequestration and trophic support and interactions by VMEs

According to Dick van Oevelen *et al*. (2009) CWC communities can act as a biological filter that intercepts and traps organic matter from the water column that would otherwise not be deposited on the seafloor. The combined CWC effect of depleting the particle concentration in the lower layers of the benthic boundary layer, and increasing physical turbulence levels may result in an increased particle flux towards the CWC. This classical example of ecosystem engineering, through modification of the physical environment, has shown to elevate levels of ecosystem functioning, biomass, and biodiversity (Coleman and Williams, 2002). At the same time, CWC are capable of retrieving significant amounts of organic carbon out of the water column. Tracing studies (using stable isotope and fatty acid signatures) have suggested that *Lophelia* rely on fresh phytodetritus (Duineveld *et al*., 2007), zooplankton faecal pellets (Duineveld *et al*., 2004; Duineveld *et al*., 2007) and zooplankton (Kiriakoulakis *et al*., 2005) for food. Recent laboratory studies have shown that *Lophelia* is an opportunistic feeder that can feed on different food types such as zooplankton, phytoplankton, bacteria and dissolved organic matter depending on their availability (Mueller *et al*., 2014). Respiration and carbon turnover within the complete coral reef ecosystem (i.e. the live and dead *Lophelia* framework together with its associated fauna) is substantial (van Oevelen *et al*., 2009; Wehrmann *et al*., 2009). It has further been demonstrated that POC is being depleted from the up-current to the down-current part of the reef during periods of stable current directions at Tisler reef (Wagner *et al*., 2011). White *et al*. (2012) suggested that in areas densely populated by *Lophelia* up to 25% of the total carbon processing will occur in the reef ecosystem, thus, *Lophelia* ecosystems are not only biodiversity hot spots but they are also hot spots for carbon cycling on the shelf (van Oevelen *et al*., 2009; White *et al*., 2012). In all, studies suggest that *Lophelia* reefs support both fauna and ecosystem processes over a larger area than the habitat itself as defined by the area covered by live coral framework, dead-coral framework and coral rubble.

Macrobenthic biomass is almost two orders of magnitude higher in the CWC food-web as compared to soft sediments at comparable water depth, and it is even higher than in shallow coastal sediments (van Oevelen *et al*., 2009).

Maier *et al*. (2011) reports enhanced nutrient turnover, mucus release and growth stimulation of prokaryotes and viruses by CWCs. The authors suggest that since CWC reefs on continental margins are more frequent than previously thought (Roberts *et al*., 2006), they might replenish nitrogen species and influence the nitrogen cycle in these areas and counterbalance the low N:P ratios in the sediment. Wild *et al*. (2009; 2008) have suggested that CWC reefs could stimulate microbial activity in bottom water by mucus release and potentially exert some control over organic C cycling. This could explain why prokaryotic (and viral) abundances seem to be stimulated in bottom water of CWC reefs.

In terms of trophic support, the colony morphology of CWCs has a great influence on feeding efficiency for suspension-feeders (Buhl-Mortensen *et al*., 2010). These authors concluded that suspension feeding, habitat-forming organisms modify the environment to optimize their food uptake. This environmental advantage is also passed on to associated filter-feeding species. Interestingly, Duineveld *et al*. (2007) showed that compared to other deep-water habitats a CWC mound community in the Rockall Bank area comprised a simplified foodweb sustained by an advection of fresh particles derived from production higher on the bank where the CWC was found. This is most likely owing to the fact that deposit-feeders were excluded from the coral community. There is also evidence that trophic characteristics of the corals themselves may possibly depend on the coral species; Kiriakoulakis *et al*. (2005) showed that *Madrepora oculata* and *Lophelia pertusa* exhibited different stable isotope signatures, potentially caused by different feeding strategies or assimilation/storage efficiencies of zooplankton tissue or different metabolism in the two coral species.

6.4 Conclusions

Evidence from recent scientific literature indicates 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 to only VME presence.
- VMEs and in particular CWC 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 bioprospection.
- More research is needed to document the variety, quantity and quality of ecosystem functions of various VMEs.

Figure 31. Two left images: Shark habitat use at the Mingulay Reef Complex, a cold-water coral reef VME west of Scotland. (Left side, red arrow) Egg cases of the deep-water blackmouth catshark *Galeus melastomus* are found nested in live coral framework formed by the VME indicator species *Lophelia pertusa* (D366/367 cruise, RRS Discovery cruise, UKOA programme). (Middle) Another catshark, the lesser-spotted catshark *Scyliorhinus canicula*, rests among coral framework and dense zoanthid colonies (RRS James Cook 073 Changing Oceans Expedition, Heriot-Watt University and NERC, UKOA programme). Far right image: A colony of *Paragorgia arborea* with 26 eggs of deep-sea catshark (*Apristurus profundurum*) collected in bottom trawl at around 500 m depth in the Northeast Channel, Nova Scotia (Mortensen and Buhl-Mortensen, 2005).

6.5 References

Anon. The Sustainable Fisheries Act of 1996. USA, 1996.

Armstrong, C.W., N.S. Foley, V. Kahui, A. Grehan. 2014. Cold water coral reef management from an ecosystem service perspective. Marine Policy, 50:126–134.

Auster P.J. 2005. Are deep-water corals important habitats for fishes? In: Freiwald A., Roberts J.M. (Eds), Cold-Water Corals and Ecosystems. Springer-Verlag, Berlin: 747–760.

Baillon S, Hamel J-F, Wareham VE, and Mercier A. 2012. Deep cold-water corals as nurseries for fish larvae. Front Ecol Environ 2012; 10(7): 351–356, doi:10.1890/120022.

Beaumont, N.J., Austen, M.C., Atkins, J.P., Burdon, D., Degraer, S., Dentinho, T.P., Derous, S., Holm, P., Horton, T., van Ierland, E., Marboe, A.H., Starkey, D.J., Townsend, M., Zarzycki, T. 2007. Identification, definition and quantification of goods and services provided by marine biodiversity: Implications for the ecosystem approach. Marine Pollution Bulletin 54 (3), 253–265.

Biber MF, Duineveld GCA, Lavaleye MSS, Davies AJ, Bergman MJN, van den Beld IMJ. 2014. Investigating the association of fish abundance and biomass with cold-water corals in the deep Northeast Atlantic Ocean using a generalised linear modelling approach Deep-Sea Research II 99: 134–145.

Bo, M., Bertolino, M., Bavestrello, G., Canese, S., Giusti, M., Angiolillo, M., Pansini, M., Taviani, M. 2012. Role of deep sponge grounds in the Mediterranean Sea: a case study in southern Italy. Hydrobiologia 687 (1), 163–177.

Bo, M., S. Canese, M. Giusti, C. Spaggiari, M. Angiolillo, E. Salvati, S. Greco and G. Bavestrello. 2011. Mesophotic coral forests of the Italian seas. Proceedings of the World Conference on Marine Biodiversity, Scotland: 23.

Buhl-Mortensen. In prep. Coral reefs in the Southern Barents Sea: habitat description and effects of bottom fisheries.

Buhl-Mortensen L., Mortensen P.B. 2004. Symbiosis in deep-water corals. Symbiosis, 37, 33–61.

Buhl-Mortensen L., Mortensen P.B. 2005. Distribution and diversity of species associated with deep-sea gorgonian corals off Atlantic Canada. In: Freiwald A., Roberts J.M. (Eds), Cold-Water Corals and Ecosystems. Springer-Verlag, Berlin. p. 849–879.

Buhl-Mortensen, L., Vanreusel, A., Gooday, A.J., Levin, L.A., Priede, I.G., Buhl-Mortensen, P., Gheerardyn, H., King, N.J., Raes, M. 2010. Biological structures as a source of habitat heterogeneity and biodiversity on the deep ocean margins. Marine Ecology 31, 21–50.

Castro, J.I., Bubucis, P.M., Overstrom, N.A. 1988. The reproductive biology of the chain dogfish *Scyliorhinus retifer*. Copeia 1988, 740–746.

Coleman, F. C., Williams, S. L. 2002. Overexploiting marine ecosystem engineers: Potential consequences for biodiversity. Trends Ecol. Evol. 17: 40–44.

Concha, F., Bustamante, C., Oddone, M.C., Hernández, S., Lamilla, J. 2010. Egg capsules of the dusky catshark *Bythalelurus canescens* (Carcharhiniformes, Scyliorhinidae) from the southeastern Pacific Ocean. J. Fish. Biol. 77, 963–971.

Conway K.W., Krautter M., Barrie J.V., Whitney F., Thomson R.E., Reiswig H., Lehnert H., Mungov G., Bertram M. 2005. Sponge reefs in the Queen Charlotte Basin, Canada: controls on distribution, growth and development. In: Freiwald A., Roberts J.M. (Eds), Cold-water Corals and Ecosystems; Springer, Berlin: 605–621.

Cook S.E., Burd B., Conway K.W. 2008. Status of the glass sponge reefs in the Georgia Basin. Marine Environmental Research, 66, 80–86.

CoralFISH. 2013. Final Report to the European Commission, EC Grant Agreement Number: 213144.

Costello M.J., McCrea M., Freiwald A., Lundälv T., Jonsson L., Bett B.J., van Weering T.C.E., de Haas H., Roberts J.M., Allen D. 2005. Role of cold-water *Lophelia pertusa* coral reefs as fish habitat in the NE Atlantic. In: Freiwald A., Roberts J.M. (Eds), Cold-water Corals and Ecosystems. Springer-Verlag, Berlin: 771–805.

D'Onghia, G., Maiorano, P., Carlucci, R., Capezzuto, F., Carluccio, A., Tursi, A., Sion, L. 2012. Comparing Deep-Sea Fish Fauna between Coral and Non-Coral "Mega-habitats" in the Santa Maria di Leuca Cold-Water Coral Province (Mediterranean Sea). PLoSOne, 7.

D'Onghia, G., Maiorano, P., Sion, L., Giove, A., Capezzuto, F., Carlucci, R., Tursi, A. 2010. Effects of deep-water coral banks on the abundance and size structure of the megafauna in the Mediterranean Sea. Deep-SeaRes. Part II—Top. Stud. Oceanogr 57, 397–411.

Duineveld, G. C. A., M. S. S. Lavaleye, and E. M. Berghuis. 2004. Particle flux and food supply to a seamount cold-water coral community Galicia Bank, NW Spain. Mar. Ecol. Prog. Ser. 277: 13–23.

Duineveld, G. C. A., M. S. S. Lavaleye, M. I. N. Bergman, H. De Stigter, and F. Mienis. 2007. Trophic structure of a cold-water coral mound community (Rockall Bank, NE Atlantic) in relation to the near-bottom particle supply and current regime. Bulletin of Marine Science 81:449–467.

Durán Muñoz, P., Murillo, F. J., Sayago-Gil, M., Serrano, A., Laporta, M., Otero, I., and Gómez, C. 2011. Effects of deep-sea bottom longlining on the Hatton Bank fish communities and benthic ecosystem, north-east Atlantic. Journal of the Marine Biological Association of the United Kingdom, 91(04), 939–952.

Durán Muñoz, P., Sayago-Gil, M., Cristobo, J., Parra, S., Serrano, A., Díaz del Rio, V., Patrocinio, T., Sacau, M., Murillo, F.J., Palomino, D., Fernández-Salas, L.M. 2009. Seabed mapping for selecting cold-water coral protection areas on Hatton Bank, Northeast Atlantic. ICES J. Mar. Sci. 66, 2013–2025.

Ebert, D.A., and C.D. Davis. 2007. Descriptions of skate egg cases (Chondrichthyes: Rajiformes: Rajoidei) from the eastern North Pacific. Zootaxa 1393:1–18.

Ehrlich H, Etnoyer P, Litvinov SD, Olennikova MM, Domaschke H, Hanke T, Born R, Meissner H, Worch H. 2006. Biomaterial structure in deep-sea bamboo coral (Anthozoa: Gorgonacea: Isididae): perspectives for the development of bone implants and templates for tissue engineering. Materialwissenschaft und Werkstofftechnik 2006;37(6):552–557.

Etnoyer, P., Warrenchuk, J. 2007. A catshark nursery in a deep gorgonian field in the Mississippi Canyon, Gulf of Mexico. Bull. Mar. Sci. 81, 553–559.

Flammang, B.E., Ebert, D.A., Cailliet, G.M. 2011. Intraspecific and interspecific spatial distribution of three eastern North Pacific catshark species and their egg cases (Chondicthyes: Scyliorhinidae). Breviora Mus. Comp. Zool. 525, 1–18.

Foley, N.S., van Rensburg, T.M., Armstrong, C.W. 2010. The ecological and economic value of cold-water coral ecosystems. Ocean & Coastal Management 53 (7), 313–326.

Fosså J.H., Lindberg B., Christensen O., Lundälv T., Svellingen I., Mortensen P.B., Alvsvag J. 2005. Mapping of *Lophelia* reefs in Norway: experiences and survey methods. In: Freiwald A., Roberts J.M. (Eds), Cold-Water Corals and Ecosystems. Springer-Verlag, Berlin: 359–391.

Fosså J.H., Mortensen P.B., Furevik D.M. 2002. The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. Hydrobiologia, 471, 1–12.

Freese J.L., Wing B.L. 2003. Juvenile red rockfish associated with sponges in the Gulf of Alaska. Marine Fisheries Review, 65, 38–42.

Freiwald A., Huhnerbach V., Lindberg B., Wilson J.B., Campbell J. 2002. The Sula Reef Complex, Norwegian shelf. Facies, 47, 179–200.

