JOINT ICES/NAFO WORKING GROUP ON DEEP-WATER ECOLOGY (WGDEC)

VOLUME 6 | ISSUE 77

ICES SCIENTIFIC REPORTS

RAPPORTS SCIENTIFIQUES DU CIEM

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ISSN number: 2618-1371

ICES Scientific Reports

Volume 6 | Issue 77

JOINT ICES/NAFO WORKING GROUP ON DEEP-WATER ECOLOGY (WGDEC)

Recommended format for purpose of citation:

ICES. 2024. Joint ICES/NAFO Working Group on Deep-water Ecology (WGDEC).
ICES Scientific Reports. 6:77. 129 pp. https://doi.org/10.17895/ices.pub.27041425

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Contents

i Executive summary

The Working Group on Deep-water Ecology (WGDEC) deals with the biology and conservation of deep-sea habitats in the North Atlantic. Working Group experts collate new information on the distribution of Vulnerable Marine Ecosystems (VMEs) and fishing activities within ICES ecoregions (including the NEAFC Convention Area) and the NAFO Convention Area for use in ICES advisory processes. This information assists the development of new methods to improve the understanding of deep-sea ecosystems and informs the implementation of management tools to afford the protection of VMEs.

The working group met to review new information on the occurrence and distribution of VMEs, VME indicator taxa and VME elements that were submitted in response to the ICES VME data call in January 2024. This includes new data from the NEAFC Convention Area, as well as sub-areas of the Regulatory Area that are closed to fishing for other purposes than VME protection. WGDEC also reports on new information on the occurrence and distribution of VMEs within European Union (EU) waters, in relation to the EU Deep-Sea Access Regulation (Regulation (EU) 2016/2336), and in line with the EU request to ICES in 2023.

New data on VMEs is available from areas within Celtic Seas and Barents Sea ecoregions. A total of 1038 presence records and 32 absence (non-detection) records were accepted into the ICES VME database. In 2024, no new VME habitat records and a total of nine new sponge VME indicator records for the NEAFC Regulatory Area portion of the Barents Sea ecoregion (RA3) were submitted to ICES VME database. No VME records were reported from other NEAFC areas in 2024. New VMS data was analysed by the Working Group on Spatial Fisheries Data (WGSFD), and outputs were used by WGDEC to assess whether fishing activity occurred in the vicinity of VMEs in the NEAFC Convention Area. A total of 80 new VME occurrence records and 30 absences were reported within the 400-800 m depth zone of EU waters of the Celtic Sea ecoregion.

A further objective of the 2024 WGDEC meeting was to conduct a review of historical records to address data inconsistencies and spatial errors of holdings included in the ICES VME Database. Data inconsistencies require a robust quality control procedure and can be prevented by the continued and correct use of data call templates. The database was subjected to consistency checks and records that may warrant further investigation were flagged. The process of engaging with data submitters to check selected records is currently underway.

The Working Group was presented with an overview of the life history, connectivity and ecology of certain VME indicator taxa to identify research priorities and to progress a future incorporation of connectivity processes (biological, ecological and oceanographic) in the management of fishing activities and spatial planning in the Northeast Atlantic.

Finally, WGDEC formulated recommendations to begin the preparatory scope for dedicated workshops to address known limitations of the VME Index and the incorporation of species distribution models into the ICES VME advice framework; and to review the impact of different fishing gears on VMEs and their effects on deepwater ecosystems.

ii Expert group information

Expert group name	Working Group on Deep Water Ecology (WGDEC)
Expert group cycle	Annual
Year cycle started	2024
Reporting year in cycle	1/1
Chair(s)	Ana Colaço (Portugal)
	David Stirling (UK)
	Rui Vieira (UK)
Meeting venue(s) and dates	25 – 29 March, 2024, ICES HQ, Copenhagen, Denmark and Online

1 Introduction

1.1 Opening of the Meeting

The Working Group on Deep-water Ecology (WGDEC), chaired by Ana Colaço (PT); David Stirling (UK); Rui Vieira (UK), met at ICES HQ, Copenhagen and online via MS Teams.

WGDEC commenced in plenary at 10 am CET on Monday 25th of March 2024. Following introductions from participants and declaration of conflicts of interest, the leads for each Term of Reference (ToR) were appointed, and are outlined below:

ToR [a] lead: David Stirling

ToR [b] lead: David Stirling

ToR [c] lead: Natasha Murphy, co-Lead: David Stirling

ToR [d] lead: Lenaick Menot

ToR [e] lead: Anna Metaxas, co-Lead: Ana Colaço

ToR [f] lead: Javier Murillo, co-Lead: Christopher Pham

ToR [g] lead: Kerry Howell, co-Lead: Laura Grady

Following the review and adoption of the agenda, WGDEC began working through the Terms of Reference. A short presentation for each ToR was provided by the chair and ToR leads. The group then agreed how they would address the reporting of each ToR.

Plenary sessions were held throughout the meeting. During these plenary sessions, ToR leads updated the group with progress and issues were discussed. Participants could also comment on working documents via the WGDEC SharePoint site. The Working Group meeting was formally closed at 1 pm on Friday 29th of March 2024 by the Chairs.

2 Adoption of the Agenda

The **Joint ICES/NAFO Working Group on Deep-water Ecology** (WGDEC; 2020/OT/HAPISG02), met at ICES HQ, Copenhagen and online via MS Teams, 25-29 March 2024 to address Terms of References that enable ICES to respond to advice requests. The aim of the meeting was to collate information on vulnerable habitats across the North Atlantic and to formulate recommendations for future workshops aiming further developments regarding deep-sea ecosystems and its incorporation into the ICES VME advice framework. This included:

ToR [a] *Collate, validate and QA/QC-check new information on the occurrence and distribution of vulnerable marine ecosystems (VMEs), VME indicator taxa and VME elements in the North Atlantic and adjacent waters, archive appropriately using the ICES VME Database, and disseminate via the Working Group report and ICES VME Data Portal.*

ToR [b] *Review, validate and update new information on the occurrence and distribution of VMEs, VME indicator taxa and VME elements in the NEAFC Convention Area, including subareas of the Regulatory Area that are closed to fishing for other purposes than VME protection, and in EU waters in relation to the EU deep-sea access regulation.*

ToR [c] Conduct *a review of historical records included in ICES VME Database.*

ToR [d] *Begin a preparatory framework for a future workshop on the occurrence of VMEs, in consideration of known limitations of the VME Index and the weighting algorithm method for identifying areas where VME are likely to occur in the Northeast Atlantic region.*

ToR [e] *Review and update advances in knowledge of the life history, connectivity and ecology of VME indicator taxa in the Northeast Atlantic and identify research priorities.*

ToR [f] *Conduct a literature review of the impact of different bottom-contact static gears on VMEs and understand the ecosystem effects of different static gears and begin a preparatory framework for a future workshop aiming to review and assess the impact of different gear types on VMEs across the ICES area.*

ToR [g] Recommend *next steps for a future incorporation of species distribution models into the ICES VME advice framework.*

3 ToR A: New information on the occurrence and distribution of vulnerable marine ecosystems (VMEs), VME indicator taxa and VME elements in the North Atlantic and adjacent waters

3.1 Vulnerable Marine Ecosystem (VME) terminology used by WGDEC

The inclusion of data on Vulnerable Marine Ecosystems (VMEs) in the ICES VME database has required some informal definitions to be created by WGDEC to enable users to include data on VME elements, habitats and indicators, based on different collection methods. WGDEC considers information relating to VMEs in offshore deep-water (> 200 m) areas in three ways:

1. 'VME habitat' records are generally those from visual survey data (e.g. remotely operated vehicle (ROV) or towed/drop camera seabed imagery) that demonstrates the presence and location of a VME with a high degree of confidence and spatial accuracy. VME habitats = VME (ICES, 2016). The list of VME habitats to be considered by WGDEC was reviewed and revised in 2020 (ICES, 2020).

2. 'VME indicator' refers to records of VME indicator species from data sources for which there is a degree of uncertainty that a VME is, or was, present. Typical examples are trawl-survey or static longline bycatch records (ICES, 2016). Representative taxa of VME habitats, which are recognised as VME indicators, were reviewed and revised by WGDEC in 2020 and 2021 (ICES, 2020; ICES 2021).

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

3.2 Background

The ICES VME data call in January 2024 requested ICES member states to submit data to the ICES VME database, with a particular focus on the NEAFC regulatory area. All data submitted to the database since the previous WGDEC meeting in May 2023 (ICES, 2023) is considered new data for WGDEC meeting in 2024.

The database stores records of VME habitats, VME indicators and the locations of where neither of these have been observed (absence data), as described by the database schema. The records in the ICES VME database can therefore be split into two broad categories:

- Presence records are samples where a VME habitat and/or a VME indicator have been identified.
- Absence records are samples where neither a VME habitat, nor a VME indicator, have been identified.

Presence records can include mixed (mosaic) habitats, where more than one habitat type and/or sub-type occur together in the same location (for example, two sub-types of coral garden or a cold-water coral reef and coral garden). They can also include species lists from data analyses that, combined, form a community which comprise a VME habitat. The mosaic habitats and species lists are input to the database as separate records but are linked together by a 'VME Key' indicating that they occur in the same patch of habitat. Therefore, some VME locations will be represented in the database by multiple records with the same coordinates. These records provide information on the species, communities, and habitat (sub) that make up that VME.

1038 new VME indicator presence records and 32 absence records have been submitted to the ICES VME database since May 2023. Of the newly submitted records, 9 are within the NEAFC Regulatory Area and the remaining 1029 presence and 32 absence records are within the Exclusive Economic Zones of North Atlantic ICES member states. No records were submitted from the NAFO Regulatory Area in response to this call.

Data has been submitted for 2 ICES ecoregions (Celtic Seas and Barents Sea) by data providers from three ICES member countries (Ireland, Norway and the UK) in response to the first VME data call of 2024.

3.3 WGDEC VME Data Quality Assurance sub-group

Following recommendation by WDGEC in 2020 (ICES, 2020), submissions to the VME data call were subjected to quality assurance / quality control (QA/QC) checks prior to the WGDEC 2024 meeting. The current VME data flow for ICES can be seen in Annex 3.

3.4 Data providers for ToR [a]

New records of VME indicators and habitats were submitted to the ICES VME database for the following countries operating in the ICES area (Table 3.1).

Table 3.1 Data submission status for countries operating in the ICES area to whom the 2024 ICES data call on VME data was sent.

Country	Data submission	Country	Data submission
Belgium	×	Lithuania	×
Denmark	×	The Netherlands	×
Faroe Islands	×	Norway	✓
France	×	Portugal	×
Germany	×	Russia	×
Greenland	×	Spain	×
Iceland	×	Sweden	×
Ireland	✓	United Kingdom	✓ (Scotland)
Finland	×	Latvia	×
Estonia	×	Poland	×
Canada	×	United States	×

✓: Suitable data submission ×: Unsuitable data submission ×: No data submitted

3.4.1 Ireland (Marine Institute)

The Marine Institute of Ireland undertook multiple research surveys to gather data on VMEs in Irish waters (Table 3.2): the Groundfish Survey (IGFS2023), Nephrops Underwater TV (UWTV) Survey (TC23012), the Anglerfish and Megrim Survey (IAMS2023) and the Porcupine fishing survey (PORC2023).

The Groundfish Survey on the RV Celtic Explorer (November 2, 2023 - December 14, 2023) used standard IBTC GOV nets, covering depths of 15 to 300 m. Similarly, the Anglerfish and Megrim Survey on the same vessel (February 11 - April 23, 2023) covered depths of 150 m to 1000 m using a Jackson deep water trawl. The UWTV survey (June 2, 2022- June 7, 2022) was carried out on the RV Tom Crean, using a sled- mounted camera. It focused on the Porcupine Bank area, with depths ranging from 350 m to 582 m. Additional deep water (up to 1,500m) sampling during IAMS has been in place since 2019 to monitor the recovery of exploited deep-water species. In 2019, this included deep-water stations in the porcupine bank. This is recorded as the PORC 2023 survey and was conducted during the IAMS survey between May 30 2023- August 29 2023 in the Porcupine Bank area at depths up to 1,500m.

Table 3.2 VME indicator records and absence data submitted by the Marine Institute from four research cruises (IGFS2023, TC23012, IAMS2023, PORC2023).

VME indicator	N
Anemones	1
Chemosynthetic species (seeps and vents)	2
Cup coral	3
Sea-pen	102
Sponge	15
Stony coral	9
Records without VME indicators (absence)	32
Total	**164**

3.4.2 Norway (Institute of Marine Research)

The Institute of Marine Research (IMR) reported sponge VME indicators from trawl samples collected on Norwegian vessels covering the Norwegian section of the Norwegian-Russian joint ecosystem survey in the Barents Sea (BESS) during August-October 2022 and 2023, (432 and 443 records at 134 and143 stations, respectively) (Table 3.3).

The BESS is a comprehensive ecosystem survey monitoring the status of abiotic and biotic factors annually to trace changes in the Barent Sea ecosystem for the purposes of providing scientific advice and research knowledge (van der Meeren & Prozorkevich (eds), 2023).

Two research vessels participated in the 2022 survey, *G.O. Sars* (GS) & *Johan Hjort* (JH) compared to three vessels during previous years. The cruise tracks for G.O. Sars were extended and adapted, covering as many of the planned stations of the third research vessel as possible to compensate for loss in coverage. The spatial coverage for 2022 was therefore impacted due to the reduced number of stations sampled, resulting in sparse coverage around Svalbard (van der Meeren & Prozorkevich (eds), 2023).

Spatial and temporal coverage for BESS 2023 with research vessels GS, JH and *Kronprins Haakon* (KPH), were similar to previous standard years and executed almost as planned in the 35 x 35 nautical mile regular grid (Prozorkevich & van der Meeren (eds), 2024). Sponge VME indicator taxa for 2022 and 2023 were collected with the standard Norwegian Campelen -1800 trawl used for sampling benthic biota on BESS, towed for an average of 15 minutes per station at depths ranging from 48 to 526 meters.

Table 3.3 VME indicator records submitted by the Institute of Marine Research, Norway in 2024

Year	VME indicator	N
2022	Sponge	432
2023	Sponge	443
	Total	**875**

3.4.3 United Kingdom (Scottish Government)

The Scottish Government's Marine Directorate (MD) undertook one research survey that yielded information on VMEs (Table 3.4). The biennial deepwater survey (1323S, 3 – 23 October 2023) surveyed the waters of the western deepwater continental slope (55° - 59°N). New VME indicators arose from between depths of 1020 and 2032 m. All data were checked for accuracy, completeness and consistency during acquisition and curation.

Table 3.4 VME indicator records submitted by the Marine Directorate research survey 1323S.

VME indicator	N
Black coral	2
Cup coral	4
Gorgonian	5
Sea-pen	15
Sponge	5
Total	**31**

3.5 Overview of current data holdings in the ICES VME database

In summary, there were 1038 presence records and 32 absence (non-detection) records accepted by the VME Data QA sub-group for inclusion into the ICES VME database following the January 2024 VME Data Call. There were 2 VME indicators removed in response to the work of ToR c (see Section 4 below and Annex 3).

This brings the total number of records in the ICES VME database to 74,447. Of which, 58,877 are VME indicator records, 9,902 are VME habitat records and 5,668 are absence records.

3.6 References

ICES. 2013a. Report of the ICES\NAFO Joint Working Group on Deep-water Ecology (WGDEC), 11–15 March 2013, Floedevigen, Norway. ICES CM 2013/ACOM:28. 95 pp.

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

ICES. 2020. ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC), ICES Scientific Reports, 2:62 171 pp. http://doi.org/10.17895/ices.pub.6095

ICES. 2021. Working Group on Deep-water Ecology (WGDEC). ICES Scientific Reports. 3:89. 162 pp. http://doi.org/10.17895/ices.pub.8289

ICES. 2022. ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC). ICES Scientific Reports. 4:75. 68 pp. http://doi.org/10.17895/ices.pub.21196066

Protozorkevich, D. and van der Meeren, G.I. (eds). 2024. Survey report (Part 1) from the joint Norwegian/Russian Ecosystem Survey in the Barents Sea and the adjacent waters August-October 2023. IMR/PINRO Joint Report Series, 2024-2, 88pp. https://www.hi.no/hi/nettrapporter/imr-pinro-en-2023-10

van der Meeren, G.I. and Prozorkevich, D. (eds). 2023. Survey report from the joint Norwegian/Russian Ecosystem Survey in the Barents Sea and the adjacent waters August- December 2022. IMR/PINRO Joint Report Series, 2023-10, 97pp. https://www.hi.no/hi/nettrapporter/imr-pinro-en-2023-10

4 ToR B: New information on VMEs and fishing activities within ICES ecoregions (including the NEAFC Convention Area) and the NAFO Convention Area

This chapter is organized by ICES ecoregion. New data on VMEs arose from areas within two ICES ecoregions:

- Barents Sea ecoregion
  - Norwegian EEZ
  - NEAFC regulatory area (RA3)
- Celtic Seas ecoregion
  - Scottish continental shelf margin
  - Irish continental shelf margin (north)
  - Porcupine Bank
  - Irish continental shelf margin (south)

This chapter addresses the Term of Reference b:

- *Review, validate and update new information on the occurrence and distribution of VMEs, VME indicator taxa and VME elements in the NEAFC Convention Area, including subareas of the Regulatory Area that are closed to fishing for other purposes than VME protection, and in EU waters in relation to the EU deep-sea access regulation.*

For each area, maps are shown of the new VME indicator and/or habitat records, the outputs of the VME likelihood index based on the VME weighting algorithm. Details of the method for the VME weighting algorithm are reported in Morato *et al*. (2018). It should be noted that the absence records described in Section 3 are not included in the VME weighting algorithm or in the maps presented below. It should also be noted that the VME "confidence" index developed by WGDEC, and previously used by ICES, is no longer considered a good proxy for evaluating the reliability of the VME data used in the calculation of the VME Index. Three recent ICES workshops (WKREG, WKEUVME, WKVMEBM) have expressed concerns over the validity of the weighting terms applied to derive the confidence index and is, therefore, not reported here.

4.1 Barents Sea ecoregion

The Barents Sea is one of the shelf seas surrounding the Polar basin. It connects with the deeper Norwegian Sea to the west, the Arctic Ocean to the north, and the Kara Sea to the east, and borders the Norwegian and Russian coasts to the south. The Barents Sea ecoregion consists of a portion of the ICES Area that is beyond national jurisdiction (ABNJ), i.e., outside the 200-mile limit of the exclusive economic zones (EEZs) of the EU Member States, the UK, Faroe Islands, Iceland, and Greenland (ICES, 2019).

4.1.1 Norwegian EEZ

Eight hundred and sixty six new sponge VME indicator data for the Norwegian EEZ portion of the Barents Sea ecoregion were submitted by IMR (Norway) (Figure 4.1). Updated outputs of the weighting algorithm with these new VME data are shown in Figure 4.2.

4.1.2 NEAFC regulatory area (RA3)

Nine new sponge VME indicator data for the NEAFC regulatory area portion of the Barents Sea ecoregion were submitted by IMR (Norway) (Figure 4.1). Updated outputs of the weighting algorithm with these new VME data are shown in Figure 4.2.

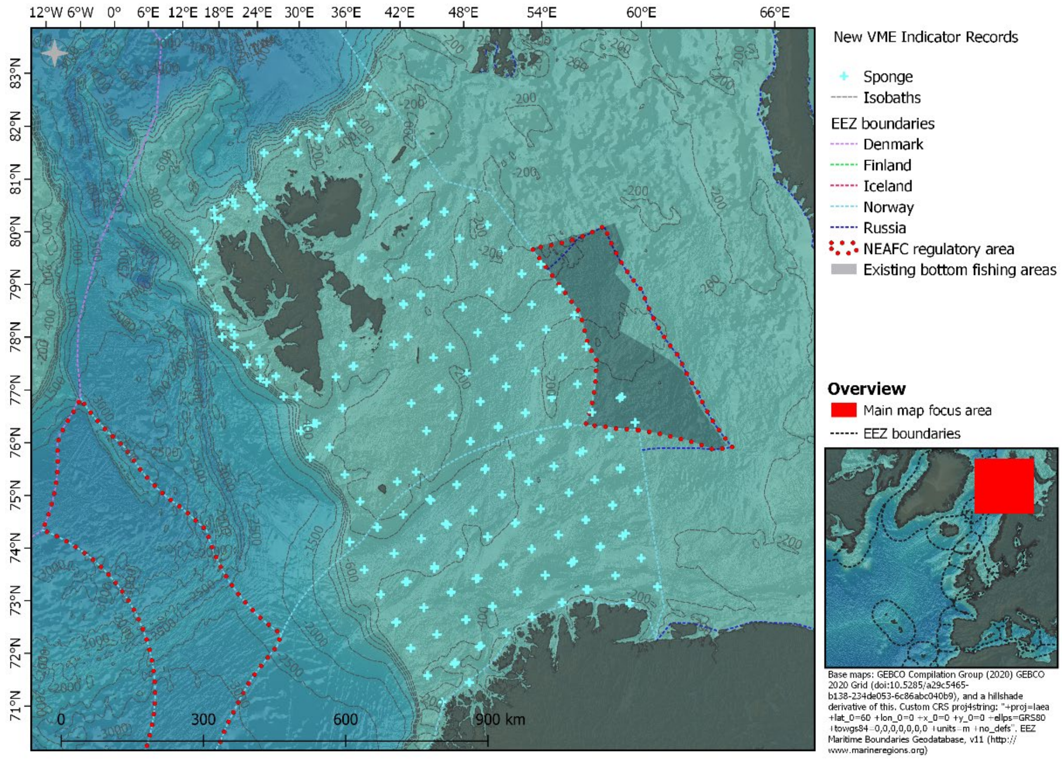

Figure 4.1. New sponge VME indicator records submitted in 2024 in the Barents Sea ecoregion (Norwegian EEZ and NEAFC regulatory area).

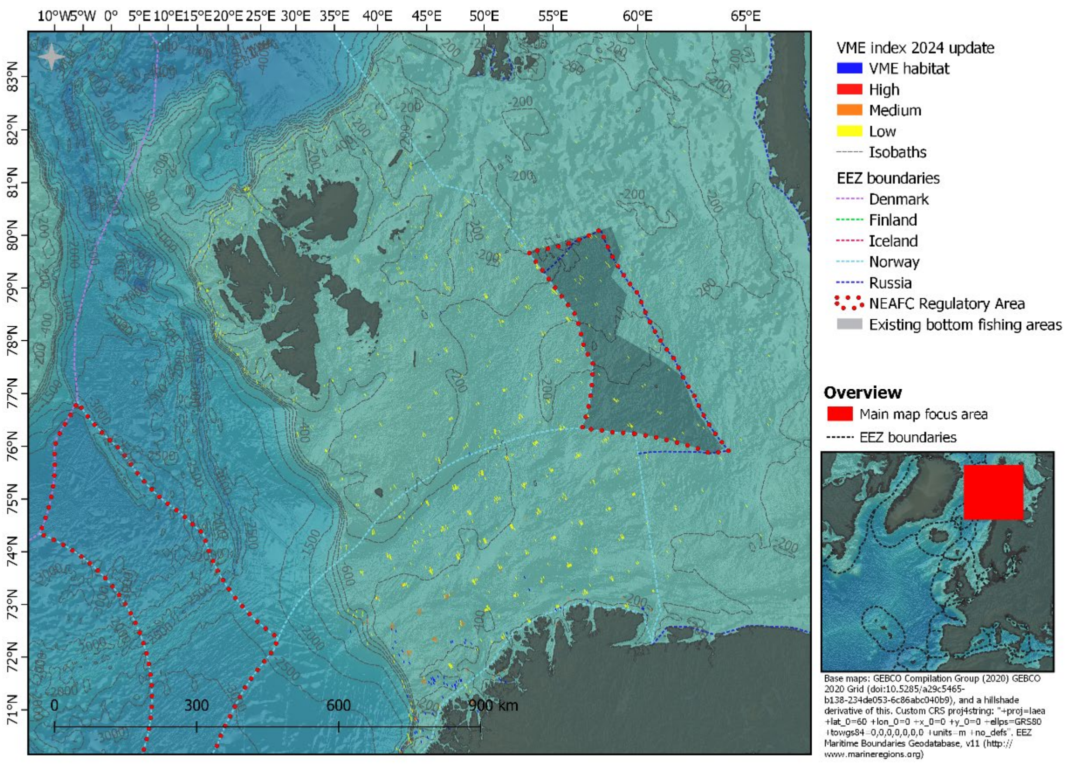

Figure 4.2. Output of the VME weighting algorithm for Barents Sea ecoregion (Norwegian EEZ and NEAFC regulatory area) showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high). Note, this includes all (not only 2023) records from the ICES VME database.

4.2 Celtic Seas ecoregion

The Celtic Seas ecoregion covers the north-western European continental shelf and seas, from western Brittany in the south to north of Shetland. The oceanography and climate of the region is strongly influenced by conditions in the adjacent Atlantic Ocean, particularly along the continental shelf edge where water exchange occurs between the ocean and shallow shelf seas (< 200 m depth) (ICES, 2021).

4.2.1 Scottish continental shelf margin

New VME indicator records were reported in this region (Figure 4.3) from the Scottish deepwater survey (1323S) and the Marine Institute's (Ireland), Megrim and Anglerfish (IAMS2023) and international groundfish (IGFS2023) surveys. Updated outputs of the weighting algorithm with these new VME data are shown in Figure 4.4.

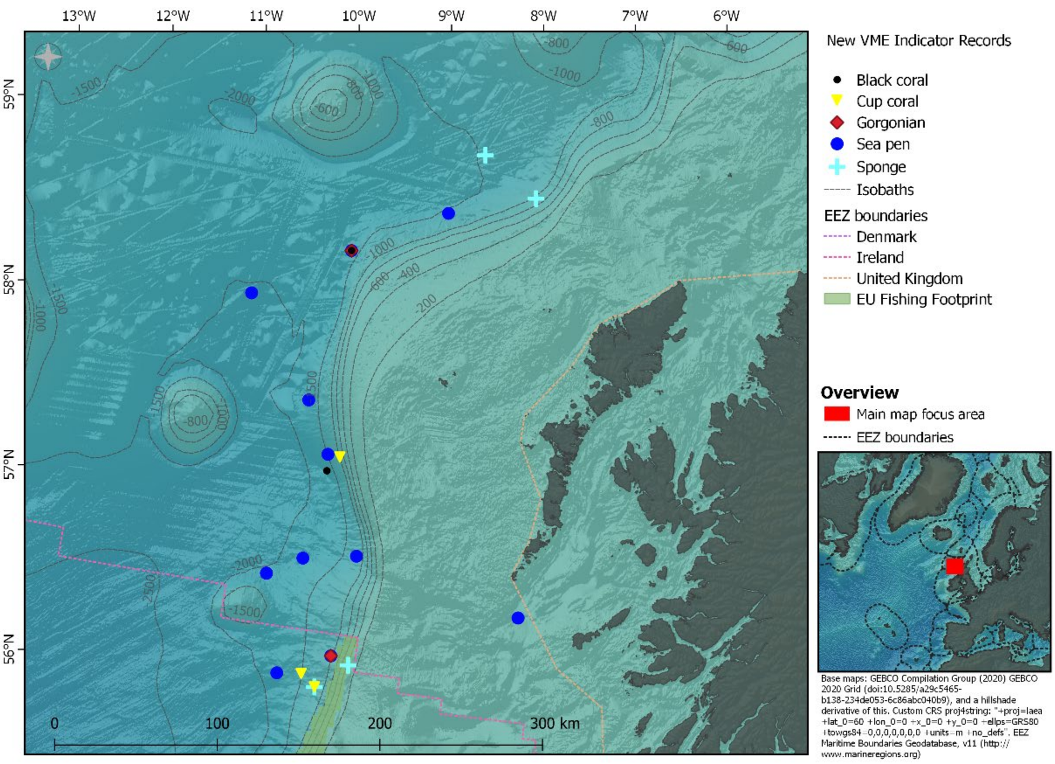

Figure 4.3. New VME indicator records submitted in 2024 for the Scottish continental shelf margin within the Celtic Seas ecoregion.