Furevik D., Nøttestad L., Fosså J.H., Husebø A., Jørgensen S. 1999. Fiskefordeling i og utenfor korallomra der pa Søregga. Fisken Havet, No. 15, 33pp.

Gage, J. Roberts, M.J. 2003. The *Lophelia* reef-associated fauna EU FP5, project ACES (Atlantic Coral Ecosystem Studies) Deliverable 16 (2003), p. 70

Grehan A, Long R, Deegan B, O'Cinneide M. 2003. The Irish Coral Task Force and Atlantic Coral Ecosystem Study Report on Two Deep Water Coral Conservation Stakeholder Workshops. Marine Environment and Health Series; 11:117.

Haines-Young, R., Potschin, M. 2013. Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August-December 2012.

Hall-Spencer J., Allain V., Fosså J.H. 2002. Trawling damage to Northeast Atlantic ancient coral reefs. Proceedings of the Royal Society of London, Series B, 269, 507–511.

Heger, A., King, N., Wigham, B., Jamieson, A., Bagley, P., Allan, L., Pfannkuche, O., Priede, I. 2007. Benthic bioluminescence in the bathyal North East Atlantic: luminescent responses of *Vargula norvegica* (Ostracoda: Myodocopida) to predation by the deep-water eel (*Synaphobranchus kaupii*). Marine Biology 151 (4), 1471–1478

Heifetz J. 2000. Coral in Alaska: distribution, abundance, and species associations 1st International Deep-Sea Coral Symposium, Halifax, Canada, p 19–28.

Henry, L.-A., Navas, J.M., Hennige, S.J., Wicks, L.C., Vad, J., Roberts, J.M. 2013. Cold-water coral reef habitats benefit recreationally valuable sharks. Biological Conservation 161, 67–70.

Henry, L.-A., Vad, J., Findlay, H.S., Murillo, J., Milligan, R., Roberts, J.M. 2014. Environmental variability and biodiversity of megabenthos on the Hebrides Terrace Seamount (Northeast Atlantic). Scientific reports 4.

Hogg, M. M., O. S. Tendal, K. W. Conway, S. A. Pomponi, R. W. M. van Soest, J. Gutt, M. Krautter and J. M. Roberts. 2010. Deep-Sea Sponge Grounds: Reservoirs of Biodiversity. UNEPWCMC Biodiversity Series no. 32. UNEPWCMC, Cambridge: 1–88.

Husebø, Å., Nøttestad, L., Fosså, J., Furevik, D., Jørgensen, S. 2002. Distribution and abundance of fish in deep-sea coral habitats. Hydrobiologia 471 (1–3), 91–99.

Kellogg, C.A., Lisle, J.T., Galkiewicz, J.P. 2009. Culture-independent characterization of bacterial communities associated with the cold-water coral *Lophelia pertusa* in the northeastern Gulf of Mexico. Applied and environmental microbiology 75 (8), 2294–2303.

Kiriakoulakis, K., E. Fisher, G. Wolff, A. Freiwald, A. Grehan, Roberts, M.J. 2005. Lipids and nitrogen isotopes of two deep-water corals from the North-East Atlantic: initial results and implications for their nutrition. In A. R. Freiwald, J.M., editor. Cold-water Corals and Ecosystems. Springer-Verlag, Berlin.

Klitgaard, A. B. and O. S. Tendal. 2004. Distribution and species composition of mass occurrences of large-sized sponges in the northeast Atlantic. Progress in Oceanography 61: 57–98.

Koenig C.C. 2001. Oculina banks: habitat, fish populations, restoration, and enforcement. Florida State University 2001.

Koslow T. 2003. Deep water fisheries and seamount conservation in Tasmanian Sea and Australia, Report Marine Environmental and Health Series No. 11. Marine Institute, Ireland 2003.

Krieger K.J. 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fishery Bulletin, 91, 87–96.

Krieger K.J., Wing B.L. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the Gulf of Alaska. 1st International Deep-Sea Coral Symposium. Hydrobiologica, 471, 83–90.

Kutti, Bergstad OA., Fosså JH, Helle K. 2014. Cold-water coral mounds and sponge-beds as habitats for demersal fish on the Norwegian shelf. Deep-Sea Research II, 99: 122–133.

Lino, S., J.R. Xavier, R.S. Santos and A. Colaço. 2015. Sponge perforating lace coral with anticancer activity. Arquipelago. Life and Marine Sciences 32.

Maier, C., Kluijver, A.D., Agis, M., Brussaard, C., Van Duyl, F., Weinbauer, M. 2011. Dynamics of nutrients, total organic carbon, prokaryotes and viruses in onboard incubations of cold-water corals. Biogeosciences 8 (9), 2609–2620.

McAllister DE, Alfonso N. 2001. The distribution and conservation of deep-water corals on Canada's west coast. In: Willison JHM, Hall J, Gass S, Kenchington E, Butler M, Doherty P. First International Symposium on Deep-sea Corals. Halifax, Nova Scotia: Ecology Action Centre, 2001. p. 126–144.

Messing C., Neumann A., Lang J. 1990. Biozonation of deepwater lithoherms and associated hardgrounds in the Northeastern Straits of Florida. Palaios, 5, 15–33.

Millennium assessment Ecosystem Assessment: Ecosystems and Human Well-being: Synthesis, Millennium Ecosystem Assessment, Island Press, Washington DC, 2005.

Mohn, C., A. Rengstorf, M. White, G. Duineveld, F. Mienis, K. Soetaert, A. Grehan. 2014. Linking benthic hydrodynamics and cold-water coral occurrences: A high-resolution model study at three cold-water coral provinces in the NE Atlantic. Progress in Oceanography, 122: 92–104.

Mortensen P.B., Buhl- Mortensen L., Gordon D.C. Jr, Fader G.B.J., McKeown D.L., Fenton D.G. 2005. Effects of fisheries on deep-water gorgonian corals in the Northeast Channel, Nova Scotia (Canada). American Fisheries Society Symposium, 41, 369–382.

Mortensen P.B., Fosså J.H. 2006. Species diversity and spatial distribution of invertebrates on *Lophelia* reefs in Norway. Proceedings of the 10th International Coral Reef Symposium. Okinawa: 1849–1868.

Mortensen P.B., Hovland M., Brattegard T., Farestveit R. 1995. Deep water biotherms of the scleractinian coral *Lophelia pertusa* (L.) at 64ºN on the Norwegian shelf: structure and associated megafauna. Sarsia, 80, 145–158.

Mortensen, P.B. and L. Buhl-Mortensen. 2005. Morphology and growth of the deep-water gorgonians *Primnoa resedaeformis* and *Paragorgia arborea*. Marine Biology 147: 775–788.

O'Connell V.M., Carlile D.W. 1994. Comparison of a remotely operated vehicle and a submersible for estimating abundance of demersal shelf rockfishes in the Eastern Gulf of Alaska. North American Journal of Fisheries Management, 14, 196–201.

Peterson CH, Summerson HC, Thomson E, Lenihan HS, Grabowski J, Manning L, Micheli F, Johnson G, Coleman FC, Travis J. 2000. Synthesis of linkages between benthic and fish communities as a key to protecting essential fish habitat. Bulletin of Marine Science; 66(3):759–774.

Pham CK, Vandeperre F, Menezes G, Porteiro F, Isidro F, Morato T. 2015. The importance of deep-sea vulnerable marine ecosystems for demersal fish in the Azores. Deep-Sea Research I 96: 80–88.

Puglise KA, Brock RJ, McDonough JJ. 2005. Identifying critical information needs and developing institutional partnerships to further the understanding of Atlantic deep-sea coral ecosystems. In: Freiwald A, Roberts JM Cold-water corals and ecosystems. Berlin-Heidelberg: Springer-Verlag, 2005. p. 1129–1140.

Purser, A., Orejas, C., Gori, A., Tong, R., Unnithan, V., Thomsen, L. 2013. Local variation in the distribution of benthic megafauna species associated with cold-water coral reefs on the Norwegian margin. Continental Shelf Research 54, 37–51.

Quattrini, A.M., Partyka, M.L., Ross, S.W. 2009. Aspects of the reproductive biology of the skate *Fenestraja plutonia* (Garman) off North Carolina. Southeast Nat. 8, 55–70.

Reed J.K., Weaver D.C., Pomponi S.A. 2006. Habitat and fauna of deep-water *Lophelia pertusa* coral reefs off the southeastern US: Blake Plateau, Straits of Florida, and Gulf of Mexico. Bulletin of Marine Science, 78, 343–375.

Reed JK. 2002. Deep-water Oculina coral reefs of Florida: biology, impacts and management. Hydrobiologia 2002; 471:43–55.

Roberts, J. M., Wheeler, A. J., and Freiwald, A. 2006. Reefs of the Deep: The biology and geology of cold-water coral ecosystems, Science, 312, 543–547, 2006.

Roberts, J.M., Henry, L.-A., Long, D., Hartley, J.P. 2008. Cold-water coral reef frameworks, megafaunal communities and evidence for coral carbonate mounds on the Hatton Bank, north east Atlantic. Facies 54, 297–316.

Rosenberg, E., Kellogg, C.A., Rohwer, F. 2007. Coral microbiology. Oceanography-Washington DC-Oceanographic Society 20 (2), 146.

Rosenberg A, Bigford TE, Leathery S, Hill RL, Bickers K, Coleman FC, Travis J. 2000. Ecosystem approaches to fishery management through essential fish habitat. Bulletin of Marine Science 2000; 66(3):535–542.

Ross S.W., Quattrini A.M. 2007. The fish fauna associated with deep coral banks off the southeastern United States. Deep-Sea Research I, 54, 975–1007.

Söffker, M., Sloman, K., Hall-Spencer, J. 2011. In situ observations of fish associated with coral reefs off Ireland. Deep Sea Research Part I: Oceanographic Research Papers 58 (8), 818–825.

Stone R.P. 2006. Coral habitat in the Aleutian Islands of Alaska: depth distribution, fine-scale species associations, and fisheries interactions. Coral Reefs, 25, 229–238.

Sulak, K.J., Brooks, R.A., Luke, K.E., Norem, A.D., Randall, M., Quaid, A.J., Yeargin, G.E., Miller, J.M., Harden, W.M., Caruso, J.H., Ross, S.W. 2007. Demersal fishes associated with *Lophelia pertusa* coral and hard-substrate biotopes on the continental slope, northern Gulf of Mexico. In: George, R.Y., Cairns, S.D. (Eds.), Conservation and adaptive management of seamount and deep-sea coral ecosystems. Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, pp. 65–92.

TEEB: The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations, in: Earthscan, edited by: Kumar, P., London and Washington. 2010.

Thurber AR, Sweetman AK, Narayanaswamy BE, Jones DOB, Ingels J, and Hansman RL. 2014. Ecosystem function and services provided by the deep sea. Biogeosciences, 11, 3941–3963, 2014 www.biogeosciences.net/11/3941/2014/.

Tursi, A., Mastrototaro, F., Matarrese, A. 2004. Biodiversity of the white coral reefs in the Ionian Sea (Central Mediterranean). Chem. Ecol. 20 (Suppl. 1), S107–S116.

Van Gaever S., Vanreusel A., Hughes A., Bett B.J. 2004. The macro- and micro-scale patchiness of meiobenthos associated with the Darwin Mounds (NE Atlantic). Journal Marine Biology Association UK, 84, 547–556.

van Oevelen, D., Duineveld, G., Lavaleye, M., Mienis, F., Soetaert, K., Heip, C.H.R. 2009. The cold-water coral community as a hot spot for carbon cycling on continental margins: A food-web analysis from Rockall Bank (Northeast Atlantic). Limnology and Oceanography 54 (6), 1829–1844.

Wagner, H., Purser, A., Thomsen, L., Jesus, C. C., and Lundälv, T. 2011. Particulate organic matter fluxes and hydrodynamics at the Tisler cold-water coral reef. Journal of Marine Systems, 85(1), 19–29.

Wallace, K. J. 2007. Classification of ecosystem services: Problems and solutions, Biol. Conserv., 139, 235–246, 2007.

Wehrmann, L. M., Knab, N. J., Pirlet, H., Unnithan, V., Wild, C., and Ferdelman, T. G. 2009. Carbon mineralization and carbonate preservation in modern cold-water coral reef sediments on the Norwegian shelf. Biogeosciences, 6(4), 663–680.

Wild, C., Mayr, C., Wehrmann, L., Schöttner, S., Naumann, M., Hoffmann, F., and Rapp, H. T. 2008. Organic matter release by cold water corals and its implication for fauna-microbe interactions, Mar. Ecol. Prog. Ser., 372, 67–75, 2008.

Wild, C., Wehrmann, L. M., Mayr, C., Schöttner, S. I., Allers, E., and Lundälv, T. 2009. Microbial degradation of cold-water coral derived organic matter: potential implication for organic C cycling in the water column above Tisler Reef, Aquat. Biol., 372, 65–75, 2009.

Wilson JB. 2001. *Lophelia* 1700 to 2000 and beyond. In: Willison JHM, Hall J, Gass S, Kenchington E, Butler M, Doherty P First International Symposium on Deep-Sea Corals. Halifax, Nova Scotia: Ecology Action Centre, 2001. p. 1–5.

Witherell D, Coon C. 2001. Protecting Gorgorian corals off Alaska from fishing impacts. In: Willison JHM, Hall J, Gass S, Kenchington E, Butler M, Doherty P First International Symposium on Deep-sea Corals. Halifax, Nova Scotia: Ecology Action Centre, 2001. p. 117–125.

Yakimov, M.M., Cappello, S., Crisafi, E., Tursi, A., Savini, A., Corselli, C., Scarfi, S., Giuliano, L. 2006. Phylogenetic survey of metabolically active microbial communities associated with the deep-sea coral *Lophelia pertusa* from the Apulian plateau, Central Mediterranean Sea. Deep Sea Research Part I: Oceanographic Research Papers 53 (1), 62–75.

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Annex 2: WGDEC terms of reference for the next meeting

The **Working Group on Deep-water Ecology** (WGDEC), chaired by Neil Golding, UK, will meet at ICES HQ in Copenhagen, Denmark, from 15th–19th February 2016 to:

a) Provide all available new information on distribution of VMEs in the North Atlantic with a view to advising on any new closures to bottom fisheries or revision of existing closures to bottom fisheries (***NEAFC standing request: this may be updated in 2015).*** In addition, provide new information on location of habitats sensitive to particular fishing activities (i.e. vulnerable marine ecosystems, VMEs) within EU waters (***EC standing request: this may be updated in 2015***);

b) Review the process by which boundaries for bottom fishing closures are considered and develop a consolidated approach in light of recent work undertaken by WGDEC;

c) Continue development of the ICES VME Database and ICES VME Data Portal;

d) What is the spatial distribution of fishing as a result of closures brought into effect between 2006 and 2014? How do bottom fishing closures within the NEAFC Regulatory Area affect the distribution of fishing effort?

WGDEC will report by Friday 25th March 2016 to the attention of the ACOM Committee.

Supporting Information

PRIORITY:	HIGH AS A JOINT GROUP WITH NAFO AND IS ESSENTIAL TO PROVIDING INFORMATION TO HELP ANSWER EXTERNAL REQUESTS
Scientific justification and relation to action plan:	This information and maps are required to meet part of the European Commission MoU request to “provide any new information regarding the impact of fisheries on ..... sensitive habitats” and the NEAFC request “ 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.” The location of newly discovered/mapped sensitive habitats is critical to these requests. It is essential that ICES/WG chair asks its Member Countries etc. to supply as much relevant information as they may have by one month in advance of the WGDEC meeting; Over the past few years, WGDEC has reviewed the various elements considered when creating bottom fishing closures including buffer zones, closure delineation methods, VME indicator record weighting methodologies along with ways to aggregate the geographic locations of VMEs indicator records. These approaches require consolidation to form a set of guiding principles for recommending closed area boundaries; There is a requirement to update the ICES VME database to include new information on the distribution of VMEs (including VME indicator species) submitted under ToR (a) as well as continue development of the VME data portal. Over the last 8 years, many bottom fishing closures have been implemented within the NEAFC Regulatory Area. It is important to know the effect that these closures have on fishing pressure, and consider whether they cause fishing pressure to be increased in the same fishing areas, or whether they cause displacement of fishing effort into new areas that hadn’t previously been fished.
Resource requirements:	The usual helpful support from the Secretariat will be appreciated.
Participants:	The Group is normally attended by some 15–20 members and guests.
Secretariat facilities:	None, apart from the Sharepoint site
Financial:	No financial implications.
Linkages to ACOM and its expert groups	ACOM is parent group. WGDEEP is related, but no explicit overlap in work this year.
Linkages to SCICOM and its expert groups	No direct linkages, though the work of BEWG is related
Linkages to other organisations:	OSPAR, NEAFC

Annex 3: Recommendations

RECOMMENDATION	ADRESSED TO
1. WGDEC recommends that a formal VME data call is undertaken in summer 2015. The Data Call will invite ICES Member Countries to submit new data on occurrences of VME indicators or VME habitat types. The Data Call will be managed by the ICES Data Centre.	ICES Data Centre
2. WGDEC recommends that the ICES Data Centre continue to assist in development of the ICES online VME Database Portal and in the preparation of VMS data provided for the NEAFC Regulatory Area in order to allow the WG to carry out its Terms of Reference	ICES Data Centre
3. WGDEC recommends that 2015 VMS data for the NEAFC Regulatory Area are provided to ICES in advance of the 2016 WGDEC meeting. This VMS data should include information on fishing gear type (e.g. bottom trawl), and should be resolved to the finest possible temporal and spatial scales (not aggregated)	NEAFC & EC
4. .WGDEC recommend that WGSFD produce 'swept-area' maps at their 2015 WG showing where the seabed has been impacted by bottom fishing activity each year (from 2006 – 2014) within the NEAFC Regulatory Area. These maps (provided as ESRI raster grids) will allow WGDEC 2016 to investigate how bottom fishing closures affect fishing activity and behaviour. The ICES Data Centre will need to assist WGSFD in the use of the NEAFC VMS data from 2006 – 2014.	WGSFD Chair & ICES Data Centre
5. WGDEC recommend that the ICG-C Pressures List is ammended to include the proposals outlined in Section 6 of the report. Specifically, a number of modifications are recommended to the Pressures List and two additional presssures are recommended for inclusion, as they are not considered to be adequately covered.	OSPAR Secretariat

Annex 4: Combining the VME Index with NEAFC VMS data

Some further exploratory work was undertaken linking the outputs from the VME Index with NEAFC VMS data. This work should be considered 'a work in progress' and was not discussed in detail by WGDEC. However, it is useful to report on this developmental work with a view to its development continuing at WGDEC 2016.

VME and Fishing Effort portfolio categories

One of the main advantages of deriving a gridded VME index is that is can be directly compared to other gridded data, for example fishing effort. The main fisheries occurring in areas of VMEs in the North Atlantic use trawls and static bottom longlines. In addition to the type of fishing gear used, fishing effort (duration and frequency of fishing events) and catch data (landings, bycatch and discards) are essential to determine the actual impact of any fishery.

Fishing intensity data could therefore be used to review the anthropogenic activities occurring on each cell (Figure 32). However, considering the lack of specific data regarding most high seas fisheries, the evaluation of fishing effort on individual grid cells was here exclusively based on the number of VMS pings in a specific cell. We hereby propose an approach that combines the likelihood of a cell constituting a VME and the level of fishing activity. This methodology allows the classification of individual cells into four main categories, which can help in optimizing management efforts toward spatial management. The four portfolio categories are: Low VME index-Low fishing; Low VME index–High fishing; High VME index-Low fishing; High VME index-High fishing. VME likelihood and fishing intensity for individual cells can therefore be easily summarized and graphically compared (Figure 33).

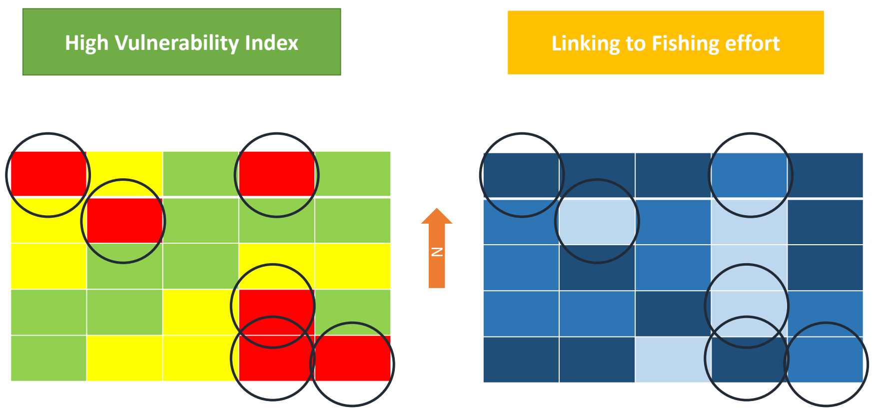

Figure 32. Representation of the usefulness of the VME and VMS data maps.

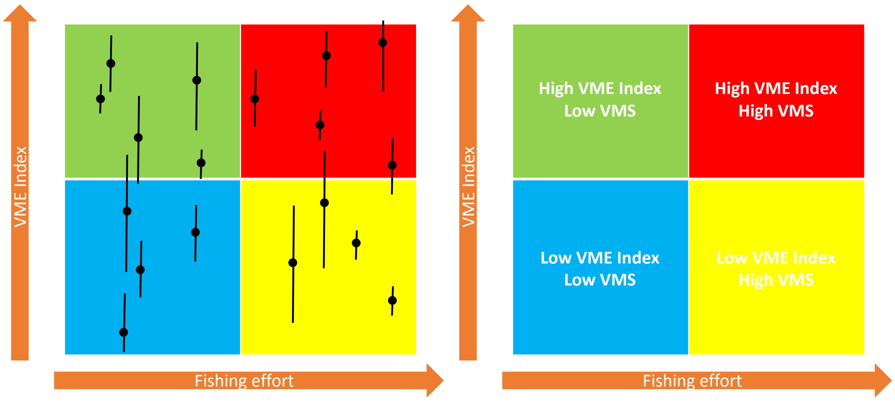

Figure 33. Representation of the application of the portfolio categories concept.

The application of the VME and fishing effort portfolio categories to the ICES VME database and NEAFC VMS data was tested. The VME index was calculated as described in Section 4. For estimating the bottom-trawl fishing effort for each grid cell, the cumulative number of records of bottom-trawling activity (gear codes TBB, OTB, PTB and OTT) from 2006 to 2014 was used. Speed filtering (as outlined in Section 2.5) was applied to identify these VMS records. Due to the large range of values and the presence of some cells with very large records of trawling activity, the cumulative number of records was log transformed. Fishing effort was then re-scaled from 1 where no fishing activity was present to 5 where the maximum value of fishing effort was reached.

The VME Index outputs and NEAFC VMS data were assigned to all 4 portfolio categories (Figure 34, right panel) with a large portion of the cells considered as low VME and low VMS (73%) or high VME and low VMS (21%). Only a small portion of the cells fell in the category high VME and high VMS (4%) (Figure 34, right panel). These results indicate that the framework is adequate to assign cells to different portfolio categories. However, the large numbers of cells with low fishing effort should be considered with caution since 1) many cells fall within areas of national jurisdiction where these is no NEAFC VMS data, 2) a large portion of the fishing vessels don't have a fishing licence assigned and therefore are not considered as trawlers and were excluded from the analyses, 3) some areas were closed to fishing in recent years and therefore low fishing effort may truly represent a decreased fishing activity. In Figure 34, left panel, the outcomes of the framework can be visualized and cells compared allowing managers to prioritize their choices or policies in terms of closing VME undisturbed areas, closing disturbed areas for recovery of VMEs, or both.

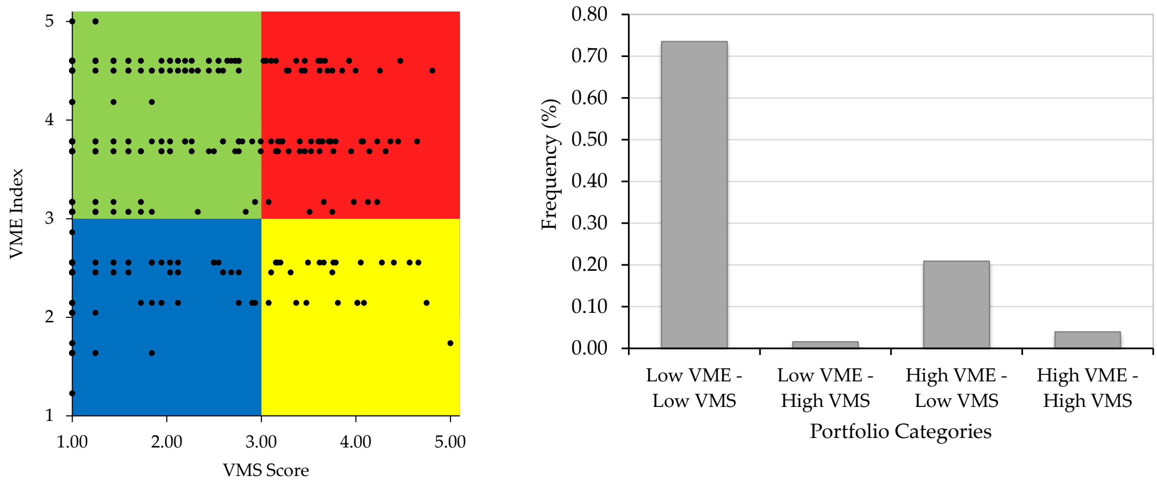

Figure 34. Application of the portfolio categories concept to the ICES database. The different colours represent four portfolio categories: blue is low VME - low VMS, yellow is low VME - high VMS, green is high VME - low VMS, and red is high VME - high VMS. Proportions of cells falling into those categories are also shown.

Mapping the outcomes of the framework can be another way to visualize areas falling in different portfolio categories. For example, in the Hatton-Rockall area (Figure 35), despite the problems with the VMS data described above, most areas of high VME score lie inside closed areas and have low fishing effort. Only few cells with high VME index and high fishing effort are observed mostly around the closed areas.