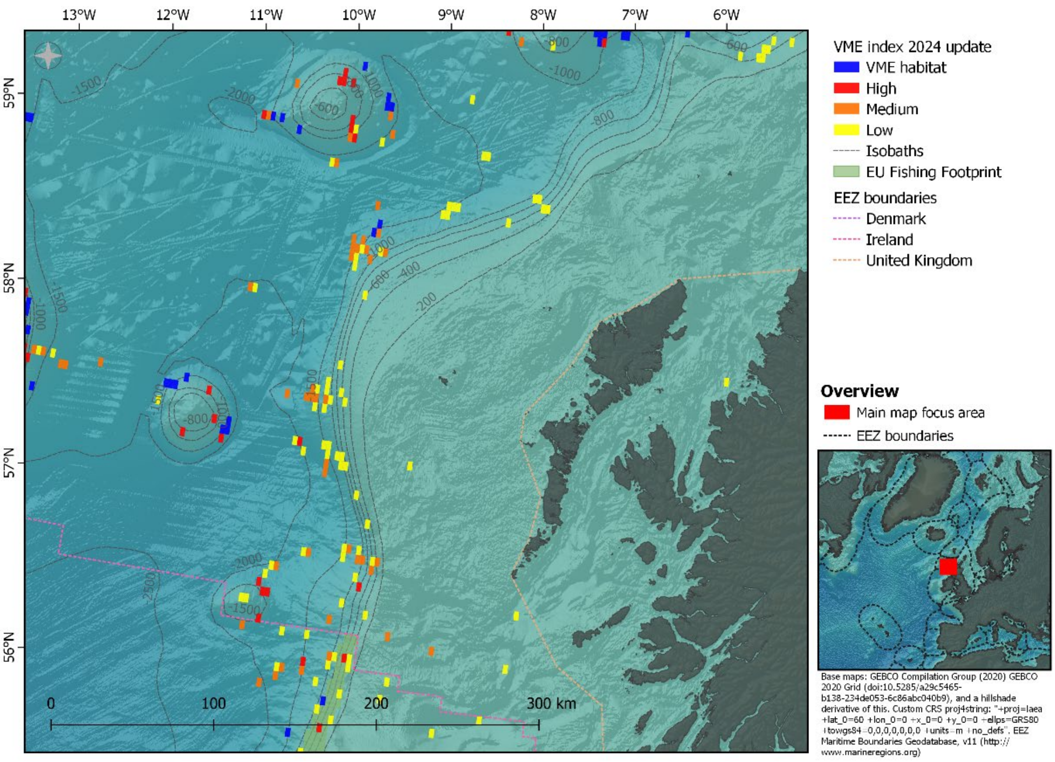

Figure 4.4. Output of the VME weighting algorithm for the Scottish continental shelf margin showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high). Note, this includes all (not only 2023) records from the ICES VME database.

4.2.2 Irish continental shelf margin (north)

New VME indicator records in this region (Figure 4.5) were submitted by the Marine Institute (Ireland) (surveys: IAMS2023, IGFS2023 and PORC2023)and the Marine Directorate (UK) (survey 1323S). Updated outputs of the weighting algorithm with these new VME data are shown in Figure 4.6.

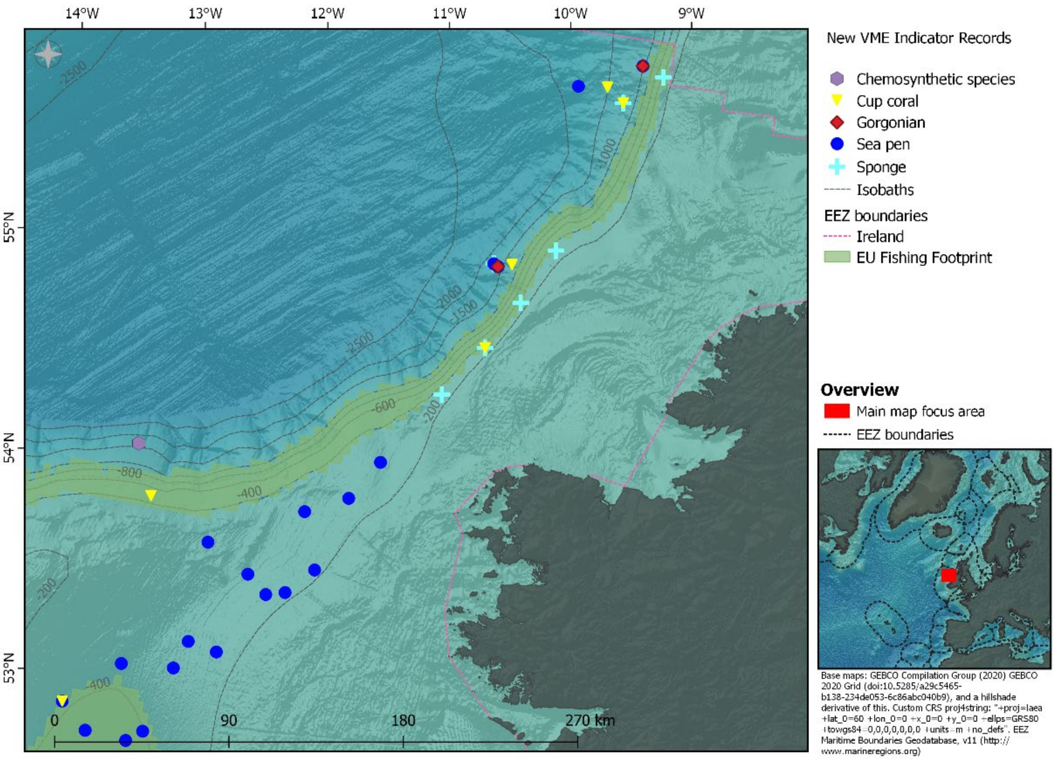

Figure 4.5. New VME indicator records submitted in 2024 for the Irish continental shelf margin (north) within the Celtic Seas ecoregion.

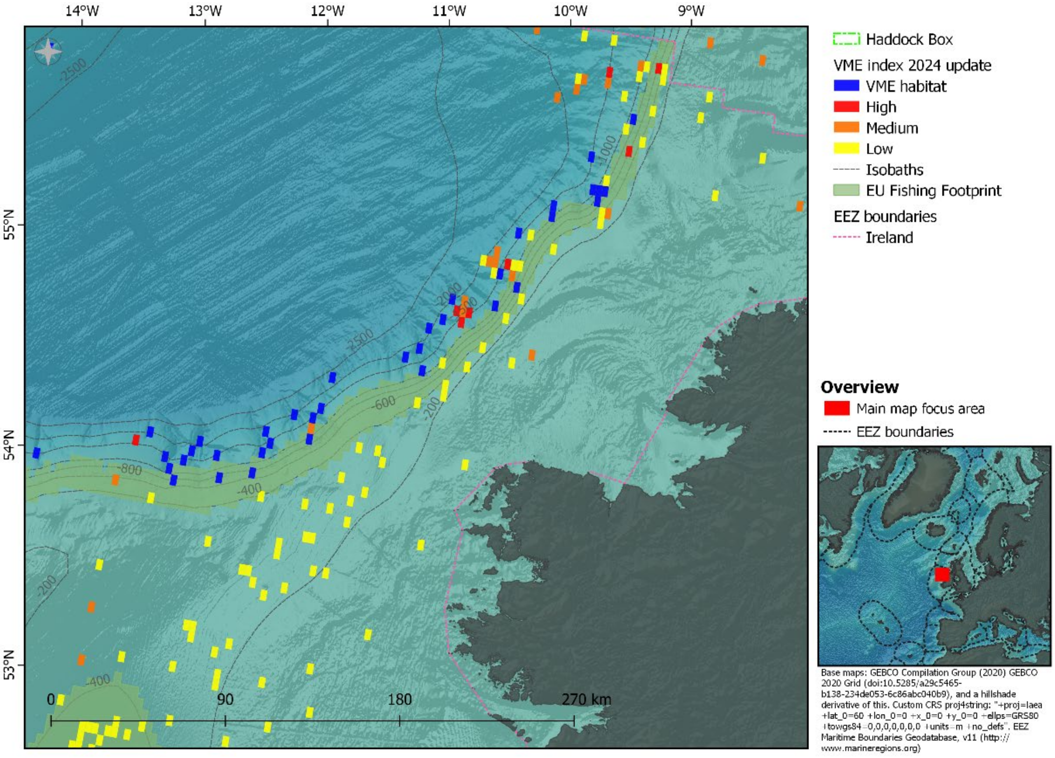

Figure 4.6. Output of the VME weighting algorithm for the Irish continental shelf margin (north) showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high). Note, this includes all (not only 2023) records from the ICES VME database.

4.2.3 Porcupine Bank

VME indicator records were submitted for Porcupine Bank area (Figure 4.7) by the Marine Institute (Ireland, surveys: IAMS2023, IGFS2023, PORC2023 and TC23012). Updated outputs of the weighting algorithm with these new VME data are shown in Figure 4.8.

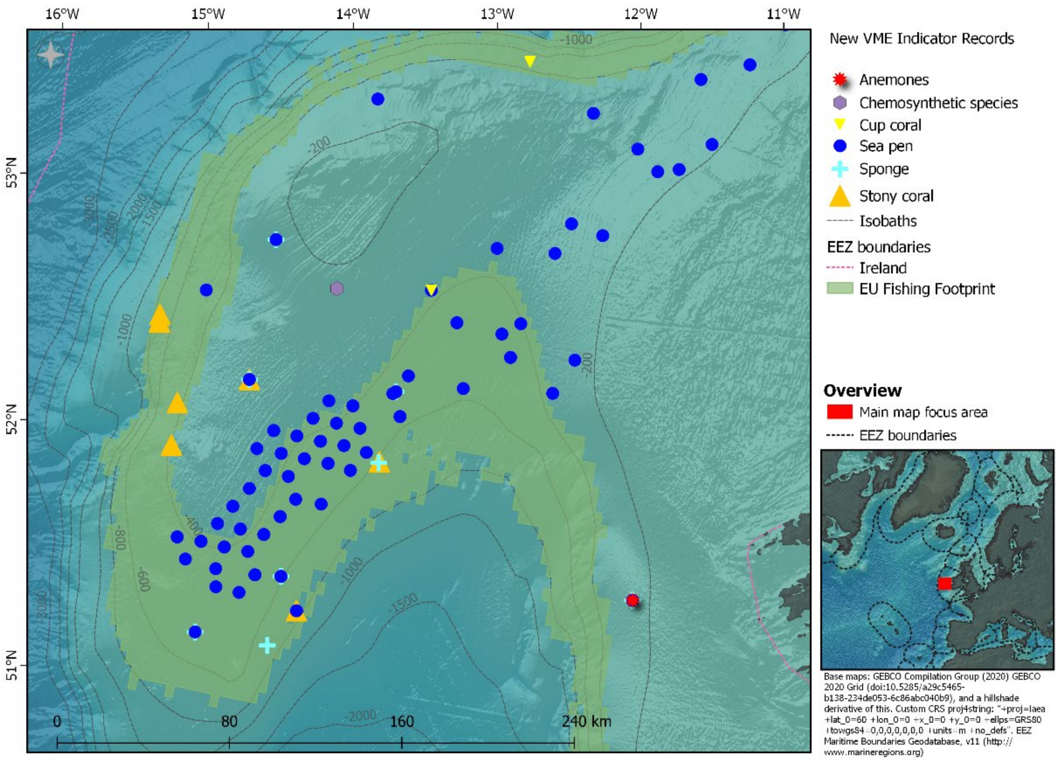

Figure 4.7. New VME indicator records submitted in 2024 for Porcupine Bank within the Celtic Seas ecoregion.

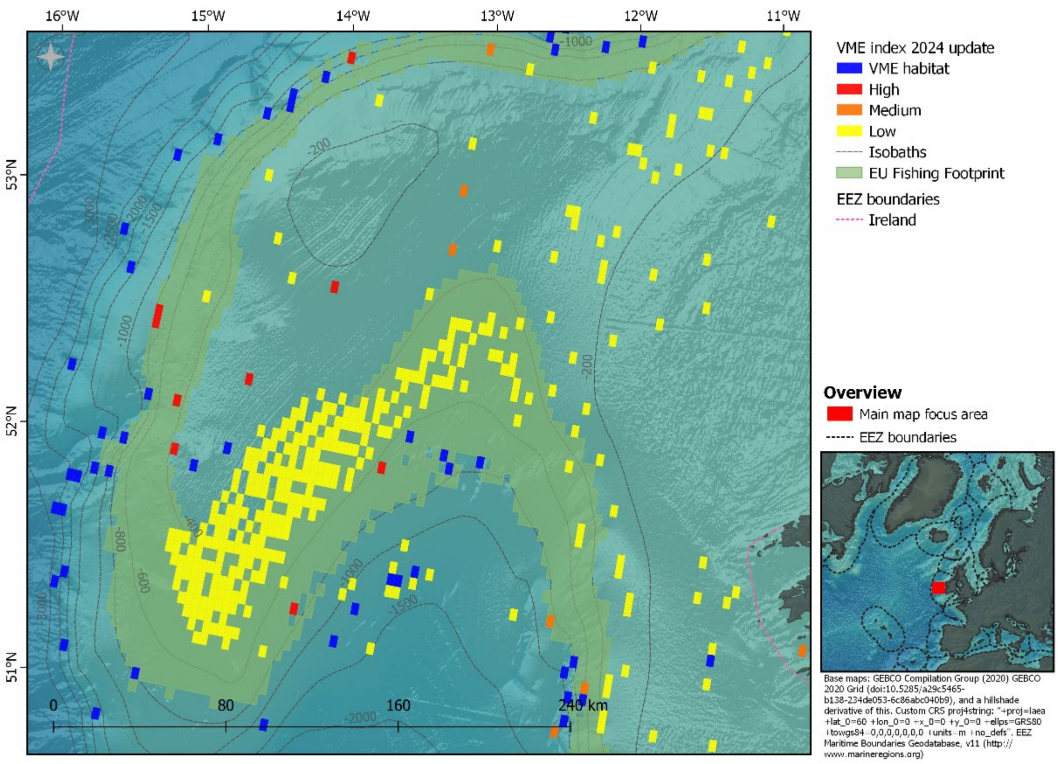

Figure 4.8. Output of the VME weighting algorithm for Porcupine Bank showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high). Note, this includes all (not only 2023) records from the ICES VME database.

4.2.4 Irish continental shelf margin (south)

VME indicator records were submitted for the southern Irish continental shelf margin (Figure 4.9) by the Marine Institute (Ireland, surveys: IAMS2023, IGFS2023). Updated outputs of the weighting algorithm with these new VME data are shown in Figure 4.10.

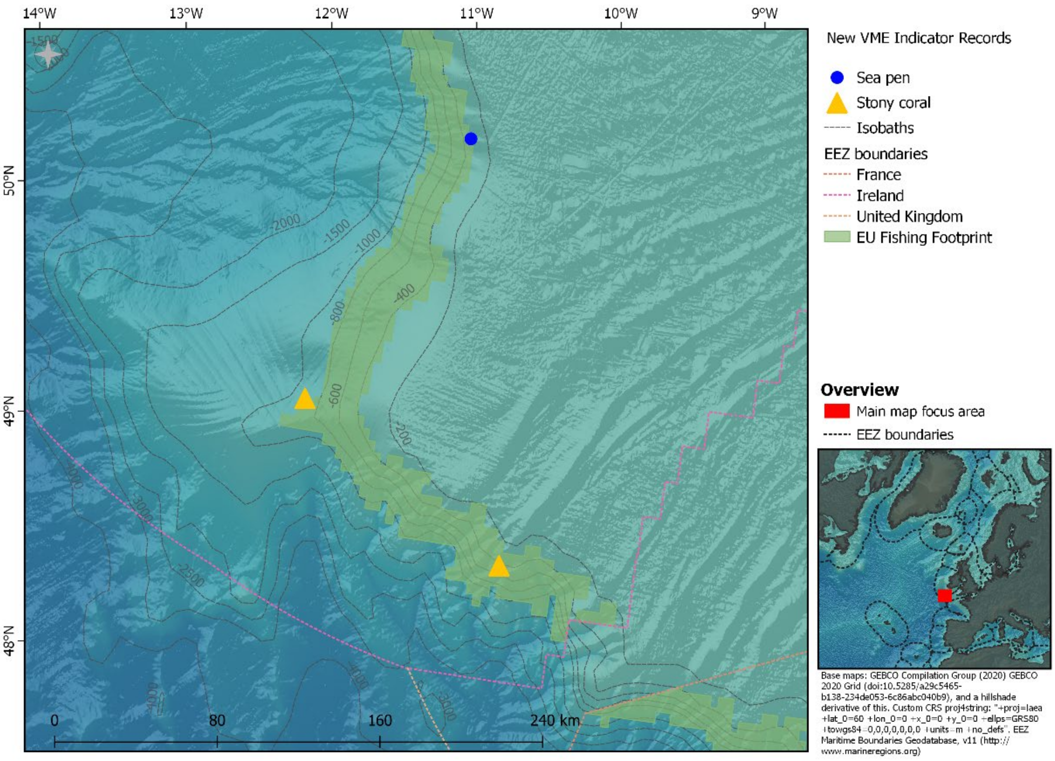

Figure 4.9. New VME indicator records submitted in 2024 for the Irish continental shelf margin (south) within the Celtic Seas ecoregion.

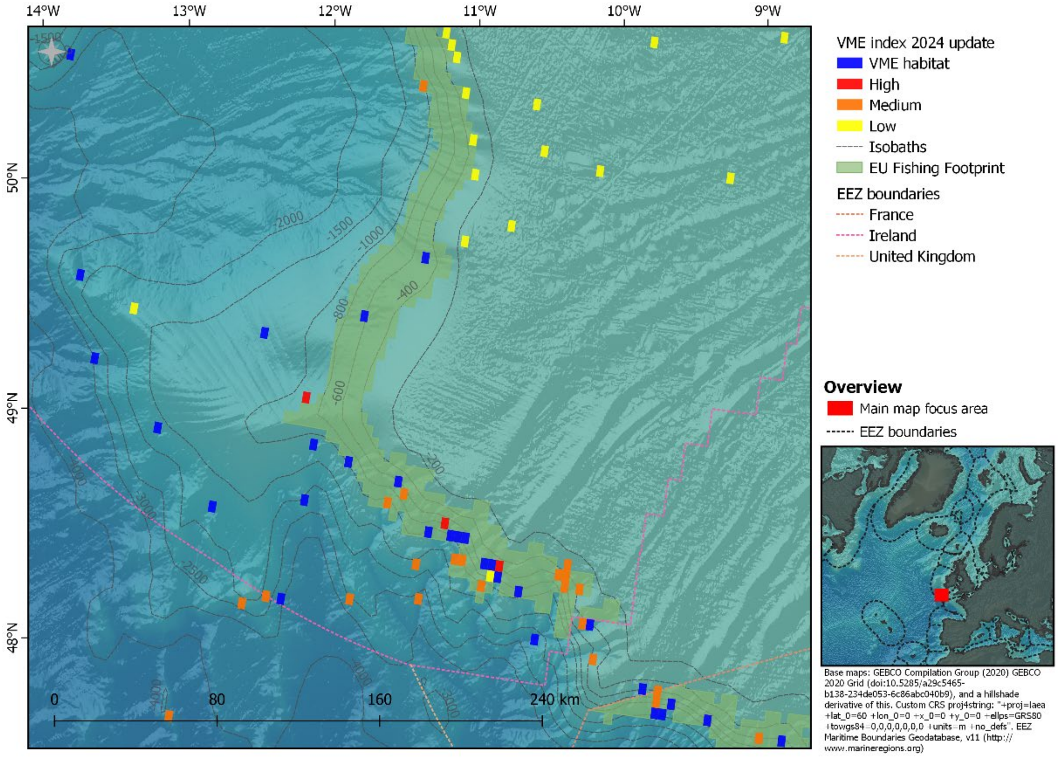

Figure 4.10. Output of the VME weighting algorithm for the Irish continental shelf margin (south) showing the VME Index; the likelihood of encountering a VME within each grid cell (ranging from low to high). Note, this includes all (not only 2023) records from the ICES VME database.

4.3 Summary of records in EU waters (in relation to the deep-sea access regulations)

There was a total of 80 new VME indicator presence records and 30 absence records reported within the 400 – 800 m depth zone of the EU portion (Irish EEZ) of the Celtic Seas ecoregion (Table 4.1). All records were reported by the Marine Institute (Ireland, survey numbers: IAMS2023, IGFS2023, PORC2023, TC23012).

Table 4.1 VME indicator records submitted in 2024 within the 400 – 800 m depth zone in EU waters

VME indicator	N
Cup coral	1
Sea-pen	66
Sponge	7
Stony coral	6
Records without VME indicators (absence)	30
Total	**110**

4.4 Analysis of the 2023 VMS submission from NEAFC, to provide information and maps on fisheries activities in the vicinity of vulnerable habitats (VMEs)

4.4.1 Methods

Vessel monitoring system (VMS) data were received from NEAFC, via the ICES Secretariat, along with catch information from logbooks, authorisation details, and vessel information from the NEAFC fleet registry. These data were analysed by the Working Group on Spatial Fisheries Data (WGSFD), in advance of the WGDEC meeting, to support the NEAFC request to ICES to provide information on the distribution of fisheries activities in and in the vicinity of VME habitats. The tables were linked using a unique identifier (the "RID" field) which changes on a yearly basis to protect anonymity of vessels. This year, ICES received information on the catch date and the catches were linked to vessels on the date of operation.

The VMS data were filtered in R to exclude all duplicate reports, polls outside the year 2023, and messages denoting entry and exit to the NEAFC regulatory area ("ENT" and "EXT" reports). The time interval (difference) between consecutive pings for each vessel was calculated and assigned to each position. Any interval values greater than four hours were truncated to this duration, as this is the minimum reporting frequency specified in the Article 11 of the NEAFC Scheme of Control and Enforcement. Such a scenario could occur when a vessel leaves the NEAFC Regulatory Area or has issues with its transmission system.

Quality of the speed data had improved in recent years, however 2023 was marked by a decline overall data quality, due to a reduction in the proportion of vessels which were associated with a specific gear type (Figure 4.11). Data was validated against a derived speed, calculated as the great-circle (orthodromic) distance between consecutive points reported by a vessel, divided by the time difference between them. Fishing effort is inferred from VMS data on the basis of speed, with pings at slower speeds deemed to represent fishing activity, and those at faster speeds to represent steaming and/or searching. In this instance, a speed of 5 knots or lower has been used to demarcate fishing from non-fishing pings for mobile bottom gears, 4 knots for vessels using static gears, and 6 knots for vessels with undefined gear types. Consecutive pings at fishing speeds for vessels using mobile-bottom contacting gears were grouped into putative "tows", manually reviewed to remove any erroneous sequences, and plotted, as a means to validate where fishing is taking place with the vessel tracks running parallel to bathymetric contours, as would be expected. A majority of the vessels still had no gear specified (53%), and in 2023 these were responsible for 40% of the fishing activity.

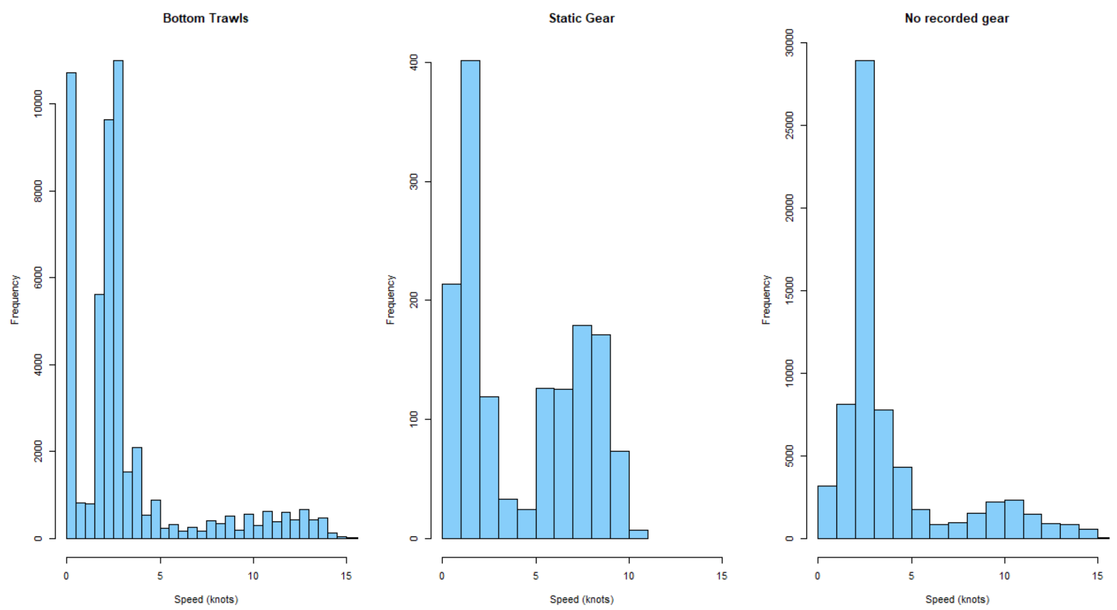

Figure 4.11 Histogram of derived speeds for all gears, based on position and time, conforms to expected distribution.

4.4.2 Results

The grided NEAFC fishing activity data, VME closures and existing fishing areas were mapped along with the VME Index outputs, which show the likelihood of VME presence based on the VME weighting algorithm, to assess whether the level of protection offered to areas of VME in the NEAFC Convention Area is sufficient. Results of this analysis are shown for Hatton Bank, Rockall Bank, southwest of Iceland, the Mid-Atlantic Seamount (Josephine Seamount) and the Barents Sea.

4.4.3 Hatton Bank

There was no activity recorded for vessels using bottom trawling or static bottom contact gears on Hatton Bank during 2023 and very limited activity for vessels that had no gear specified (Figure 4.13) in this area. Given the distribution of activity on Hatton Bank in relation to the VME index (Figure 4.14) the current VME areas appear adequate.

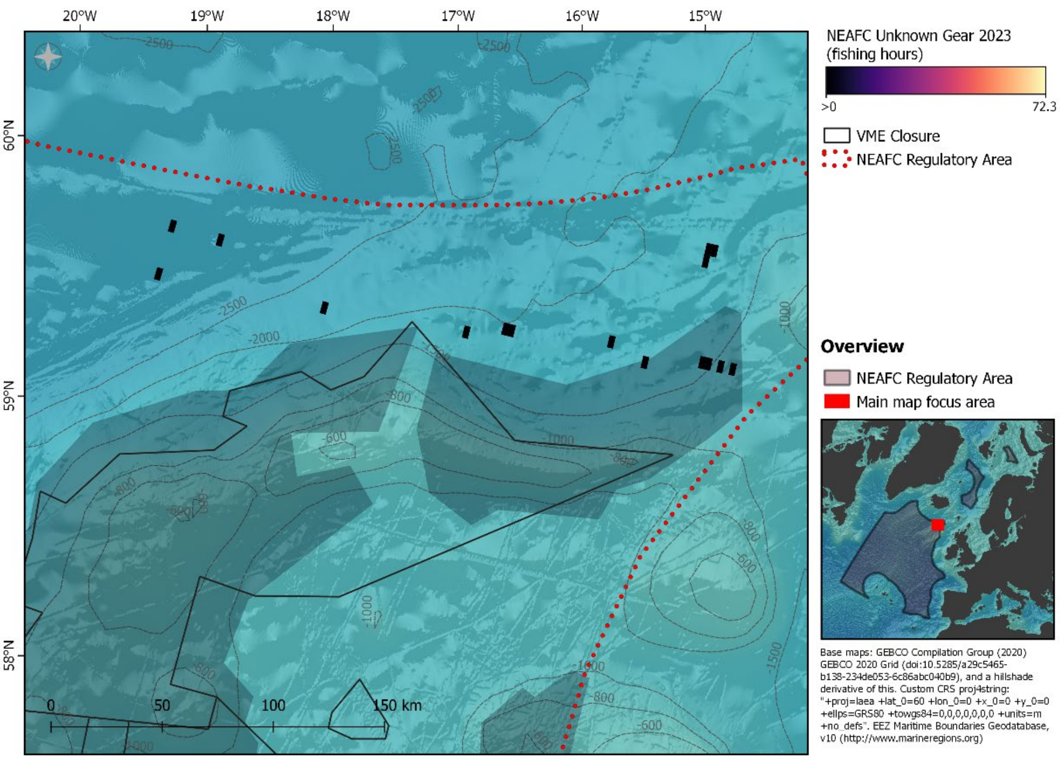

Figure 4.12. Gridded data (fishing hours) for vessels with no specified gear type on Hatton Bank (north), overlain with VME closures, existing NEAFC fishing areas and EEZ boundaries.