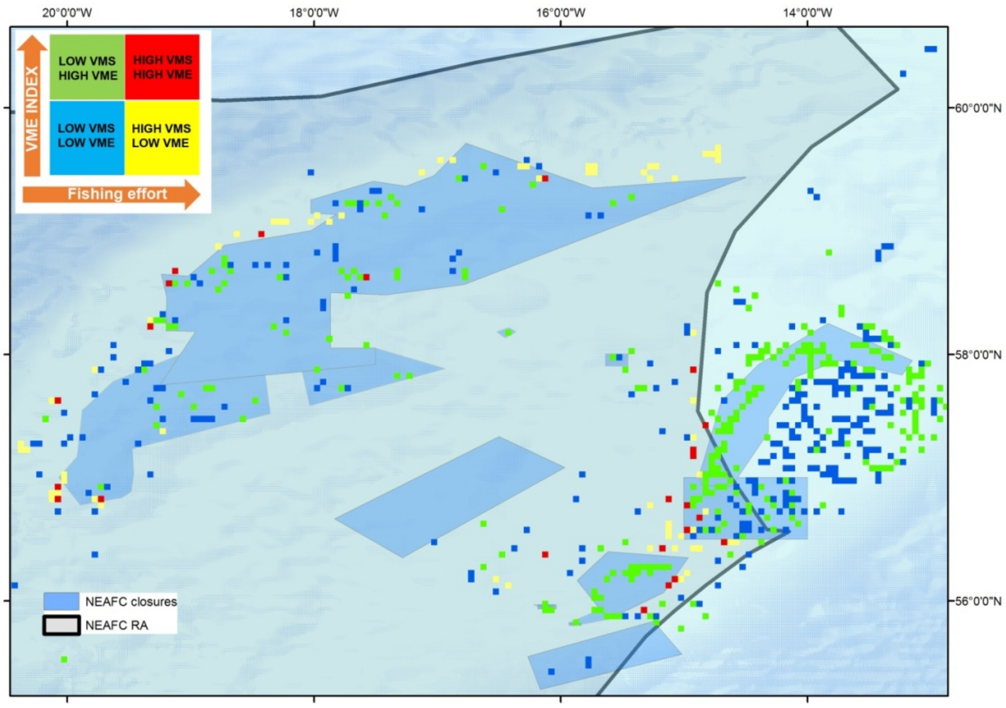

Figure 35. Application of the portfolio categories concept to the Hatton-Rockall area. Blue cells are low VME - low VMS, yellow cells are low VME - high VMS, green cells are high VME - low VMS, and red cells are high VME - high VMS.

Annex 5: A proposal submitted by Russia to WGDEC considering ways to delineate bottom fishing closure boundaries through the development of a standardised approach to combining individual VME indicator records

Background

One of the most effective ways for protection of vulnerable marine ecosystems (VMEs) is the closure of areas to bottom trawling where there is evidence of VME presence.

Previously, ICES (ICES, 2013) has detailed methods to create buffer zones around VME indicator records (Figure 36). According to those recommendations, buffer zones are defined as follows:

a) For VMEs that occur on flat or undulating seabed a buffer zone of approximately two (>500 m depth) or three times (<500 m depth) the local depth is advised.

b) In the case of VMEs on very steep slopes, the risk of straying of bottom trawls is mitigated by the fishers' own incentive to avoid the steep slopes and cliff edges, in which case the buffer zone may be reduced.

c) In some cases the presence of geomorphological features are used to define boundaries for closures on the basis that they are considered to be VME elements, in which case the VME reflects the topographic relief of the VME element without a buffer zone.

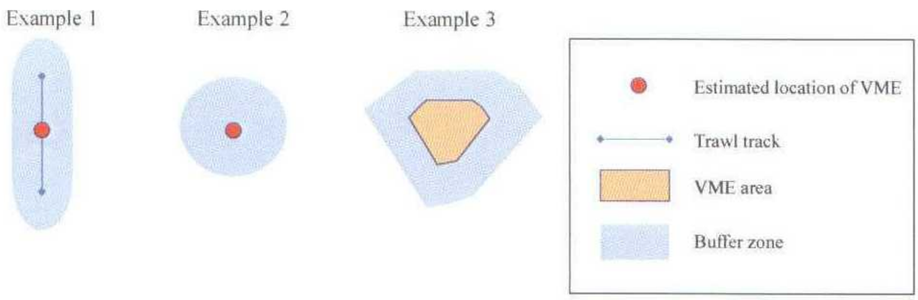

Figure 36. Buffer zones around the known VME locations (ICES, 2013). Example 1: isolated VME detection with low geospatial certainty (e.g. trawl track); Example 2: isolated VME detection with high geospatial certainty (e.g. ROV observation); and Example 3: area identified as hosting a VME.

Buffer zones are usually established when encountering a single record or group of VME indicator records. Often, VME indicators are separated by varying distances and there is currently no standardised method for deciding whether to unite the encountered VMEs under a single larger closure or multiple smaller closures. Depending on the experts' position, the number and area of proposed closures may vary greatly.

To improve the efficiency of VME protection measures, increase the transparency of delineating closures and remove the subjective errors in that process, further refining of the buffer zone evaluation method proposed by ICES is required, as well as developing a standard method for drawing the closures' borders. In order achieve this, certain actions are required:

- establish a criterion for evaluating the distance between VME indicator records to decide if these should be united under a single closure; and,
- develop a method for drawing the closure when considering several VME indicator records.

Proposed method when combining geographically isolated VME indicator records

It is important to recognise when isolated VME indicator records should be combined under a single closure.

Bottom fishing closures should be established in such a way as:

- to minimize the possibility of vessels accidently entering closed areas containing VMEs during fishing activity;
- to minimize the possibility of including the areas without VMEs into said closures.

For a certain criterion of uniting the areas, a set distance travelled by the vessel between the two observed locations according to the VMS system may be used. Currently there is usually no more than an hour between these observations. Considering the vessel speed during bottom fishery can equal 3–3.5 knots, the vessel will travel no more than 3.5 nautical miles in one hour. Thus, that distance (3.5 nm) may be used as the criterion for when to unite VME occurrences into one closure.

The aforementioned distance (3.5 nm) is sufficient for controlling the vessels' trajectories, preserving the potential VME distribution areas and considers the bottom relief. Increasing this distance may lead to the unjustified expansion of closures between the VME encounter locations, even if those have different bathymetric conditions (depth shifts, canyons, valleys, seamounts, etc.) which present changes in habitat and the absence of VMEs.

It seems reasonable to use the following method of establishing the closures:

a) if the distance between the buffer zones of nearby VME is less than 3.5 nm, those should be united into a single closure (Figures 37a–d);

b) if the distance between the buffer zones of nearby VME is greater than 3.5 nm, it is reasonable to establish several (two or more) separate closures (Figure 37e);

c) the borders of closures should be placed at the shortest distance between the buffer zones' edges (Figures 37a–d);

d) the shape of closures should be kept as simple as possible (square, rectangle, trapeze, triangle, etc.);

e) for further simplicity of closures' shape, a closure for any single isolated VME location should be in the shape of square, written around the buffer zone' edges (Figure 37e).

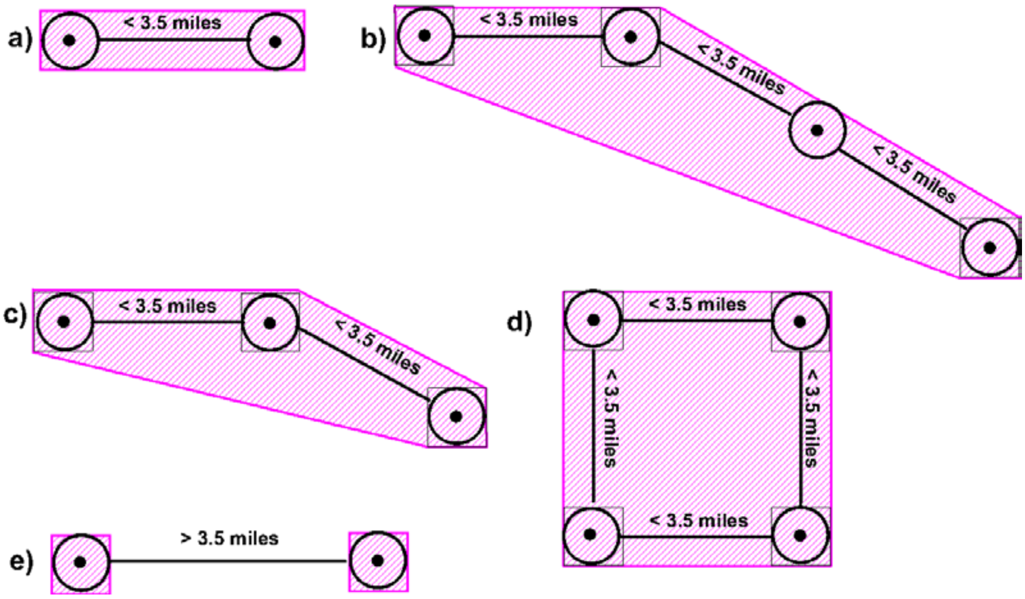

Figure 37. Variants of establishing the closures depending on the VME indicator species locations distribution.

- VME locations - buffer zones - area of closure

Future perspectives of development of a standardised method for recommending closed area boundaries

This proposal to standardise the method of combining isolated geographic locations of VMEs were submitted to WGDEC 2015 for consideration, and represents a first attempt at developing a standardised method. Further development is recommended, particularly with respect to large areas of VME records which have varying densities.

References

ICES. 2013. Evaluation of the appropriateness of buffer zones, Advice 2013, Book 1. Advice 1.5.5.2. May 2013, P.5.

Annex 6: Agreed modifications to the WGDEC VME database

Table 2. Proposed data format updates for the WGDEC vulnerable marine ecosystem database; in the 'Obligation' column, M stands for mandatory, O stands for optional and C stands for conditional.

FIELD NAME	FIELD TYPE	OBLIGATION	DESCRIPTION	GUIDANCE
WGDECGUI	Text	M	Globally Unique ID for each dataset	To be created by data supplier - Follow the format: "WGDECHab" + year + 2-letter country code (corresponding to ISO 3166-1) + 1 alpha/numeric digit (different for each dataset) + "v" + version of dataset, e.g. if the UK supplied 2 datasets, they may be called WGDECHab2010UK1v1 and WGDECHab2010UK2v1.
Sample	Number	M	Unique number for each Indicator record	Sequential number for identifying individual records within WGDECGUI dataset
RecordKey	Text	M	Unique key for each Indicator record	To be created by data supplier. May be numeric, text or a combination of numbers and text, which may relate back to original data management convention for traceability. If no original data management key exists, this can be added as a sequential numeric list (1,2,3, etc.)
VME_Indicator	Text	C	Grouping of species/habitats used by WGDEC.	A VME indicator must be chosen if no bona fidae VME habitat type is known to occur, e.g. a sponge from trawl bycatch. This should match the indictor list provided below. If the record is known to occur within a VME habitat type, leave this field blank. Choose from: • Black coral • Cold Seeps • Cup coral • Gorgonian • Hydroid

FIELD NAME	FIELD TYPE	OBLIGATION	DESCRIPTION	GUIDANCE
				• Lace coral • Oceanic ridges with hydrothermal vents/fields • Sea-pen • Soft coral • Sponge • Stony coral
VME_HABITAT_TYPE	Text	C	VME habitat types used by WGDEC.	A VME habitat type should be chosen if the record occurs within a bona fidae VME habitat, e.g.from a ROV transect surveying a cold-water coral reef. The 'VME_Indicator' field should be left blank. All datapoints representing the known extent of a VME habitat type along a transect or tow should be recorded within one line of the database (e.g. a video tow split into sections of cold-water coral reef; bathyal rock; cold-water coral reef, would represent two VME habitat records of cold-water coral reef in the database). Choose from: • Cold-water coral reef • Coral Garden • Deep-sea Sponge Aggregations • Seapen fields • Tube-dwelling anemone patches • Mud and sand emergent fauna
VME_HABITAT_SUBTYPE	Text	O	VME sub-habitat types used by WGDEC	If no 'VME_habitat_type' is filled in, this field should be left blank. If VME_habitat_type is filled in, this field is optional. Choose from: • *Lophelia pertusa* reef • *Solenosmilia variablis* reef • Hard-bottom coral garden • Soft-bottom coral garden • Ostur sponge aggregations • Hard-bottom sponge aggregations

FIELD NAME	FIELD TYPE	OBLIGATION	DESCRIPTION	GUIDANCE
				• Glass sponge communities
Status	Text	M	Presence or absence of habitat or species	Choose either Present or Absent
GeneralTaxonDescriptor	Text	M	Most detailed name of taxon (according to Highest Taxonomic Resolution)	e.g. Porifera, *Lophelia pertusa*, soft coral
HighestTaxonomicResolution	Text	C	Highest taxonomic resolution described in GeneralTaxonDescriptor	Only use if a scientific taxon name is given. E.g. order, species, genus.
Order	Text	C	Order of taxon, if known	If not known, use "NA"
Genus	Text	C	Genus of taxon, if known	If not known, use "NA"
Species	Text	C	Species of taxon, if known	If not known, use "NA"
Dead_alive	Text	O	Indication of whether most of sample was dead or live	Choose either "Dead" or "Alive"
Number	Double	O	Number of individuals associated with record	If not known, leave blank. Do not include if the record is a VME habitat type.
Weight_kg	Double	O	Mass of Indicator, in kg, associated with record	If not known or not relevant, leave blank. Do not include if the record is a VME habitat type.
Density	Double	O	Number of individuals per metre squared	If not known or not relevant, leave blank. Do not include if the record is a VME habitat type.
% Cover	Double	O	Percentage cover of Indicator (relevant to observation data)	If not known or not relevant, leave blank. Do not include if the record is a VME habitat type.
SACFOR	Text	O	Semi-quantitative abundance scale (relevant to observation data)	If not known or not relevant, use "NA". Do not include if the record is a VME habitat type.
TaxonDeterminer	Text	M	Name of organization that identified the GeneralTaxonDescriptor.	Free text; e.g. JNCC
TaxonDeterminationDate	Date	M	Date of identification of the GeneralTaxonDescriptor.	All dates must be supplied as text in the format YYYY-MM-DD (ISO date format).
ObsDate	Date	M	Date the habitat or species was recorded.	All dates must be supplied as text in the format YYYY-MM-DD (ISO date format).
ObsDateType	Text	M	A one or two character code that identifies the type of dates used in ObsDate. Explicitly stating the code avoids any ambiguity, which might lead to subtly different interpretations.	Choose from: D - Dates specified to the nearest day. O - Dates specified to the nearest month

FIELD NAME	FIELD TYPE	OBLIGATION	DESCRIPTION	GUIDANCE
				Y - Dates specified to the nearest year ND - No date U – Unknown
StationID	Text	O	ID of the survey station, if known.	May be numeric, text or a combination of numbers and text.
SurveyKey	Text	O	Unique key for each dataset making up the country submission to WGDEC (e.g. representing actual separate surveys, data from different sources, museum collections, etc.). SurveyKey links to the Survey Key Metadata worksheet, where survey details are described in full.	Each SurveyKey must refer to a record in the SurveyKey Metadata worksheet.
SurveyMethod	Text	O	A description of the survey method(s) used.	Choose one or more from: • Multibeam echosounder • Single beam echosounder • Sidescan sonar • Interferometric sonar • AGDS • Multibeam ground discrimination • 3D seismic imagery • Sub bottom profiling • Grab • Core • Trawl • Commercial trawl bycatch • Survey trawl bycatch • Survey longline bycatch • Dredge • Particle size analysis • Geotechnical measurements • Towed camera

FIELD NAME	FIELD TYPE	OBLIGATION	DESCRIPTION	GUIDANCE
				• Drop camera • ROV • Sediment profile imagery
PlaceName	Text	O	Name of place in reference to the record collection.	Free text; e.g. "Rockall Bank"
StartLatitude	Double	C	Start latitude of the record, if line (if point, use MidLatitude and leave this blank).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
StartLongitude	Double	C	Start longitude of the record, if line (if point, use MidLongitude and leave this blank).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
EndLatitude	Double	C	End latitude of the record, if line (if point, leave blank).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
EndLongitude	Double	C	End longitude of the record (if point, leave blank).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
MidLatitude	Double	M	Midpoint Latitude of the record if line (if point, use this field for position).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
MidLogitude	Double	M	Midpoint longitude of the record if line (if point, use this field for position).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
GeometryType	Text	M	Point or line	Enter "point" or "line"
RecordPositionAccuracy	Integer	O	Accuracy of spatial position of record.	Value in metres; e.g. "10" means the given position of the habitat is accurate to ± 10 metres.
ShipPositionPrecision	Integer	O	An estimate of the precision of the lat/long coordinates relative to the benthic Indicator. Relevant to bycatch records	Calculated or estimated precision of the benthic feature in metres. Take into account whether position is determined from the ship position or from ROV.
Reference	Text	M	A reference to the data source	Complete citation for the data source e.g. "Mortensen *et al*., 2006"
Filename	Text	O	Name of the excel or shape file submitted	
DataOwner	Text	M	Name of person or organization that owns the data.	Free text; e.g. "JNCC"

FIELD NAME	FIELD TYPE	OBLIGATION	DESCRIPTION	GUIDANCE
DataAccess	Text	M	Data access constraints	e.g. “public” or “restricted”. Please use 'public' if you are content with the data being shown (in grid form) and downloaded from the ICES data portal.
Depth Upper	Double	O	For transect data (video or trawl) indicate the shallowest depth in metres	e.g. 110
Depth Lower	Double	O	For transect data (video or trawl) indicate the deepest depth in metres	e.g. 150
Comments	Text	O	Any other comments or information	e.g. “sample was 60% live coral and 40% dead”

Annex 7: Pressures and impacts associated with deep-sea mining activities

Table 3. Suggested modifications to document – "Intersessional Correspondence Group on Cumulative Effects – Amended 25th March 2011" – for pressures potentially associated with deep-sea mining activities (modifications highlighted in yellow).

Pressure theme	Pressures	Code	Pressure Descriptor	MSFD Annex III Table 2
Hydrological changes (inshore/local)	Temperature changes - local	H1	Events or activities increasing or decreasing local water temperature. This is most likely from thermal discharges, e.g. the release of cooling waters from power station; release of warmer water in the return water plume during deep-sea mining operations. This could also relate to temperature changes in the vicinity of operational sub sea power cables. This pressure only applies within the thermal plume generated by the pressure source. It excludes temperature changes from global warming which will be at a regional scale (and as such are addressed under the climate change pressures).	Significant changes in thermal regime (e.g. by outfalls from power stations)
Hydrological changes (inshore/local)	Salinity changes - local	H2	Events or activities increasing or decreasing local salinity. This relates to anthropogenic sources/causes that have the potential to be controlled, e.g. freshwater discharges from pipelines that reduce salinity, or brine discharges from salt caverns washings that may increase salinity. This could also include hydromorphological modification, e.g. capital navigation dredging if this alters the halocline, or erection of barrages or weirs that alter freshwater/seawater flow/exchange rates. This might also include the release plume during deep-sea mining operation if the water used has different properties (e.g. surface water and deep water).The pressure may be temporally and spatially delineated derived from the causal event/activity and local environment.	Significant changes in salinity regime (e.g. by constructions impeding water movements, water abstraction)

Pressure theme	Pressures	Code	Pressure Descriptor	MSFD Annex III Table 2
Pollution and other chemical changes	Transition elements & organo-metal (e.g. TBT) contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC.	P1	The increase in transition elements levels compared with background concentrations, due to their input from land/riverine sources, by air or directly at sea. This might also include the Extraction plume and/or return water plume during deep-sea mining operations), which may contain trace metals as elements of concern. For marine sediments the main elements of concern are Arsenic, Cadmium, Chromium, Copper, Mercury, Nickel, Lead and Zinc Organo-metallic compounds such as the butyl tins (Tri butyl tin and its derivatives) can be highly persistent and chronic exposure to low levels has adverse biological effects, e.g. Imposex in molluscs.	Introduction of non-synthetic substances and compounds (e.g. heavy metals, hydro-carbons, resulting, for example, from pollution by ships and oil, gas and mineral exploration, atmospheric deposition, riverine inputs)
Pollution and other chemical changes	Introduction of other substances (solid, liquid or gas)	P4	The 'systematic or intentional release of liquids, gases …' (from MSFD Annex III Table 2) is being considered e.g. in relation to produced water from the oil industry. It should therefore be considered in parallel with P1, P2 and P3.This includes mining agent facilitators (potential use of flocculants)	Introduction of other substances, whether solid, liquid or gas, in marine waters resulting from their systematic and/or international release into the marine environment, as permitted in accordance with other Community legislation and/or international conventions
Pollution and other chemical changes	Radionuclide contamination	P5	Introduction of radionuclide material, raising levels above background concentrations. Such materials can come from nuclear installation discharges, and from land or sea-based operations (e.g. oil platforms, medical sources). The disposal of radioactive material at sea is prohibited unless it fulfils exemption criteria developed by the International Atomic Energy Agency (IAEA), namely that both the following radiological criteria are satisfied: (i) the effective dose expected to be incurred by any member of the public or ships crew is 10 μSv or less in a year; (ii) the collective effective dose to the public or ships crew is not more than 1 man Sv per annum, then the material is deemed to contain de minimis levels of radioactivity and may be disposed at sea pursuant to it fulfilling all the other provisions under	Introduction of radio-nuclides

Pressure theme	Pressures	Code	Pressure Descriptor	MSFD Annex III Table 2
			the Convention. The individual dose criteria are placed in perspective (i.e. very low), given that the average background dose to the UK population is ~2700 µSv/a. Ports and coastal sediments can be affected by the authorised discharge of both current and historical low-level radioactive wastes from coastal nuclear establishments. Potentially, natural radionuclides that are present in polymetallic sulphides could be released during the mining operation	
Pollution and other chemical changes	Nutrient enrichment	P6	Increased levels of the elements nitrogen, phosphorus, silicon (and iron) in the marine environment compared to background concentrations. Nutrients can enter marine waters by natural processes (e.g. decomposition of detritus, riverine, direct and atmospheric inputs) or anthropogenic sources (e.g. wastewater run-off, terrestrial/agricultural run-off, sewage discharges, aquaculture, atmospheric deposition). Nutrients can also enter marine regions from 'upstream' locations, e.g. via tidal currents to induce enrichment in the receiving area. Nutrient enrichment may lead to eutrophication (see also organic enrichment). Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes. Nodules and SMS are iron rich. The plumes might increase the iron concentration locally (e.g. in photic areas, and increase the productivity (iron fertilization of the oceans Pollard, R. T. *et al*. Southern Ocean deep-water carbon export enhanced by natural iron fertilization. Nature 457, 577–580 (2009).	Inputs of fertilisers and other nitrogen - and phosphorous-rich substances (e.g. from point and diffuse sources, including agriculture, aquaculture, atmospheric deposition)

Pressure theme	Pressures	Code	Pressure Descriptor	MSFD Annex III Table 2
Pollution and other chemical changes	Deoxygenation	P8	Any deoxygenation that is not directly associated with nutrient or organic enrichment. The lowering, temporarily or more permanently, of oxygen levels in the water or substrate due to anthropogenic causes (some areas may naturally be deoxygenated due to stagnation of water masses, e.g. inner basins of fjords).. This is typically associated with nutrient and organic enrichment, but it can also derive from the release of ballast water or other stagnant waters (where organic or nutrient enrichment may be absent). Ballast waters may be deliberately deoxygenated via treatment with inert gases to kill non-indigenous species.	X
Physical loss (Permanent Change)	Physical change (to another seabed type)	L2	The permanent change of one marine habitat type to another marine habitat type, through the change in substatum, including to artificial (e.g. concrete). This therefore involves the permanent loss of one marine habitat type but has an equal creation of a different marine habitat type. Associated activities include the installation of infrastructure (e.g. surface of platforms or wind farm foundations, marinas, coastal defences, pipelines and cables and deep-sea nodule mineral extraction), the placement of scour protection where soft sediment habitats are replaced by hard/coarse substrate habitats, removal of coarse substrate (marine mineral extraction) in those instances where surficial finer sediments are lost, capital dredging where the residual sedimentary habitat differs structurally from the pre-dredge state, creation of artificial reefs, mariculture i.e. mussel beds. Protection of pipes and cables using rock dumping and mattressing techniques. Placement of cuttings piles from oil & gas activities could fit this pressure type, however, there may be an additional pressures, e.g. "pollution and other chemical changes" theme. This pressure excludes navigation dredging where	Smothering (e.g. by man made structures, disposal of dredge spoil)

Pressure theme	Pressures	Code	Pressure Descriptor	MSFD Annex III Table 2
			the depth of sediment is changes locally but the sediment typology is not changed.	
Physical damage (Reversible Change)	Habitat structure changes - removal of substratum (extraction)	D1	Unlike the "physical change" pressure type where there is a permanent change in seabed type (e.g. sand to gravel, sediment to a hard artificial substrate) the "habitat structure change" pressure type relates to temporary and/or reversible change, e.g. from marine mineral extraction where a proportion of seabed sands or gravels are removed but a residual layer of seabed is similar to the pre-dredge structure and as such biological communities could re-colonise (e.g. removal of cobalt crust and polymetallic sulphide mounds); navigation dredging to maintain channels where the silts or sands removed are replaced by non-anthropogenic mechanisms so the sediment typology is not changed.	Selective extraction (e.g. by exploration and exploitation of living and non-living resources on seabed and subsoil)
Physical damage (Reversible Change)	Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	D2	The disturbance of sediments where there is limited or no loss of substrate from the system. This pressure is associated with activities such as anchoring, taking of sediment/geological cores, deep-sea mining; cone penetration tests, cable burial (ploughing or jetting), propeller wash from vessels, certain fishing activities, e.g. scallop dredging, beam trawling. Agitation dredging, where sediments are deliberately disturbed by and by gravity & hydraulic dredging where sediments are deliberately disturbed and moved by currents could also be associated with this pressure type. Compression of sediments, e.g. from the legs of a jack-up barge could also fit into this pressure type. Abrasion relates to the damage of the seabed surface layers (typically up to 50cm depth) Activities associated with abrasion can cover relatively large spatial areas and include: fishing with towed demersal trawls (fish & shellfish); bio-prospecting such as harvesting of biogenic features such as maerl beds where, after extraction,	Abrasion (e.g. impact on the seabed of commercial fishing, boating, anhoring)

Pressure theme	Pressures	Code	Pressure Descriptor	MSFD Annex III Table 2
			conditions for recolonisation remain suitable or relatively localised activities including: seaweed harvesting, recreation, potting, aquaculture. Change from gravel to silt substrate would adversely affect herring spawning grounds.	
Physical damage (Reversible Change)	Changes in suspended solids (water clarity)	D3	Changes in water clarity from sediment & organic particulate matter concentrations. It is related to activities disturbing sediment and/or organic particulate matter and mobilising it into the water column. Could be 'natural' land run-off and riverine discharges or from anthropogenic activities such as all forms of dredging, deep-sea mining activities; disposal at sea, cable and pipeline burial, secondary effects of construction works, e.g. breakwaters. Particle size, hydrological energy (current speed & direction) and tidal excursion are all influencing factors on the spatial extent and temporal duration. This pressure also relates to changes in turbidity from suspended solids of organic origin (as such it excludes sediments - see the "changes in suspended sediment" pressure type). Salinity, turbulence, pH and temperature may result in flocculation of suspended organic matter. Anthropogenic sources mostly short lived and over relatively small spatial extents.	X
Physical damage (Reversible Change)	Siltation rate changes, including smothering (depth of vertical sediment overburden)	D4	When the natural rates of siltation are altered (increased or decreased). Siltation (or sedimentation) is the settling out of silt/sediments suspended in the water column. Activities associated with this pressure type include mariculture, land claim, navigation dredging, disposal at sea, marine mineral extraction (plume and overburden), cable and pipeline laying and various construction activities. It can result in short lived sediment concentration gradients and the accumulation of sediments on the sea floor. This accumulation of sediments is	Changes in siltation (e.g. by outfalls, increased run-off, dredging/disposal or dredge spoil)