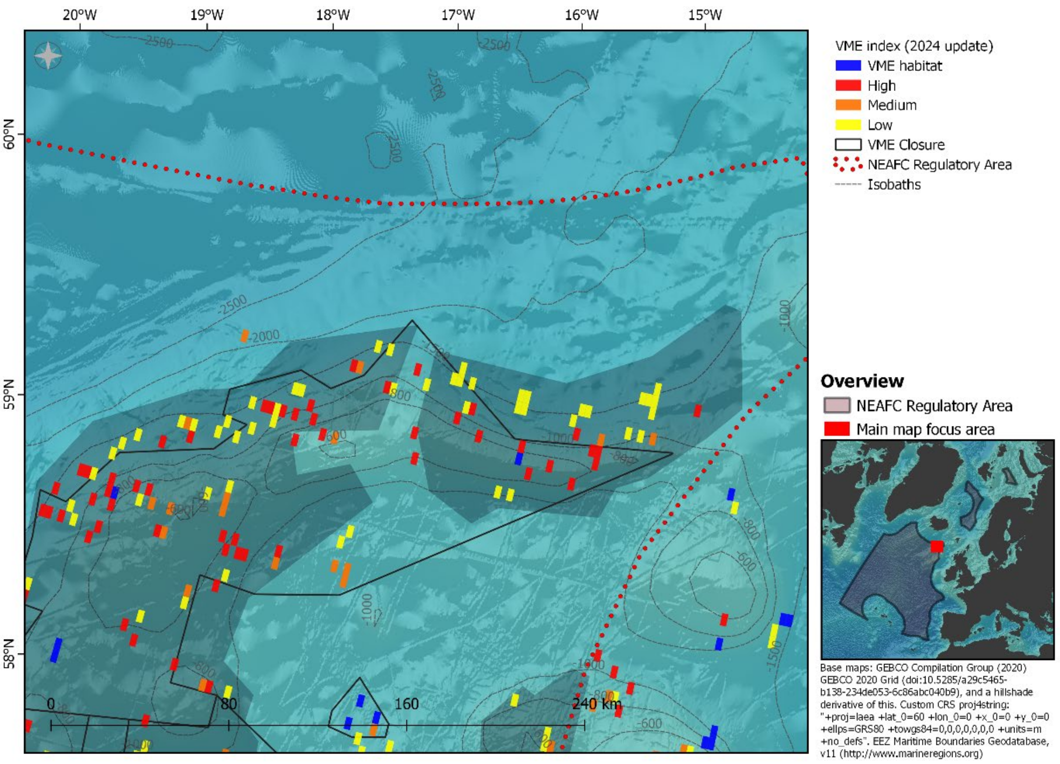

Figure 4.43. The VME Index, VME closures, existing NEAFC fishing areas and EEZ boundaries for Hatton Bank (north).

4.4.4 Rockall Bank

No fishing activity on Rockall Bank was reported for bottom trawls during 2023. Fishing activity was reported for static gears (Figure 4.14) and from vessels that didn't specify a gear type (Figure 4.15). The highest intensity of static gear activity occurs in the area to the west and within the northwest section of the Haddock Box. With the highest intensity of unreported gears being along the 400 m contour to the west of the Haddock Box. Some low level activity is observed for unreported gear types within the Haddock Box. All VME boundaries are respected except for low levels of activity within the Empress of Britain Bank and Northwest Rockall Bank closures, but this is likely an artifact arising from data processing. The VME index for Rockall Bank is given in Figure 4.16.

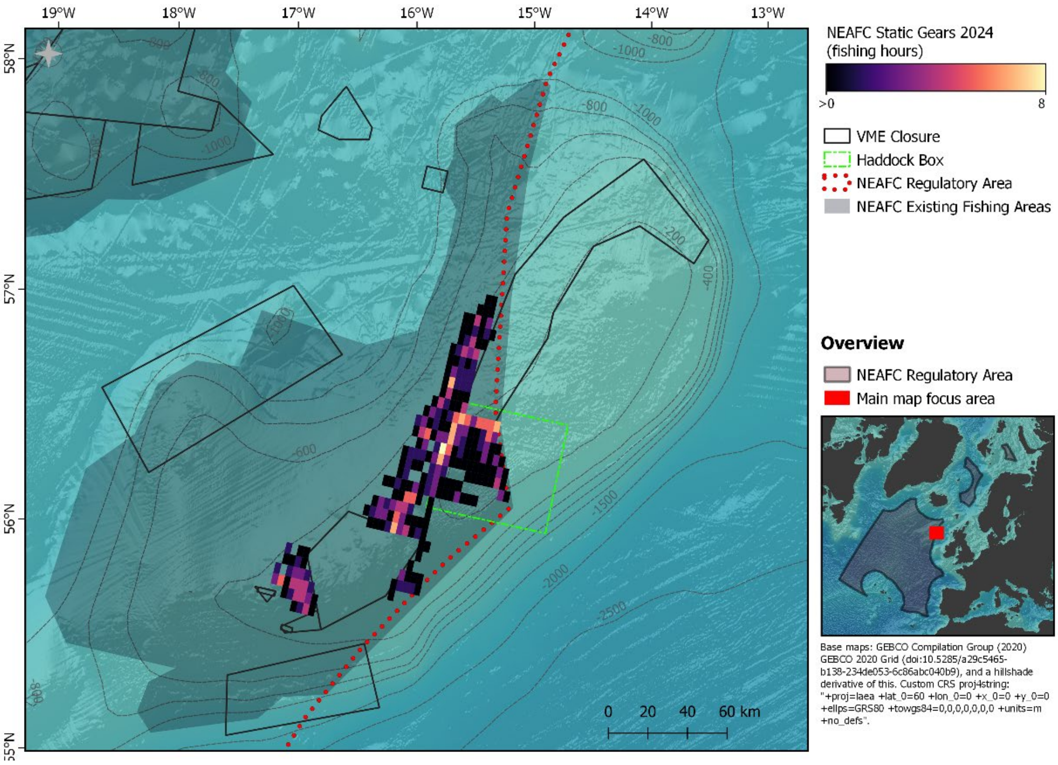

Figure 4.14. Gridded data (fishing hours) for vessels with static gears on Rockall Bank, overlain with VME closures, the Haddock Box, existing NEAFC fishing areas and EEZ boundaries.

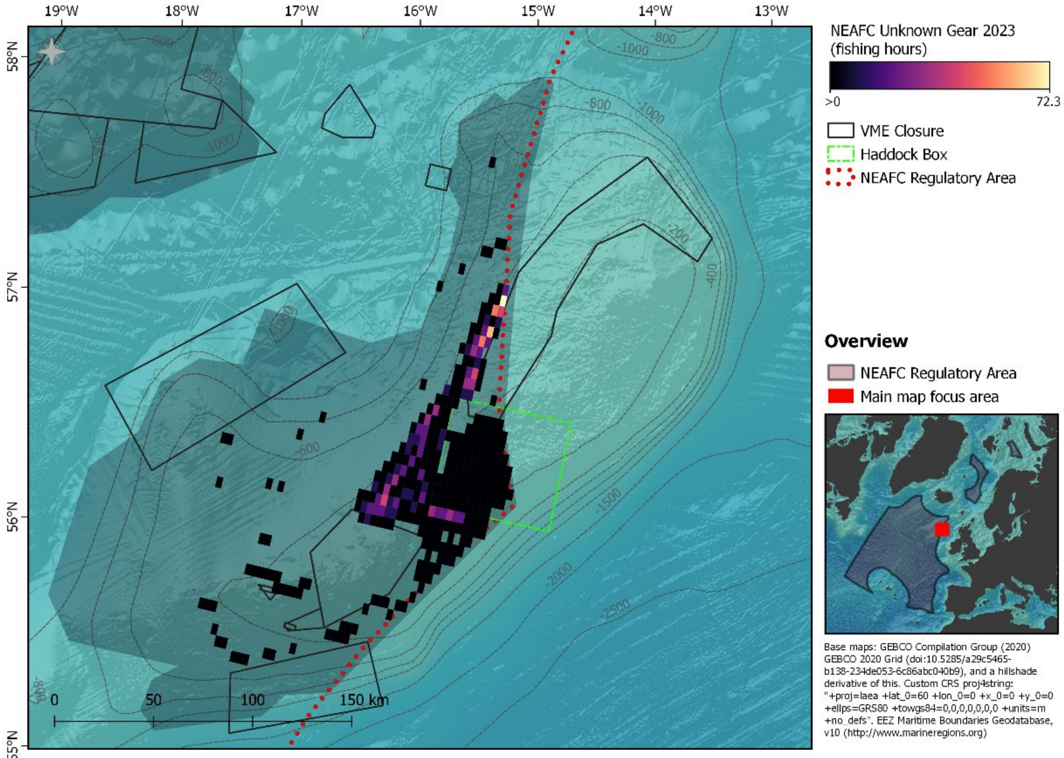

Figure 4.15. Gridded data (fishing hours) for vessels with no specified gear type on Rockall Bank, overlain with VME closures, existing NEAFC fishing areas and EEZ boundaries.

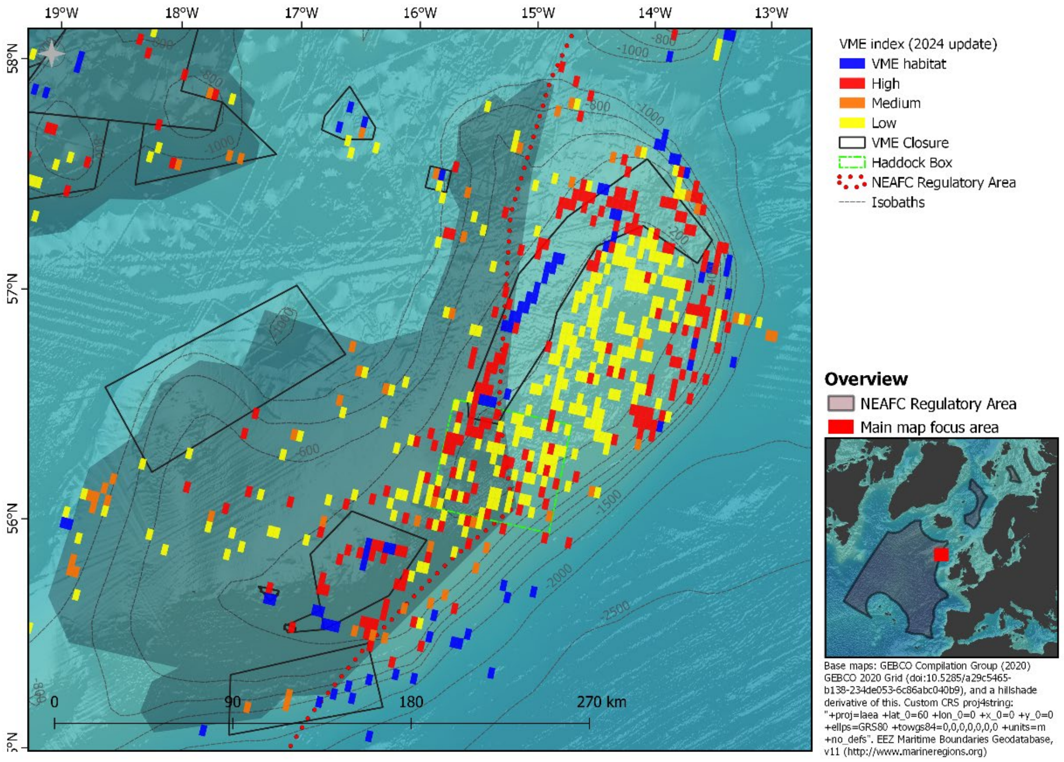

Figure 4.56. The VME Index, VME closures, existing NEAFC fishing areas and EEZ boundaries for Rockall Bank.

4.4.5 Southwest of Iceland

In the area to the southwest of Iceland there was no reported activity for vessels using bottom trawl or static gears in 2023. Activity for vessels with unreported gear type was reported (Figure 4.17). VME closures in the area seem adequate given the level and distribution of fishing activity, with the VME index for Rockall Bank given in Figure 4.18.

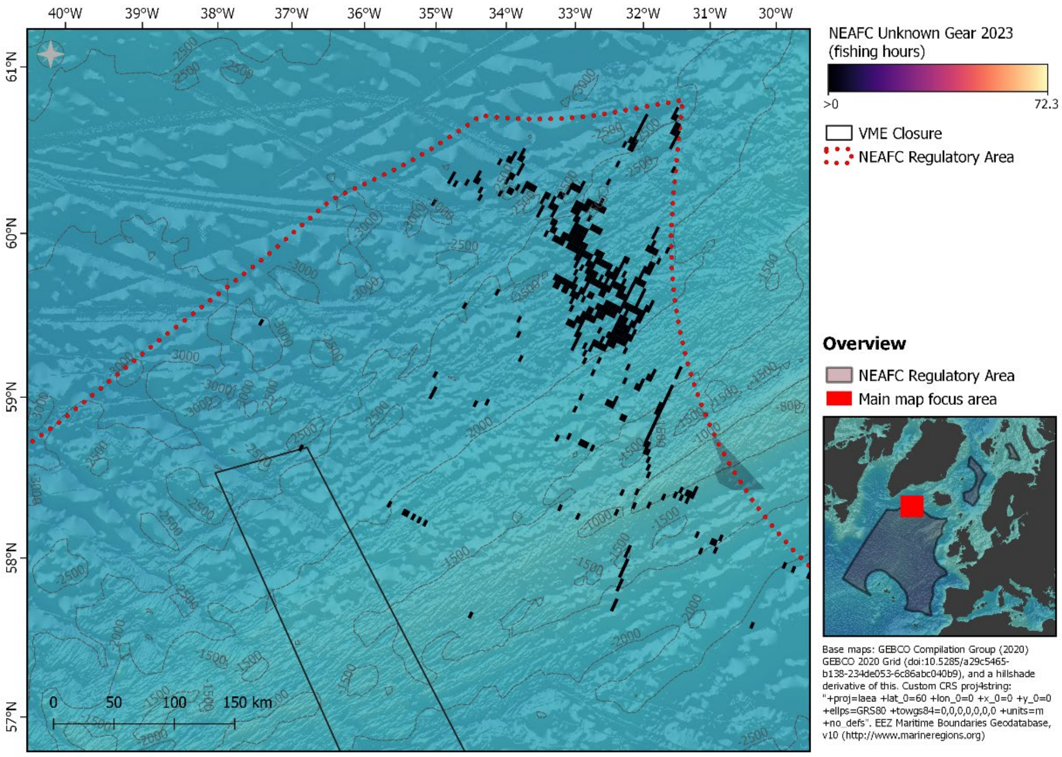

Figure 4.17. Gridded data (fishing hours) for vessels with no specified gear type in the area south of Iceland, overlain with VME closures, existing NEAFC fishing areas and EEZ boundaries.