Pressure theme	Pressures	Code	Pressure Descriptor	MSFD Annex III Table 2
			synonymous with "light" smothering, which relates to the depth of vertical overburden. "Light" smothering relates to the deposition of layers of sediment on the seabed. It is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the seabed. For "light" smothering most benthic biota may be able to adapt, i.e. vertically migrate through the deposited sediment. "Heavy" smothering also relates to the deposition of layers of sediment on the seabed but is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the seabed. This accumulation of sediments relates to the depth of vertical overburden where the sediment type of the existing and deposited sediment has similar physical characteristics because, although most species of marine biota are unable to adapt, e.g. sessile organisms unable to make their way to the surface, a similar biota could, with time, re-establish. If the sediments were physically different this would fall under L2. (B7)Impact of plumes that destroy part of the surrounding ecosystem leading to loss of function and ecosystem change Eleftheriou and McIntyre, 2005 describe that the majority of animals will inhabit the top 5-10 cm in open waters and the top 15 cm in intertidal areas. The depth of sediment overburden that benthic biota can tolerate is both trophic group and particle size/sediment type dependant (Bolam, 2010). Recovery from burial can occur from: - planktonic recruitment of larvae - lateral migration of juveniles/adults - vertical migration (see Chandrasekara and Frid, 1998; Bolam *et al*., 2003,	

Pressure theme	Pressures	Code	Pressure Descriptor	MSFD Annex III Table 2
			Bolam & Whomersley, 2005). Spatial scale, timing, rate and depth of placement all contribute the relative importance of these three recovery mechanisms (Bolam *et al*., 2006). As such the terms "light" and "heavy" smothering are relative and therefore difficult to define in general terms. Bolam, 2010 cites various examples: - H. ulvae maximum overburden 5 cm (Chandrasekara & Frid, 1998) - H. ulvae maximum overburden 20 cm mud or 9 cm sand (Bijerk, 1988) - S. shrubsolii maximum overburden 6 cm (Saila *et al*., 1972, cited by Hall, 1994) - N. succinea maximum overburden 90 cm (Maurer *et al*., 1982) - gastropod molluscs maximum overburden 15 cm (Roberts *et al*., 1998). Bolam, 2010 also reported when organic content was low: - H. ulvae maximum overburden 16 cm - T, benedii maximum overburden 6 cm - S. shrubsolii maximum overburden <6 cm - Tharyx sp.A. maximum overburden <6 cm	
Other physical pressures	Electromagnetic changes	O2	Localised electric and magnetic fields associated with operational power cables and telecommunication cables (if equipped with power relays). Such cables may generate electric and magnetic fields that could alter behaviour and migration patterns of sensitive species (e.g. sharks and rays). Also if deep-sea mining instruments and mining machinery have electric or magnetic cables.	X
Other physical pressures	Underwater noise changes	O3	Increases over and above background noise levels (consisting of environmental noise (ambient) and incidental man-made/anthropogenic noise (apparent)) at a particular location. Species known to	Underwater noise (e.g. from shipping, underwater acoustic equipment)

Pressure theme	Pressures	Code	Pressure Descriptor	MSFD Annex III Table 2
			be affected are marine mammals and fish. The theoretical zones of noise influence (Richardson et al 1995) are temporary or permanent hearing loss, discomfort & injury; response; masking and detection. In extreme cases noise pressures may lead to death. The physical or behavioural effects are dependant on a number of variables, including the sound pressure, loudness, sound exposure level and frequency. High amplitude low and mid-frequency impulsive sounds and low frequency continuous sound are of greatest concern for effects on marine mammals and fish. Some species may be responsive to the associated particle motion rather than the usual concept of noise. Noise propagation can be over large distances (tens of kilometres) but transmission losses can be attributable to factors such as water depth and seabed topography. Noise levels associated with construction activities, such as pile-driving, are typically significantly greater than operational phases (i.e. shipping, operation of a wind farm). Also includes the mining instruments at the bottom of the ocean, for the mining operations, and risers that transport broken aggregates through the water column to the surface.	
Other physical pressures	Introduction of light	O4	Direct inputs of light from anthropogenic activities, i.e. lighting on structures during construction or operation to allow 24 hour working; new tourist facilities, e.g. promenade or pier lighting, lighting on oil & gas facilities etc. Ecological effects may be the diversion of bird species from migration routes if they are disorientated by or attracted to the lights. It is also possible that continuous lighting may lead to increased algal growth. It includes the lights of the mining machines at the deep-sea mining area, as also the permanent vessel on the surface for long-term-station field. (Some deep-sea species associated with	X

Pressure theme	Pressures	Code	Pressure Descriptor	MSFD Annex III Table 2
			(e.g. Bresiliid shrimp) are sensitive to very low amounts of light.)	
Biological pressures	Introduction or spread of non-indigenous species	B3	The direct or indirect introduction of non-indigenous species, e.g. chinese mitten crabs, slipper limpets, Pacific oyster and their subsequent spreading and outcompeting of native species. Ballast water, hull fouling, stepping stone effects (e.g. offshore wind farms) may facilitate the spread of such species. This pressure could be associated with aquaculture, mussel or shellfishery activities due to imported seed stock imported or from accidental releases. During exploration phase on deep-sea mining operations, instruments should be cleaned in between mining areas, in order to avoid non-indigenous species introduction. J.R. Voight, R.W. Lee, A.J. Reft, A.E. Bates Scientific gear as a vector for non-native species at deep-sea hydrothermal vents Conserv. Biol., 26 (2012), pp. 938–942.	Introduction of non-indigenous species and translocations

Table 4. Impacts associated with SMS mining activity.

Impact	Related ICG-C Pressure	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
Removal of crusts	D1 Habitat structure changes - removal of substratum (extraction) P1 Transition elements & organo-metal (e.g. TBT) contamination. L2. Physical change (to another seabed type) D4. Siltation rate changes, including smothering (depth of vertical sediment overburden).	Long term. Probably hundreds to thousands of years.		Destruction of habitat of attached epifauna	Likely to be very slow (tens to hundreds of years).	1.Biodiversity is maintained 6. Sea floor integrity ensures the functioning of the ecosystem
Sediment laden plumes near seabed containing particle load	D4 Siltation rate changes, including smothering (depth of vertical sediment overburden) P1 Transition elements & organo-metal (e.g. TBT) contamination. D3. Changes in suspended solids (water clarity) D4. Siltation rate changes, including smothering (depth of vertical sediment overburden).	During mining activity	Spread will depend on mining process and local currents. Could be tens of kilometres beyond licensed area boundaries. Plumes are likely to flow down the seamount flanks	Smothering of seabed animals	Likely to be very slow (tens to hundreds of years) if epifaunal organisms are impacted on bare rock surfaces	1.Biodiversity is maintained 4. Elements of foodwebs ensure long-term abundance and reproductive capacity 5. Eutrophication is minimised 6. Sea floor integrity ensures the structure and functions of ecosystems are safeguarded 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem 8. Concentrations of contaminants have no pollution effects

Impact	Related ICG-C Pressure	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
						9. Contaminants in seafood do not exceed agreed standards
Sediment laden plumes in water column	H1 Temperature changes P6 Nutrient enrichment D3 Changes in suspended solids (water clarity) P6 Nutrient enrichment D3. Changes in suspended solids (water clarity)	During mining activity	Spread will depend on local currents, grain size of material and volume of material released plus length of time of release. Potential areas affected could be very large – thousands of square kilometres	If plumes are released in the photic zone (c200 metres) they will cause a reduction in light penetration and in temperature. These are likely to reduce plankton growth with knock-on impacts to whole food chain. Sediment load likely to affect feeding of gelatinous zooplankton. High nutrient load from deep waters introduced into oligotrophic waters may stimulate primary production and of different species than those normally occurring in the area.	Recovery will be rapid once activity ceases	1.Biodiversity is maintained 4. Elements of foodwebs ensure long-term abundance and reproductive capacity 6. Sea floor integrity ensures the structure and functions of ecosystems are safeguarded 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem 8. Concentrations of contaminants have no pollution effects 9. Contaminants in seafood do not exceed agreed standards

Impact	Related ICG-C Pressure	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
Size and ecosystem function fractionated impact on life	D4. Siltation rate changes, including smothering (depth of vertical sediment overburden)	Shifts in sediment grain size distribution. May also include changes in fine scale (biologically relevant) bathymetry.	Depending on position relative to mining and/or sediment plume impacts, sediments may change in their grain size towards sandier or finer composition. Shifts at crust sites likely larger than nodule mining sites	This changes the habitat in terms of the sizes of life that will either be benefited or be impacted negatively	These effects may be long lasting as background sedimentation rates are low.	1. Biodiversity is maintained 4. Elements of foodwebs ensure long-term abundance and reproductive capacity
Noise and light pollution	O3 Underwater noise changes O4. Introduction of light	During mining activity	The sound characteristics of deep-sea mining have yet to be established. It is likely to be similar to shallow water dredging in terms of frequencies emitted (generally low frequency, but with some high frequency components). The amplitude is unknown. The Area impacted is generally a product of frequency and amplitude, so cannot be determined at present.	Probable masking effects on marine mammals that use the main frequencies emitted.	Impacts on species are not known. While short-term masking can occur for individuals within the area affected, the long-term consequences and effects at the population level from masking are unknown.	11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Table 5. Impacts associated with cobalt-crust mining.

Impact	Related ICG–C Pressure	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
Removal of crusts	D1 Habitat structure changes - removal of substratum (extraction) P1 Transition elements & organo-metal (e.g. TBT) contamination. L2. Physical change (to another seabed type) D4. Siltation rate changes, including smothering (depth of vertical sediment overburden).	Long term. Probably hundreds to thousands of years		Destruction of habitat of attached epifauna	Likely to be very slow (tens to hundreds of years).	1.Biodiversity is maintained 6. Sea floor integrity ensures the functioning of the ecosystem
Sediment laden plumes near seabed containing particle load	D4 Siltation rate changes, including smothering (depth of vertical sediment overburden) P1 Transition elements & organo-metal (e.g. TBT) contamination. D3. Changes in suspended solids (water clarity) D4. Siltation rate changes, including smothering (depth of vertical sediment overburden).	During mining activity	Spread will depend on mining process and local currents. Could be tens of kilometres beyond licensed area boundaries. Plumes are likely to flow down the seamount flanks	Smothering of seabed animals	Likely to be very slow (tens to hundreds of years) if epifaunal organisms are impacted on bare rock surfaces	1.Biodiversity is maintained 4. Elements of foodwebs ensure long-term abundance and reproductive capacity 5. Eutrophication is minimised 6. Sea floor integrity ensures the structure and functions of ecosystems are safeguarded 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem 8. Concentrations of contaminants have no pollution effects

Impact	Related ICG-C Pressure	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
						9. Contaminants in seafood do not exceed agreed standards
Sediment laden plumes in water column	H1 Temperature changes P6 Nutrient enrichment D3 Changes in suspended solids (water clarity) P6 Nutrient enrichment D3. Changes in suspended solids (water clarity).	During mining activity	Spread will depend on local currents, grain size of material and volume of material released plus length of time of release. Potential areas affected could be very large – thousands of square kilometres	If plumes are released in the photic zone (c200 metres) they will cause a reduction in light penetration and in temperature. These are likely to reduce plankton growth with knock-on impacts to whole food chain. Sediment load likely to affect feeding of gelatinous zooplankton. High nutrient load from deep waters introduced into oligotrophic waters may stimulate primary production and of different species than those normally occurring in the area.	Recovery will be rapid once activity ceases	1.Biodiversity is maintained 4. Elements of foodwebs ensure long-term abundance and reproductive capacity 6. Sea floor integrity ensures the structure and functions of ecosystems are safeguarded 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem 8. Concentrations of contaminants have no pollution effects 9. Contaminants in seafood do not exceed agreed standards
Size and ecosystem function fractionated impact on life	D4. Siltation rate changes, including smothering (depth of vertical sediment overburden).	Shifts in sediment grain size distribution. May also include changes in fine scale (biologically relevant) bathymetry	Depending on position relative to mining and/or sediment plume impacts, sediments may change in their grain size towards sandier or finer composition. Shifts at crust sites	This changes the habitat in terms of the sizes of life that will either be benefited or be impacted negatively	These effects may be long lasting as background sedimentation rates are low.	Biodiversity is maintained 4. Elements of foodwebs ensure long-term abundance and reproductive capacity

Impact	Related ICG-C Pressure	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
			likely larger than nodule mining sites			
Noise and light pollution	O3 Underwater noise changes O4. Introduction of light	During mining activity	The sound characteristics of deep-sea mining have yet to be established. It is likely to be similar to shallow water dredging in terms of frequencies emitted (generally low frequency, but with some high frequency components). The amplitude is unknown. The Area impacted is generally a product of frequency and amplitude, so cannot be determined at present.	Probable masking effects on marine mammals that use the main frequencies emitted.	Impacts on species are not known. While short-term masking can occur for individuals within the area affected, the long-term consequences and effects at the population level from masking are unknown.	11.Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Annex 8: Ecosystem functioning; Fish species that have been observed in coral and sponge habitats and elasmobranch species occurring in cold-water coral macrohabitats

Table 6. Fish species that have been observed in coral and sponge habitats and are discussed in Buhl-Mortensen *et al*. (2010). Source literature is indicated with numbers and corresponding references are listed below. Taken from Buhl-Mortensen *et al*. (2010).

FISH TAXA	*LOPHELIA*				GORG.	PARAGORGIA		PRIMNOA		MIXED CORALS	ALCYON.	DEMOSP.	PUBLICATIONS
	UN SPEC.	LIVE	DEAD	RUBBLE	UNSP.	ROV	TRAWL	ROV	TRAWL	SINKHOLES & BIOHERMS		OUTSIDE	
Agnatha													
Eptatretus Lopheliae	x												4
Myxine glutinosa	x												2
Holocephali													
Chimaeriformes													
Rhinochimaera atlantica	x												5
Chimaera monstrosa	x												7, 3
Hydrolagus affinis	x												5
Hydrolagus colliei												x	21
Elasmobranchii													
Carchariniformes													
Carcharhinus falciformis										x			2
Galeus arae										x			2
Scyliorhinidae	x												3
Scyliorhinus stellaris	x												3
Triakidae	x												2
Squaliformes													

Fish taxa	*Lophelia*				Gorg.	Paragorgia		Primnoa		Mixed corals	Alcyon.	Demosp.	Publications
	Un spec.	Live	Dead	Rubble	unsp.	ROV	Trawl	ROV	Trawl	sinkholes & bioherms		outside	
Squalidae	x												5
Squalus acanthias												x	6
Shark?	x												3
Rajiformes													
Skates										x			1
Rajidae												x	6
Raja sp.	x												2
Neopterygii													
Albuliformes													
Notacanthus sp.	x												3
Anguilliformes													
Gymnothorax cf. *funebris*										x			2
Synaphobranchidae?	x												2
Dysommina rugosa	x												4
Synaphobranchus kaupii	x												3
Conger oceanicus	x												4
Congridae										x			2
Osmeriformes													
Alepocephalus rostratus	x												5
Alepocephalus bairdii	x												5
Aulopiformes													
Chloropthalmus agassizi										x			2
Myctophiformes													

Fish taxa	*Lophelia*				Gorg.	Paragorgia		Primnoa		Mixed corals	Alcyon.	Demosp.	Publications
	Un spec.	Live	Dead	Rubble	unsp.	ROV	Trawl	ROV	Trawl	sinkholes & bioherms		outside	
Myctophidae	x												2
Gadiformes													
Caelorinchus labiatus	x												5
Coryphaenoides rupestris	x												5, 3
Albatrossia pectoralis										x			1
Nezumia sclerorhynchus	x									x			4
Nezumia spp.	x									x			2
Trachyrincus murrayi	x												5
Laemonema barbatulum	x									x			4
Laemonema melanurum	x									x			4
Lepidion eques	x												5
Phycis blennoides	x												9
Phycis/Urophycis	x												3
Urophycis sp.										x			2
Gadidae											x	x	8, 6
Gadus morhua	x	x											7, 9,3
Melanogrammus aeglefinus	x												9, 3
Gadus macrocephalus										x			1
Pollachius virens	x	x	x	x									7, 10, 9,14, 3
Trisopterus luscus	x												3
Trisopterus minutus	x												3
Brosme brosme	x	x	x										7, 10, 9, 11,3
Molva molva	x												7, 10, 9, 11, 3

Fish taxa	*Lophelia*				Gorg.	Paragorgia		Primnoa		Mixed corals	Alcyon.	Demosp.	Publications
	Un spec.	Live	Dead	Rubble	unsp.	ROV	Trawl	ROV	Trawl	sinkholes & bioherms		outside	
Ophidiiformes													
Ophidiid/bythitid					x								19
Ophidiidae										x			2
Spectrunculus grandis	x												5
Lophiformes													
Lophius piscatorius	x												3
Lophius sp.	x												2
Beryciformes													
Gephyroberyx darwinii										x			2
Hoplostethus atlanticus	x												5
Hoplostethus mediterraneus										x			2
Hoplostethus sp.										x			2
Beryx decadactylus	x									x			4
Ostichthys trachypoma										x			2
Zeiformes													
Neocyttus helgae	x									x			20, 3
Scorpaeniformes													
Scorpaenidae	x									x			2
Sebastolobus alascanus										x		x	1, 6
Helicolenus dactylopterus	x									x			3,2,4
Sebastes aleutianus										x			1
Sebastes alutus										x			1
Sebastes borealis										x			1

Fish taxa	*Lophelia*				Gorg.	Paragorgia		Primnoa		Mixed corals	Alcyon.	Demosp.	Publications
	Un spec.	Live	Dead	Rubble	unsp.	ROV	Trawl	ROV	Trawl	sinkholes & bioherms		outside	
Sebastes ciliatus										x			1
Sebastes polyspinis										x			1
Sebastes zacentrus										x			1
Sebastes spp.	x	x	x	x	x	x		x		x		x	13,15, 7, 8, 11, 12, 9, 16, 17, 3, 18, 1, 6
Ophiodon elongatus												x	6
Pleurogrammus monopterygius					x					x			8, 7, 10, 14
Icelus bicornis	x												3
Micrenophrys lilljeborgi	x												3
Sculpins										x			1
Agonidae												x	6
Cottunculus thomsoni	x												5
Perciformes													
Polyprion americanus	x												19, 2
Anthias nicholsi										x			2
Anthias woodsi	x												4
Epinephelus drummondhayi										x			2
Epinephelus flavolimbatus										x			2
Epinephelus nigritus										x			2
Epinephelus niveatus										x			2
Hemanthias sp.										x			2
Hemanthias vivanus										x			2
Plectranthias garrupellus										x			2

Fish taxa	*Lophelia*				Gorg.	Paragorgia		Primnoa		Mixed corals	Alcyon.	Demosp.	Publications
	Un spec.	Live	Dead	Rubble	unsp.	ROV	Trawl	ROV	Trawl	sinkholes & bioherms		outside	
Pronotogrammus martinicensis										x			2
Cookeolus japonicus										x			2
Caulolatilus microps										x			2
Seriola dumerili										x			2
Pagrus pagrus										x			2
Pareques iwamoti										x			2
Anarhichas minor	x												9
Anarichas lupus	x												12
Zaprora silenus										x			1
Xiphias gladius										x			2
Antigonia capros										x			2
Pleuronectiformes													
Flatfish											x		8
Hippoglossus hippoglossus	x												9, 3
Microstomus kitt	x												3
Pleuronectidae												x	6
Unidentified													
Unidentified teleost	x	x									x		7

1) Stone 2006; 2) Reed *et al.*, 2006; 3) Costello *et al.*, 2005; 4) Ross and Quattrini, 2007; 5) Hall-Spencer *et al.*, 2002; 6) Cook *et al.*, 2008; 7) Mortensen *et al.*, 1995; 8) Heifetz, 2000; 9) Husebø *et al.*, 2002; 10) Furevik *et al.*, 1999; 11) Fosså *et al.*, 2002; 12) Freiwald *et al.*, 2002; 13) O'Connell *et al.*, 1994; 14) Fosså *et al.*, 2005; 15) Krieger, 1993; 16) Krieger and Wing, 2002; 17) Freese and Winge, 2003; 18) Mortensen *et al.*, 2005: 19) Messing *et al.*, 1990; 20) Auster *et al.*, 2005; 21) Conway *et al.*, 2005.

Table 7. Taxonomic checklist of elasmobranch species occurring in cold-water coral macrohabitats (including framework, individual colonies, coral rubble >200 m water depth, exclusive of records <200 m or from areas without corals such as off-reef habitats) and the nature of the association (Co=co-occurrence; Tr=possible trophic links; Juv=nursery grounds for juveniles; Egg=nursery grounds for eggs). Taxonomy and synonymies were validated using the World Register of Marine Species (Appeltans *et al.*, 2011). *Elasmobranch species identity was tentative.

Species	Region	Main coral species	Association	Citations
Selachii				
Apristurus brunneus	eastern North Pacific	*Euplexaura marki*	Egg	Flammang *et al.*, 2011
?*Apristurus* sp.	Northeast Atlantic	*Paranthipathes* sp.	Egg	Roberts *et al.*, in prep., JC073 cruise
Apristurus sp.	Northeast Atlantic	mixed corals	Co	Durán Muñoz *et al.*, 2011
Bythaelurus canescens	Southeast Pacific	*Antipathes speciosa*	Egg	Concha *et al.*, 2010
Carcharhinus altimus	Southeast USA	*Lophelia pertusa*	Co	Ross and Quattrini, 2007
Carcharhinus falciformis	Southeast USA	*Lophelia pertusa*	Co	Reed *et al.*, 2006
Centrophorus squamosus	Northeast Atlantic	mixed Scleractinia	Co	Hall-Spencer *et al.*, 2002; Durán Muñoz *et al.*, 2011
Centrophorus sp.	Northeast Atlantic	*Lophelia pertusa*	Co	Söffker *et al.*, 2011
Centroselachus crepidater	Northeast Atlantic	mixed corals	Co	Durán Muñoz *et al.*, 2011
Centroscyllium fabricii	Northeast Atlantic	mixed corals	Co	Durán Muñoz *et al.*, 2011
Centroscymnus coelolepis	Northeast Atlantic	mixed Scleractinia and other corals	Co	Hall-Spencer *et al.*, 2002; Durán Muñoz *et al.*, 2011
Cirrhigaleus asper	Southeast USA, Gulf of Mexico	*Lophelia pertusa*	Co; Tr	Ross and Quattrini, 2007; Sulak *et al.*, 2007
Dalatias licha	Central Mediterranean	*Lophelia pertusa*	Co	D'Onghia *et al.*, 2010
Deania calcea	Northeast Atlantic	*Lophelia pertusa* and mixed corals	Co	Durán Muñoz *et al.*, 2011; Söffker *et al.*, 2011
Etmopterus spinax	Central Mediterranean	*Lophelia pertusa*	Co; Juv	Tursi *et al.*, 2004; D'Onghia *et al.*, 2010
Etmopterus virens	Gulf of Mexico	*Lophelia pertusa*	Co	Sulak *et al.*, 2007
Etmopterus sp.	Southeast USA, Northeast Atlantic	*Lophelia pertusa* and mixed corals	Co	Reed *et al.*, 2006; Durán Muñoz *et al.*, 2011
Galeus arae	Southeast USA, Gulf of Mexico	*Lophelia pertusa*	Co	Reed *et al.*, 2006; Sulak *et al.*, 2007
Galeus melastomus	Northeast Atlantic, Central Mediterranean	*Lophelia pertusa* and mixed corals	Co; Egg	Tursi *et al.*, 2004; Heger *et al.*, 2007; Roberts *et al.*, 2008; Durán Muñoz *et al.*, 2009; D'Onghia *et al.*, 2010; Durán Muñoz *et al.*, 2011; Henry *et al.*, 2013

SPECIES	REGION	MAIN CORAL SPECIES	ASSOCIATION	CITATIONS
SELACHII				
Galeus murinus	Northeast Atlantic	*Lophelia pertusa*	Co	Heger *et al*., 2007
Galeus sp.	Northeast Atlantic	mixed corals	Co	Durán Muñoz *et al*., 2011
Mustelus sp.	Southeast USA	*Lophelia pertusa*	Co	Reed *et al*., 2006
Odontaspis ferox	Southeast USA, Gulf of Mexico	*Lophelia pertusa*	Co; Tr	Ross and Quattrini, 2007; Sulak *et al*., 2007
Odontaspis noronhai	Straits of Florida	*Lophelia pertusa*	Co	Messing *et al*., 1990
Oxynotus centrina	Northeast Atlantic	*Lophelia pertusa*	Co	Gage and Roberts, 2003
Parmaturus xaniurus	eastern North Pacific	*Antipathes* sp.	Egg	Flammang *et al*., 2011
Pseudotriakis microdon	Northeast Atlantic	mixed corals	Co	Durán Muñoz *et al*., 2011
Scyliorhinus hesperius	Southeast USA	*Lophelia pertusa*	Co	Ross and Quattrini, 2007
Scyliorhinus meadi	Southeast USA	*Lophelia pertusa*	Co	Ross and Quattrini, 2007
Scyliorhinus retifer	Southeast USA, Gulf of Mexico	*Lophelia pertusa*, *Callogorgia americana delta*	Co; Egg	Castro *et al*., 1988; Reed *et al*., 2006; Etnoyer and Warrenchuk, 2007*; Ross and Quattrini, 2007; Sulak *et al*., 2007
Scyliorhinus stellaris	Northeast Atlantic	*Lophelia pertusa*	Co	Costello *et al*., 2005
Scyliorhinus spp.	Southeaste USA	*Lophelia pertusa*	Co	Ross and Quattrini, 2007
Scyliorhinidae spp.	NortheastAtlantic	*Lophelia pertusa*	Co	Costello *et al*., 2005; Söffker *et al*., 2011
Squalus acanthias	Northeast Atlantic	*Lophelia pertusa*	Co	Gage and Roberts, 2003
Squalus cubensis	Southeast USA, Gulf of Mexico	*Lophelia pertusa*	Co; Tr	Reed *et al*., 2006; Ross and Quattrini, 2007; Sulak *et al*., 2007
Squalus spp.	Southeast USA, Gulf of Mexico	*Lophelia pertusa*	Co: Tr	Reed *et al*., 2006; Ross and Quattrini, 2007; Sulak *et al*., 2007
Squalidae	Southeast USA, Northeastern Atlantic	*Lophelia pertusa*	Co	Hall-Spencer *et al*., 2002; Reed *et al*. 2006: Söffker *et al*., 2011
Triakidae spp.	Southeast USA	*Lophelia pertusa*	Co	Reed *et al*., 2006
Batoidea				
Benthobatis marcida	Southeast USA	*Lophelia pertusa*	Co	Ross and Quattrini, 2007
Breviraja claramaculata	Southeast USA	*Lophelia pertusa*	Co	Ross and Quattrini, 2007