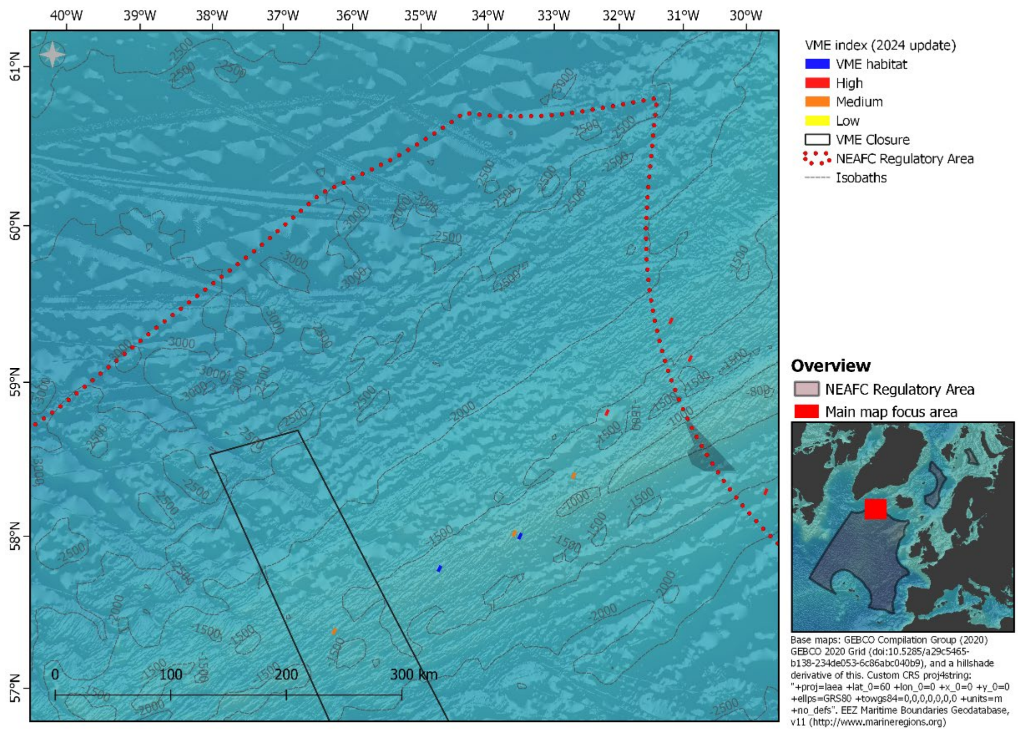

Figure 4.18. The VME Index, VME closures, existing NEAFC fishing areas and EEZ boundaries in the area south of Iceland.

4.4.6 The Mid-Atlantic Ridge Seamounts

There was no activity reported in the mid-Atlantic ridge seamounts in 2023 for bottom trawls or static gears. Activity for vessels with no specified gear type was reported from Josephine Seamount (Figure 4.19). The VME index for Josephine Seamount is given in Figure 4.20.

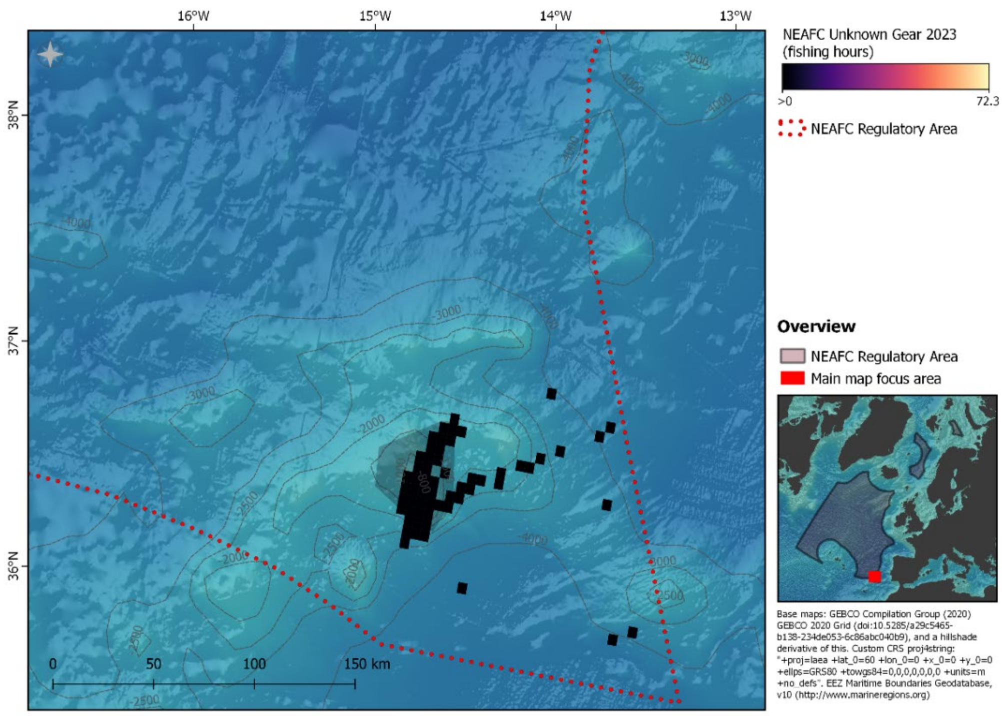

Figure 4.19. Gridded data (fishing hours) for vessels with no specified gear type in the area of Josephine Seamount, overlain with VME closures, existing NEAFC fishing areas and EEZ boundaries.

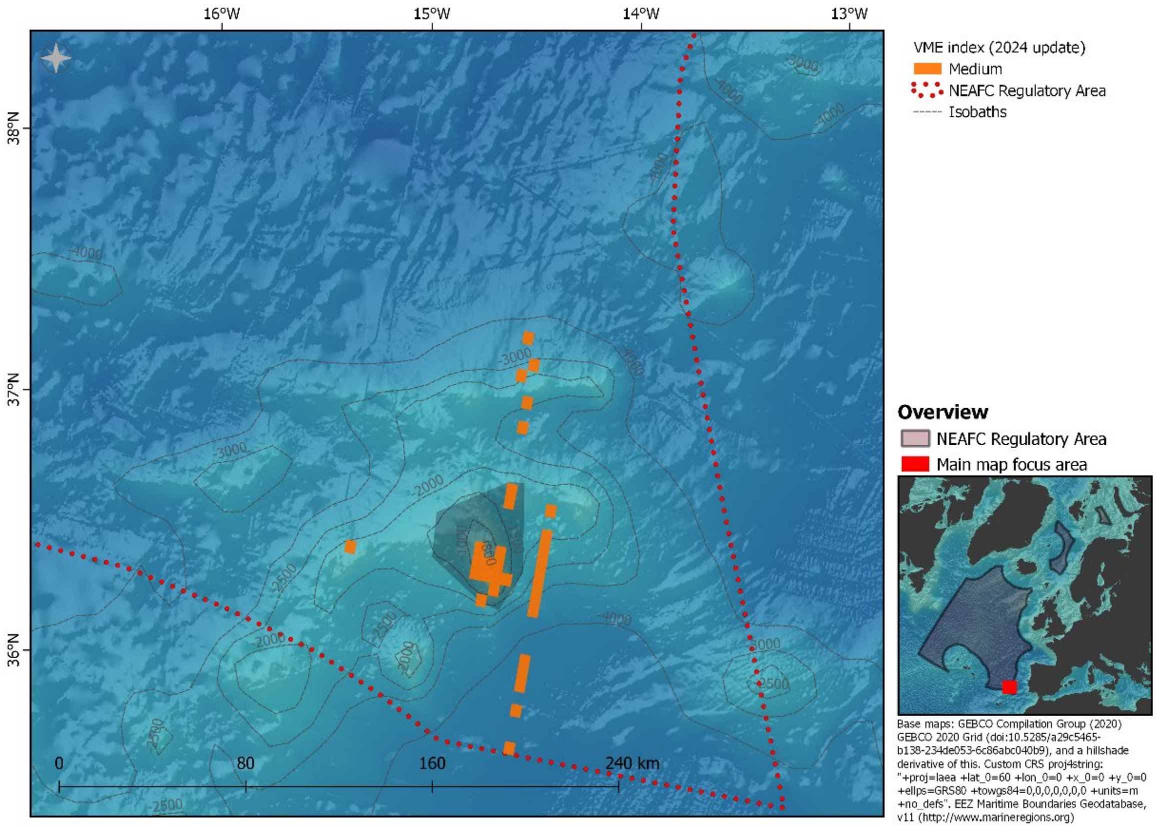

Figure 4.20. The VME Index, VME closures, existing NEAFC fishing areas and EEZ boundaries in the area of Josephine Seamount.

4.4.7 Barents Sea

Vessels registered with bottom otter trawls continue to be active in two main focus areas here, with higher intensities occurring in the south of the existing fishing area (Figure 4.21). Vessels with no specified gear type (Figure 4.22) appear to be more active in the area to the north within the existing fishing area. There is no indication of any activity using static gears. The VME index for the area is given in Figure 4.23.

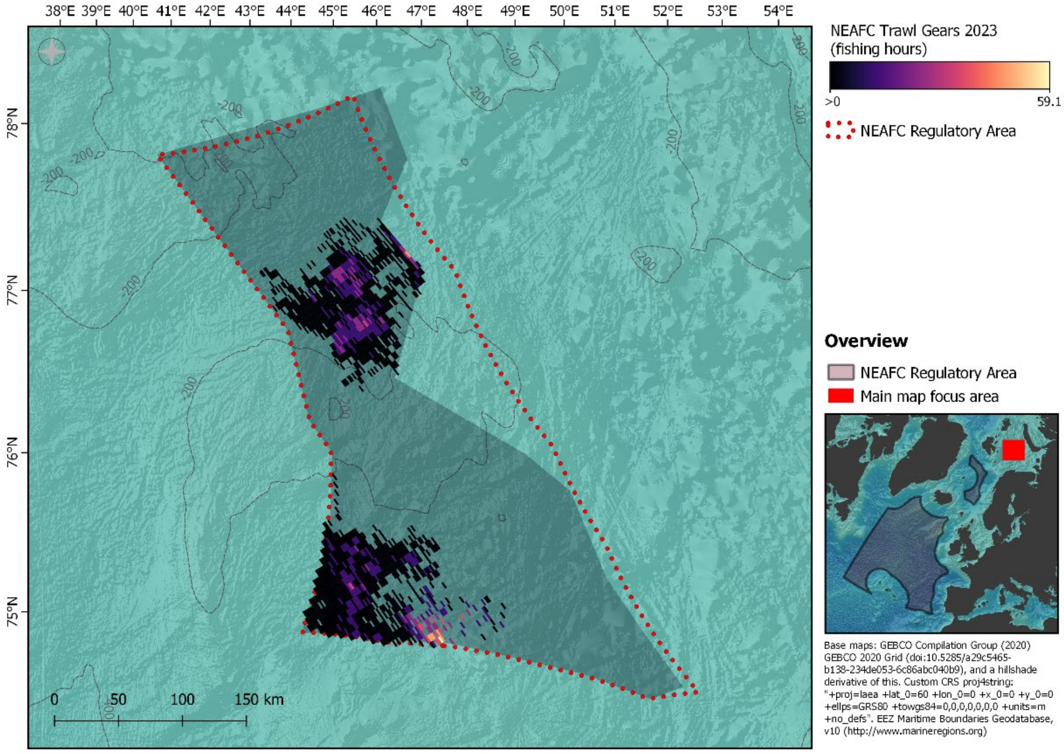

Figure 4.21. Gridded data (fishing hours) for vessels using bottom trawl gears in the Barents Sea NEAFC Regulatory Area, overlain with VME closures, existing NEAFC fishing areas and EEZ boundaries.

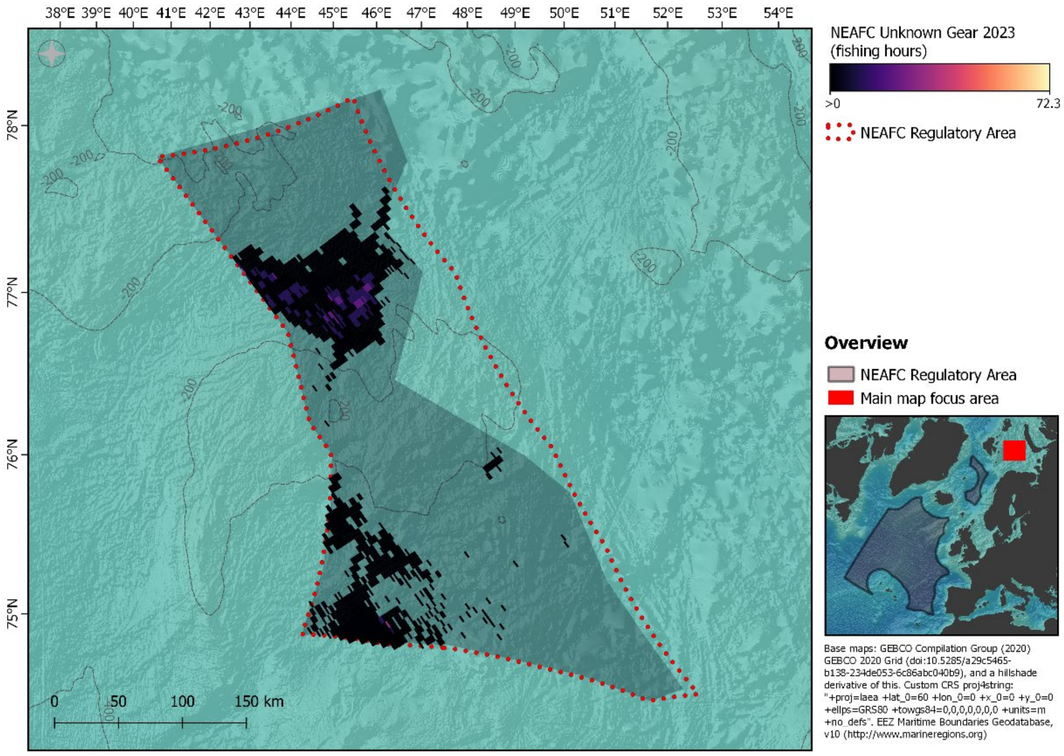

Figure 4.22. Gridded data (fishing hours) for vessels with no specified gear type in the Barents Sea NEAFC Regulatory Area, overlain with VME closures, existing NEAFC fishing areas and EEZ boundaries.

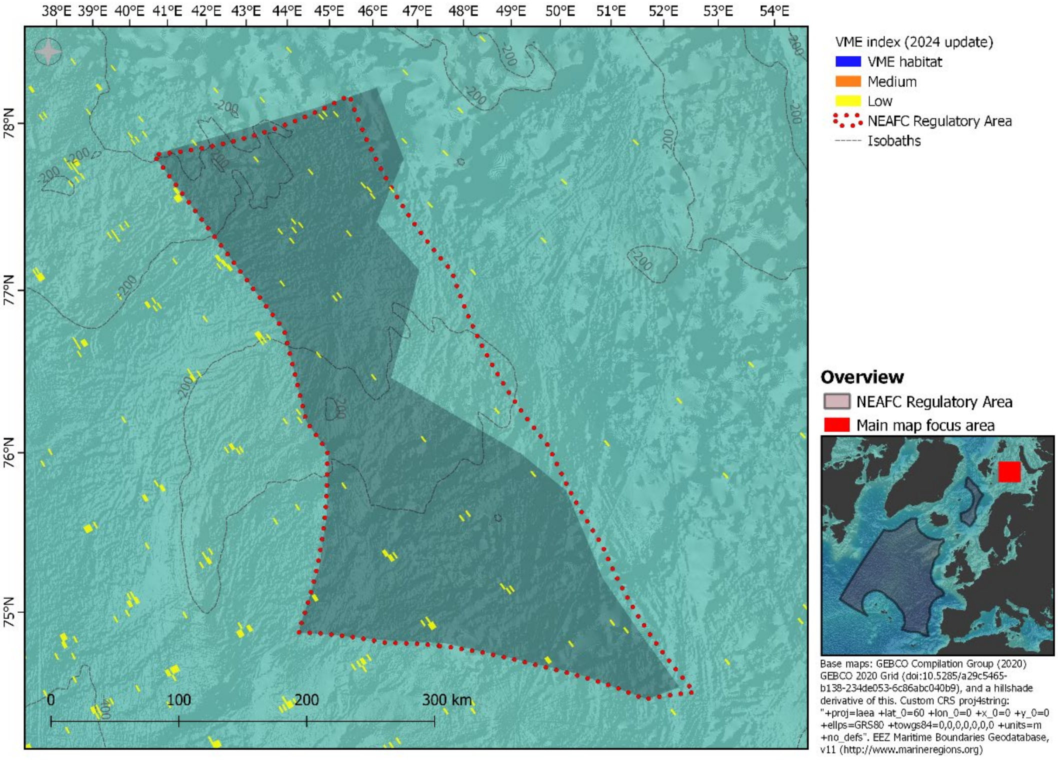

Figure 4.23. The VME Index, VME closures, existing NEAFC fishing areas and EEZ boundaries for the NEAFC Regulatory Area in the Barents Sea.

4.5 References

ICES. 2019. Oceanic Northeast Atlantic ecoregion – Ecosystem overview. *In* Report of the ICES Advisory Committee, 2019. ICES Advice 2019, EcosystemOverview_OceanicNEAtl_2019. https://doi.org/10.17895/ices.advice.5754

ICES. 2021. Celtic Seas Ecoregion – Ecosystem overview. *In* Report of the ICES Advisory Committee, 2021. ICES Advice 2021, Section 7.1, https://doi.org/10.17895/ices.advice.9432

Morato, T., Pham, C. K., Pinto, C., Golding, N., Ardron, J. A., Duran Munoz, P., Neat, F., 2018. A Multi Criteria Assessment Method for Identifying Vulnerable Marine Ecosystems in the Northeast Atlantic. Frontiers in Marine Science 5, doi:10.3389/fmars.2018.00460

5 ToR C: Historical ICES VME Data Exploration Summary

5.1 Background

This term of reference is included in response to the identification of positional errors in the VME database by stakeholders. The objectives of ToR c are to:

1. Identify areas within the database that require housekeeping/standardisation and liaise with the ICES datacentre to perform required database housekeeping.
2. Perform thorough quality control checks on the historic records within the VME database flagging records based on the spatial qualities of the record (such as the geometry). Engage with data submitters to check flagged records.

Records for a number of data submitters were flagged through the work of ToR c. It should be noted that a flagged record does not necessarily mean that there is an error in the record, only that it has been identified for further checking. Liaising with the data submitter associated with a flagged record is necessary. This is because records held within the ICES VME database are owned by the respective data submitter. If, after checking, changes to the data held in the database are required, these must be done by the data owner through the ICES Data Centre.

5.2 Data Summary

Raw ICES VME data comprised a total of 73,380 observations (including 5,636 absences) with 49 columns.

5.3 Quality Control

An assessment of the data within each field of the ICES VME database was undertaken with the following findings:

- **Dead_Alive**: Currently contains inconsistencies, i.e. dead, Alive, alive, A, D, NULL. This column should contain only Dead, Alive, or NA. Generally, NULL should be replaced with NA to avoid numeric columns being read as characters.
- **GeometryType**: Currently contains inconsistencies, i.e., Point, point, Line, line. This column should only contain Point or Line. Further, GeometryType does not always match survey method. For example, observations reported as bottom trawl data are reported as points when they should be reported as lines (Table 1).
- **Density**: This column only contains NULLs.
- **Number**: This column contains zeros (n = 4567) that do not represent non-detections and should be NA. 999 or 9999 values (n = 29) should also be checked, as these values often represent NAs. Extreme values (e.g., 202404 for Porifera) may also need to be checked.
- **Weight_kg**: This column contains zeros (n = 54608) that do not represent non-detections and should be NAs. Extreme values (e.g., 8810) may need to be checked.
- **X.Cover**: This column only contains NULLs.
- **SurveyMethod**: This column contains 1107 NULLS. Survey method should be a mandatory item.
- **Status**: Currently contains inconsistencies, i.e., Presences, Present, and a large number (n = 63107) of NULLs that do not appear to represent non-detections.

- **HighestTaxonomicResolution**: Currently contains inconsistencies, i.e., species, Species. Two species are listed (i.e., *Primnoa resedaeformis* and *Paragorgia arborea*) when this column should simply contain "Species." This column contains 64642 NULLS.
- **SACFOR**: Contains "number of observations per minute of ROV video" which does not fit with the rest of the categories in terms of data type, i.e., ACFOR scale. "Number of observations per minute" may need to be a separate optional column for ROV or similar survey methods. There is also a 'L' category (n = 127) that is not part of the SACFOR scale. This SACFOR column contains 70118 NULLs, but this not likely to be a concern.
- **TaxonDeterminer:** Currently contains inconsistencies, i.e., use of both organisation codes and full organisation names, multiple spellings/versions of organisation names.
- **TaxonDeterminationDate**: Date formatting issues, e.g. date submitted as 41528.929213. 65842 NULLs.
- **ObsDate**: Date formatting issues.
- **ObsDateType**: This column is unclear. Contains categories of D, O, U, Y, YY, blank, and NULLs.
- **Ship**: Contains 10470 NULLs.
- **VesselType**: Currently contains inconsistencies, i.e., C, Commercial, R, Research. Contains 2414 NULLs.
- **PlaceName**: Currently contains inconsistencies, e.g., Irish slope, Irish Slope. Contains 21012 NAs.
- **RecordPositionAccuracy**: Zero values (n = 1802) may be NAs. Contains 37344 NAs.
- **ShipPositionPrecision**: Zero values (n = 1579) may be NAs. Contains 40911 NULLs.
- **DataOwner**: Contains 13488 NULLs. Inconsistencies with data type (i.e., email address, staff names, organisation names) and spelling.
- **PointofContact**: Contains inconsistencies with spelling. Contains 5886 nulls.
- **ResponsiblOrganisation**: Contains 10273 NULLs.
- **ResponsibleOrganisationRole**: Currently contains inconsistencies, i.e., owner, Owner, originator, Originator. Contains 5595 NULLs.
- **ContactEmail**: Contains 4884 NULLs.
- **DepthUpper**: Data submitters appear to have submitted both signed and unsigned data; should then be standardised to signed or unsigned upon submission. Contains 37923 NAs.
- **DepthLower**: Data appears to all be unsigned, compared to DepthUpper. Contains 39840 NAs.
- **Country**: Contains 10273 NULLs.
- **Middle Latitude/Middle Longitude**: These data are calculated and submitted by each data submitter. This allows for various methods for calculating midpoints and increases possible error. Data submitters should submit start and end points, with midpoints being calculated in a standardised way after submission. Only 0.15% (n = 109) of observations have no midpoint (i.e., midpoint listed as 0,0).

Table 5.1: Survey methods associated with VME observations reported as point (n = 40,720) or line (n = 28,125) data.

Method	Point data	Line data
AGT	105	228
BAK	0	1163
BC	11	0
BMT	5	131

Method	Point data	Line data
BOT	571	18571
CTD	17	0
DIV	1	0
GOC73	4	89
GRT	2	0
GOV	0	638
JDT	0	397
LL	0	180
MBES	409	0
NCT	3733	638
NT	2	0
NULL	869	238
OD	4	0
OS	1	0
PHOTO	1234	0
RD	78	10
ROT	44	110
SH	3	0
SIDC	201	71
SIROV	5635	3091
SITC	3731	2064
UD	0	68
UG	3	0
UT	348	353
VID	1056	0
VID-DROP	0	26
VID-TOW	22231	79
VV	13	0

5.4 Spatial Errors

An assessment of the associated geometry and positional data was conducted for records within the database. A total of 35,489 observations do not have end points and are all recorded as point data. However, a number of these reported point data are using survey methods that are associated with line data, e.g., 397 bottom trawls are reported as point data and lack end points. These bottom trawls are submitted by Bedford Institute of Oceanography (n = 109), the Bayfield Laboratory for Marine Science and Surveys (n = 3), and the Polar Research Institute of Marine Fisheries and Oceanography (n = 285). Other survey methods likely incorrectly reported as points and thus missing vital line data include Agassiz trawl (n = 105), beam trawl (n = 5), bottom trawl for experimental fishing (n = 4), Granton trawl (n = 2), Norwegian Campell trawl (n = 3412), naturalists dredge (n = 2), other dredge (n = 413), rock dredge (n = 78), rock hopper otter trawl (n = 44), ROV seabed imagery (n = 3784), towed camera seabed imagery (n = 3662), unknown trawl (n = 151), and towed video (n = 22231). These potential errors have been submitted by 15 responsible organisations.

33,564 observations comprise both start and end points, with 83.8% (n = 28145) being reported as line data and the remainder categorised as points (n = 5419). Of the point data, the majority of records were from ROV imagery (n = 1851). All ROV transects had a line length of zero (i.e., start and end points were identical); these data are accurately reported as points, but have submitted end points unnecessarily. All CTD (n = 17), diver collected (n = 1), multibeam echosounder (n = 409), drop camera imagery (n = 3), towed camera imagery (n = 69), unknown trawl (n = 197), video-based determination of coverage (n = 1056) had a line length of zero (i.e., start and end point were identical). Bottom trawls (n = 174), photo-based imagery (n = 456), and Norwegian Campell trawls (n = 321) were also reported as point data, but had line lengths > 0. Bottom trawls ranged in length from 0 – 60 km ($\bar{x}$ = 20.8 ± 19.7 km). Photo-based determination transects ranged from 493.2 – 616.6 m ($\bar{x}$ = 541.4 ± 52.6 km). Norwegian Campell trawls ranged from 343 m – 2.7 km ($\bar{x}$ = 1.4 km ± 176.6 m). These data appear to be line data and were incorrectly reported as point data.

After removing any line length < 0, transect lengths ranged from 1m - 3107.3 km (Figure 5.1). Outliers in transect length can be visually identified across a variety of survey methods, including bottom trawl, unknown trawl, and video-tow. Using interquartile ranges to identify outliers in a standardised way within each survey method, a total of 2186 lengths were flagged as outliers (range = 214 m – 3107 km). No responsible organisation was reported for 997 of these observations identified as outliers, with the remaining being attributed to the Bedford Institute of Oceanography (n = 22), Department for Environment Food and Rural Affairs (n = 3), Spanish Oceanographic Institute (n = 173), Vigo Oceanographic Centre (n = 153), Ifremer Head Office (n = 252), Institute of Marine Research (n = 39), Joint Nature Conservation Committee Peterborough Office (n = 6), Marine Institute (n = 239), Marine Scotland Science (n = 87), National Oceanography Centre (n = 70), Polar Scientific Research Institute of Fishery and Oceanography (n = 139), and University of Tartu (n = 5).