Species	Region	Main coral species	Association	Citations
Selachii				
Breviraja spinsosa	Gulf of Mexico	*Lophelia pertusa*	Co	Sulak *et al.*, 2007
Dactylobatus armatus	Southeast USA	*Lophelia pertusa*	Co	Ross and Quattrini, 2007
Dipturus oregoni	Gulf of Mexico	*Lophelia pertusa*	Co	Sulak *et al.*, 2007
Dipturus oxyrinchus	Central Mediterranean	*Lophelia pertusa*	Co	Tursi *et al.*, 2004
Dipturus sp.	Southeast USA	*Lophelia pertusa*	Co	Ross and Quattrini, 2007
Fenestraja plutonia	Southeast USA	*Lophelia pertusa*	Co; Egg	Ross and Quattrini, 2007; Quattrini *et al.*, 2009
Fenestraja sinusmexicanus	Gulf of Mexico	*Lophelia pertusa*	Co	Sulak *et al.*, 2007
Leucoraja circularis	Central Mediterranean	*Lophelia pertusa*	Co	D'Onghia *et al.*, 2010
Mobula hypostoma	Southeast USA	*Lophelia pertusa*	Co	Ross and Quattrini, 2007
Raja spp.	Norway, Southeast USA	*Lophelia pertusa*	Co; Egg	Costello *et al.*, 2005; Reed *et al.*, 2006
Rajidae undetermined	Southeast USA, Northeast Atlantic	*Lophelia pertusa*	Co	Ross and Quattrini, 2007; Söffker *et al.*, 2011
Rajiformes sp.	Northeast Atlantic	*Solenosmilia variabilis*	Egg	Henry *et al.*, 2014
Rajiformes spp.	eastern North Pacific	gorgonians, black corals	Co	Ebert and Davis, 2007
Torpedo nobiliana	Southeast USA	*Lophelia pertusa*	Co	Reed *et al.*, 2006

Annex 9: Draft Terms of Referebce for WKVME

The **Workshop on the Vulnerable Marine Systems Database** (WKVME), chaired by Neil Golding, England, will meet in Peterborough, UK, 27–28 August 2015 to:

a) Review the VME database with key data providers, focusing in particular on the VME indicator/VME habitat fields and finalise the database for use by WGDEC 2016;

b) Ingest the new data on VMEs resulting from the VME data call, undertake quality checks and finalise this new data for use by WGDEC 2016;

c) Undertake some development work on the ICES VME data portal (as outlined in Section 5 of the WGDEC report) in order to make the VME database visible online using a 0.05 degree grid.

The workshop will report by Friday 30 October 2015 for the attention of the ACOM.

Supporting Information

Priority	The VME database is a core product of WGDEC and underpins many of its recommendations with respect to standing requests from NEAFC and the EU for new information on VMEs. WGDEC 2015 identified some improvements that could be made to the VME database to improve its utility, especially in light of developments with a methodology to weight the significance and reliability of VME records. There is insufficient time during the WGDEC meetings to undertake work on this core product, so a dedicated workshop is proposed to address these improvements ahead of WGDEC 2016. With an ever increasing volume of data being incorporated into the VME database, and a dedicated VME data call being proposed in 2015, this work should be considered high priority.
Scientific justification	a) Within the VME database, many of the records have an entry both in the 'VME indicator' field and also the 'VME habitat type'. Clearer database guidance was agreed at WGDEC 2015 to address this, stating that only one of these fields should be completed Distinguishing bertween these two records is essential in order for the VME indicator weighting system (ToR (b) at WGDEC 2015) to work effectively. Further work is required to review the records in the VME database alongside representatives from the ICES member countries (who have submitted the data and are familiar with it) and finalise the database ahead of WGDEC 2016. b) A dedicated VME data call is proposed for 2015. The data call would invite ICES member countries to submit new data on occurrences of VME indicators or VME habitat types. The data call is planned to run from June 2015 through to early July 2015 (dates to be confirmed). The workshop will allow assimilation of the VME data provided under this data call into the VME database, completion of data quality checks and ensure the new dataset is finalised for WGDEC 2016. c) Further development of the ICES VME Data Portal was discussed and agreed at WGDEC 2015. The VME data portal is a tool to disseminate data on the distribution, abundance and quality of habitats and species considered to be indicators of VMEs across the North Atlantic. Part of the development work planned at this workshop will see all VME indicator data being gridded using a 0.05 degree grid (an identical grid to that used in ToR (b)), and presented via a map displayed on the web portal. This map will thus show the distribution of all VME indicator records being considered by WGDEC in a publically accessible form.

Resource requirements	JNCC has offered to host the workshop at its headquarters in Peterborough, UK.
Participants	There was broad support for holding this workshop by members of WGDEC 2015. Key participants will be members of WGDEC who have submitted a significant number of records to the VME database such as Francis Neat (MSS, UK), Pal Buhl Mortensen (Norway), Lenaick Menoit (France). Database support will also be required from the ICES DataCentre.
Secretariat facilities	Meeting room facilities at the JNCC (Peterborough) and support with finalising of the report.
Financial	No financial implications.
Linkages to advisory committees	ACOM
Linkages to other committees or groups	
Linkages to other organizations	There are potential linkages between the VME data call and other data calls undertaken by ICES member countries (for example, the OSPAR data call for information on threatened and declining habitats and species coordinated by the JNCC). Discussions between the ICES DataCentre and JNCC will ensure that duplication of effort is avoided.

Annex 10: Technical minutes from the Vulnerable Marine Ecosystems Review Group

- Review of ICES/NAFO Joint Working Group on Deep-water Ecology Report 2015
- 08 April 2015
- Reviewers: Antonina dos Santos (Chair) and Louise Allcock
- Chair WGDEC: Neil Golding

General

The topics dealt with clearly reflect the ToRs as laid out in the 2014 report.

For advice other than stock summary style fisheries advice

Section 1

Short description

Adoption of the agenda.

Comments

None.

Section 2

Short description

Provide all available new information on distribution of VMEs in the North Atlantic with a view to advising on any new closures to bottom fisheries or revision of existing closures to bottom fisheries (NEAFC standing request). In addition, provide new information on location of habitats sensitive to particular fishing activities (i.e. vulnerable marine ecosystems, VMEs) within EU waters (EC request).

Comments

I note that in Sections 2.2.1 and 2.3.1 specific statements on closure advice are provided. This is in contrast to other sections (although I note that the advice request is from NEAFC). I understand (from the JNCC website) that ICES recommended a closure to bottom fisheries in the Rosemary Seamount area in 2013 and, given that as far as I am aware fisheries management measures haven't yet been put in place for the MPA on Rosemary Seamount, it might be relevant to cite this prior closure advice or even reiterate it in Section 2.3.2. A statement that fisheries management measures are currently being determined by the Scottish authorities might be relevant to both Sections 2.3.2 and 2.3.3. The analysis of VMS data appears to be technically sound and an appropriate way to assess potential impacts of fishing activity. Does WGDEC wish to reiterate its 2013 advice as to proposed closures on Josephine Seamount?

In Section 2.6, reference is missing to the paper by Braga-Henriques *et al.*, 2013 cited in the text (Section 2.3.6). Regarding this work, it is stated in p. 14 that the records on VMEs mentioned were not provided to the WGDEC and that they are not on the VME database. Bearing in mind that the work was done based on a review of the literature on VME records and surveys made by IMAR-DOP/Aç it is difficult to understand why these data were not accessible for the WGDEC to use and examine, since literature records are always available to anyone working on the field and that researchers from IMAR-DOP/Aç actively work on the WGDEC.

Page 18, Figure 16: the histogram showing 2014 NEAFC VMS vessel speed data for static long line (LLS) is difficult to interpret and it is not showed in the text how the speed of less than 5 knots was considered as "fishing activity" when we know that there are a great amount of LLS in use according to the target species and the use in a specific country. Therefore, it would be very useful to know how this specific speed was calculated as fishing activity threshold.

Josephine Seamount (Section 2.5.4), VMS 2014 data: it is a fact that there is an evidence of longline fishery in the area but there is a need to better characterize this fishery, especially knowing that there are very different LLS in use. Then, it would be good to establish if the LLS used in the Josephine have an impact on the gorgonian corals and to establish if the data on VMEs are of reliable and of good quality.

Section 3

Short description

In order that advice on closures can be more clearly presented and interpreted, continue the development of a system of weighting the reliability and significance of VME indicator records and consider ways of combining the geographic locations of VMEs through development of a standardised method for recommending closed area boundaries.

Comments

There are some statements here that need to be backed up with either reasoning or citations, and I believe there are some technical flaws in the proposed methodology that need addressing. In Section 3.2 it is stated that "WGDEC considered that stony coral reefs should score higher [in terms of vulnerability to human impacts] than seapens". This is extended in Section 3.2.1.1, Table 1 where stony corals are given a 'vunerability score' (erroneously labeled 'value' in Table 1) of 5, whereas the vulnerability score of other organisms ranges from 1.36 to 5.00. Some rationale behind the various scores is required. Expert opinion is very valid, but in the present format there is no indication what that opinion is based on. There is certainly information on growth rates, reproduction, susceptibility to smothering etc that could be provided in evidence here.

However, my major concern is with the methodology which takes "the maximum VME index score…as the overall value for that cell". By this reasoning, a grid square could contain 100 records of sea pens, clearly indicating a vulnerable seapen field, and yet that grid cell would score at most (2.73*0.9)+(5*0.1) = 2.957, assuming that at least one of those records had yielded 30 kg or more of seapens. Given the weight and size of seapens, this probably depends upon a haul containing 100s of individuals depending on the species. And yet as clearly stated, the methodology would 'pick out stony corals at any abundance'.

Why does a vulnerable seapen field merit less concern than a single incidence of stony coral? The FAO advice lists seven types of VMEs: CWC reefs, coral gardens, sponge aggregations, seapens, tube dwelling anemones (which incidentally are not mentioned in Table 1), mud and sand emergent fauna (=xenophyophores and crinoids, also not mentioned in Table 1), bryozoan patches (also not mentioned in Table

1). Surely the purpose of biodiversity conservation is to conserve all types? But the methodology applied focuses very much on stony corals to the detriment of other vulnerable marine ecosystems. This is contrary to the importance placed on these other types of VMEs in later sections of the report (e.g. p. 52, both gorgonian-dominated coral communities and seapen beds are reported as essential fish habitat). It seems that there is the opportunity to model in GIS a more appropriate indicator score for a grid cell based on all records in that cell. This would take the focus away from stony corals and ensure all VMEs are identified, recognized and afforded adequate protection. It would further recognize where more than one VME might be present in a grid square (which is possible in areas of rapidly changing depth and/or slope inclination).

The methodology presented to achieve a reliable VME indicator in order to develop a standardised method for recommending closed area boundaries needs more reasoning and to be supported by literature and/or scientific knowledge. There are some statements that need explanation: i) Subsection 3.2 taxa are important and they are ranked and some of them are more important than others e.g. p. 24, "WGDEC considered that stony coral reefs should score higher than seapens." It would be important to explain the basis for this assumption, especially when, in Section 6 review, all VME taxa are considered important, e.g. in p. 49, it is highlighted the importance of seapens, that in the ranking are considered as less important. Finally, why to consider only some corals and sponges when the FAO list of VME has much more taxa?

All the assumptions leading to the VME index lack better explanation and scientific studies to support it. Therefore they seem to be using too much expert judgment. If this is true, why not to suggest more research studies to have a better knowledge on the VME habitats on deep-water ecosystems around European waters? There are important EU programmes running in Europe, e.g. for fisheries assessment, why not consider a programme to a better monitoring of VMEs in European deep waters? The implementation of such a programme would provide more information on the extension and dynamics of VME habitats, as well as on the biology of the taxa, which could contribute to produce a more accurate VME index.

Section 4

Short description

Maintenance and development of the ICES VME database.

Comments

None.

Section 5

Short description

In light of two deep-sea mining exploration licences that have been granted by the International Seabed Authority (ISA) along the mid-Atlantic Ridge, review the sensitivity of vulnerable deep-water habitats to these activities and make recommendations for their protection.

Comments

None.

Section 6

Short description

Review new evidence of ecosystem functioning of VME indicators in the North Atlantic arising from the CORALFISH project and recent scientific literature.

Comments

Section 6 in particular, presents a very good review on VMEs knowledge.

I would suggest replacing ‘ecosystem functioning’ with ‘ecosystem functioning and services’ in the heading of this section as there is considerable focus on the latter.

Note that the first paragraph of Section 6.3 would benefit from some referencing.

Generally in Section 6, the word ‘coral’ is often used in placed of ‘scleractinian coral’ and, given the prevalence of other types of coral in VMEs this is a little confusing in places.

Conclusions

None.