Substantial variation in transect length remains for some survey methods after removing outliers, particularly unknown trawls (Figure 5.2). Unknown trawls range in length from 1.3 – 55.5 km with a mean of 32.2 km. There is no responsible organisation listed for these unknown trawls (n = 345), but the contact email is listed as a Polar Research Institute of Marine Fisheries and Oceanography, Russia (PINRO) address. A more detailed exploration of these transects may be required to identify any further outliers.

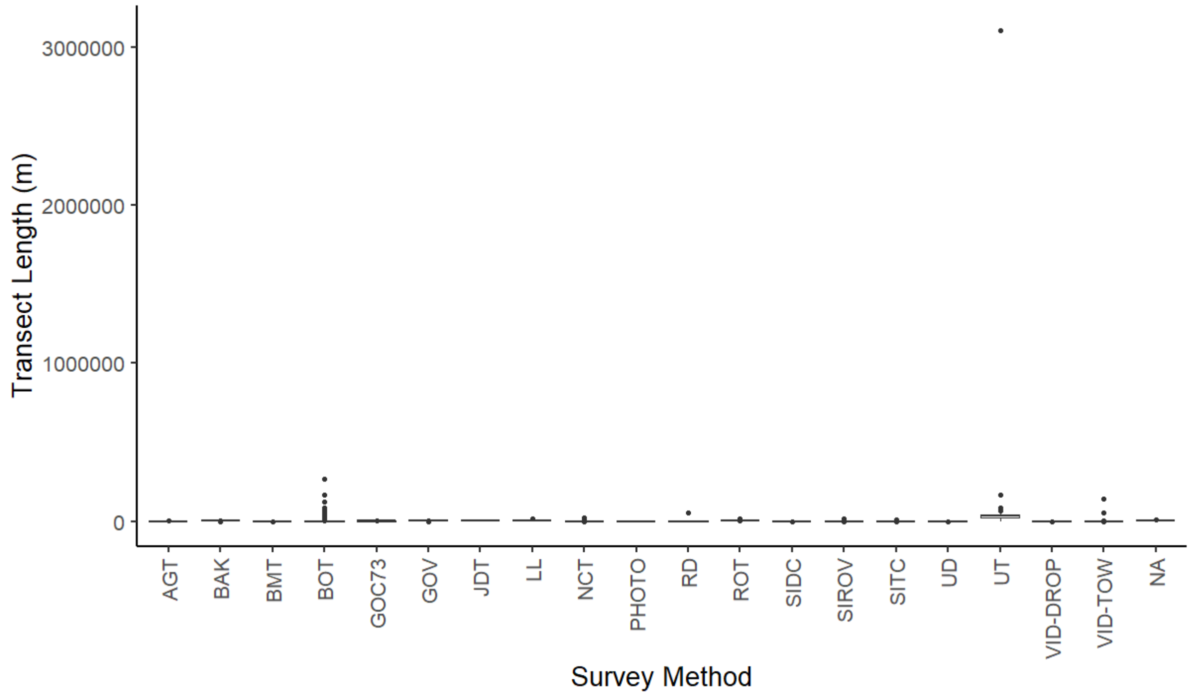

Figure 5.1: Line lengths (>0 m) calculated from the provided start and end points from 28979 VME observation transects.

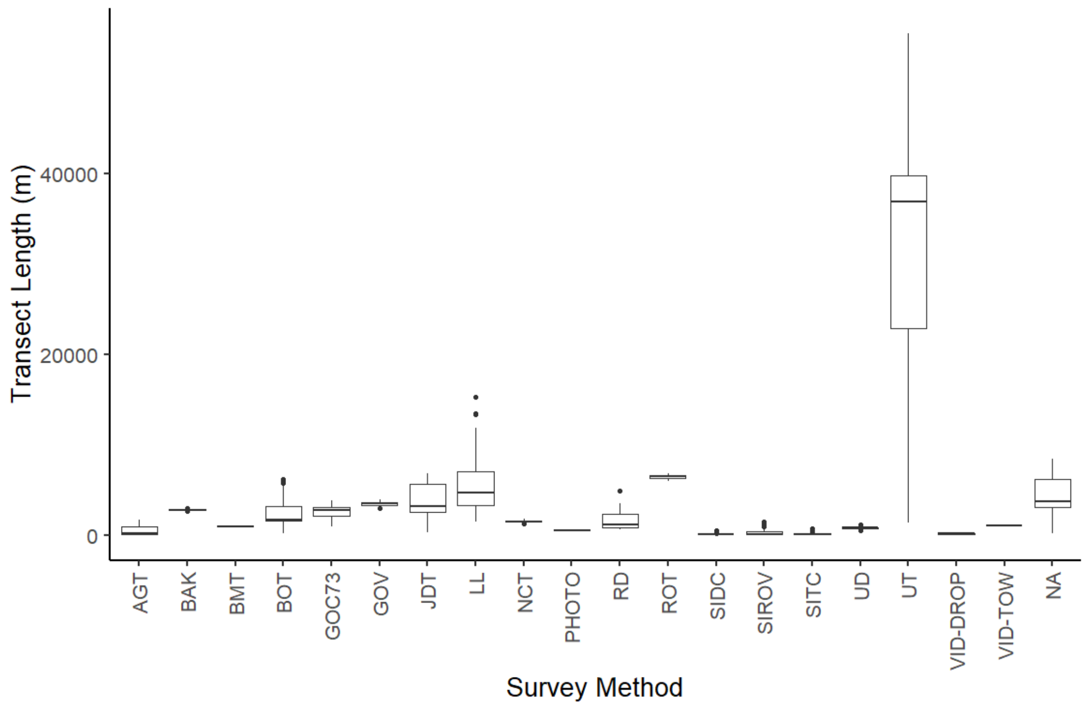

Figure 5.2: Line lengths (>0 m) calculated from the provided start and end points from 28979 VME observation transects after removing outliers using the interquartile range method.

When plotted, outlier transects are again clearly visible, by both length and geographical placement (Figure 5.3). 10 start points occur on land, in Greenland (n = 1), Iceland (n = 1), Spain (n = 4), Portugal (n = 1), and the Azores (n =2). All are listed as a point geometry (despite 9/10 have end points) and all but one has no survey method listed. Only a single observation has a responsible organisation reported (Natural History Museum of Denmark). Nine of the corresponding end points occur on land in Iceland, Spain, Portugal, and the Azores. This can be quality controlled by extracting depth from a bathymetry raster, such as GEBCO or EMODnet, for each start and end point. This can then flag any coordinates with a depth > 0 m as potential errors. Additionally, 9,140 observations occurred in waters < 200 m deep (range 200 – 1 m). Several transects appear to travel perpendicular to the shelf, which is not possible using a variety of survey methods (Figure 5.4). Transect length may not be able to adequately capture these spatial errors, and further exploration is needed to systematically identify a method to flag transects that traverse perpendicular to the shelf.

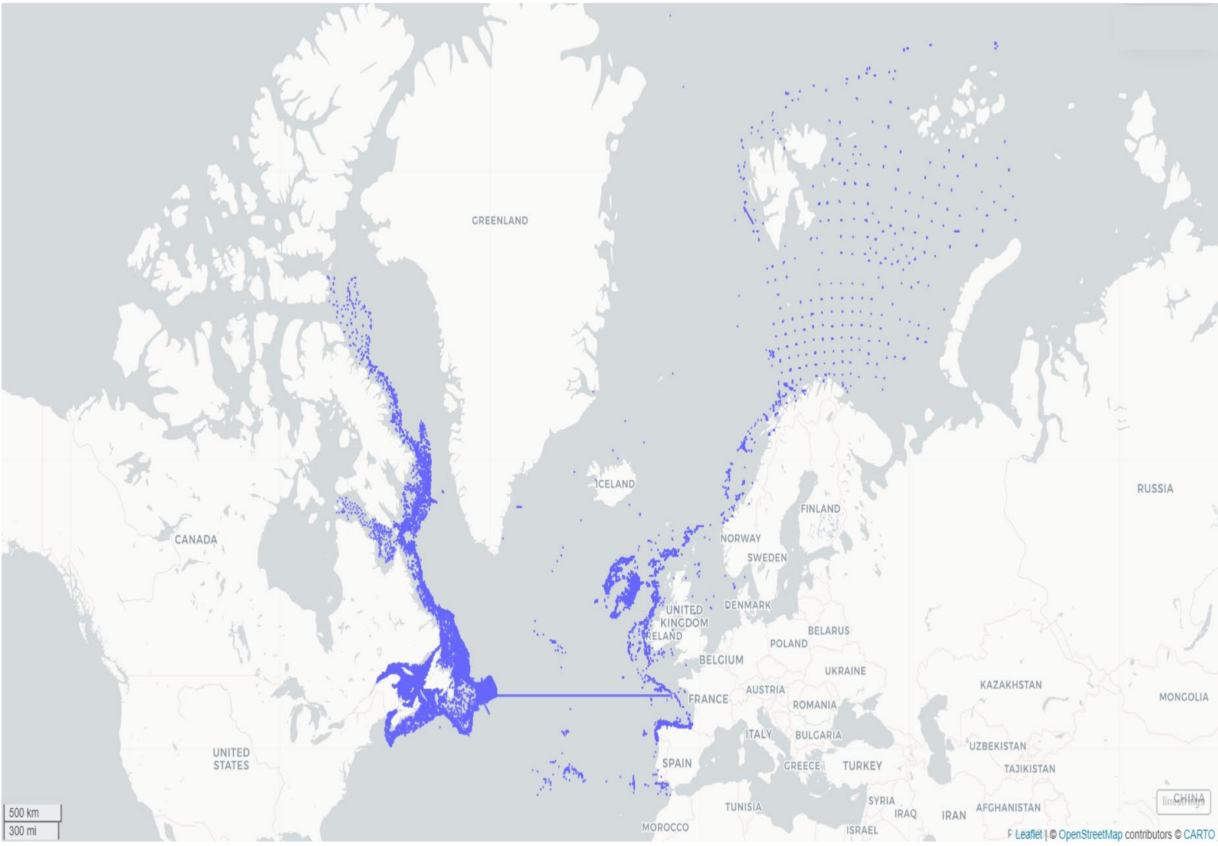

Figure 5.3: Spatial VME data (n = 33,564) plotted as transects using reported start and end points, including data attributed as both point and line data.

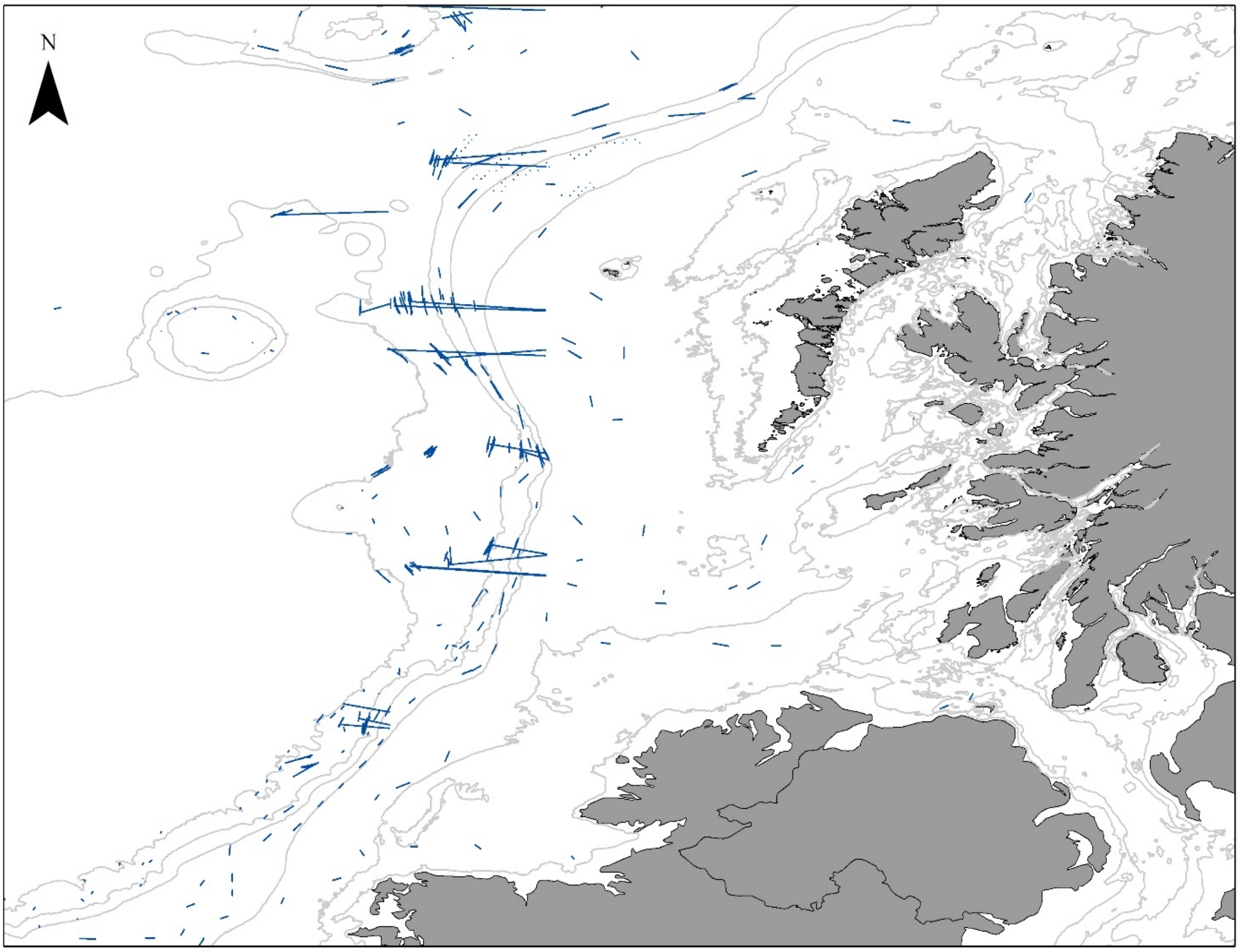

Figure 5.4: Spatial VME data plotted as transects using reported start and end points over 500 m contours to highlight individual transects that traverse perpendicular to the shelf.

Absence data are also submitted to the VME data base, and comprise 5636 records of point (n = 219) and line (n = 4296) data. No survey method is listed for 53 absence records. The remainder are primarily bottom trawls (61.3%, n = 2769) and baka trawls (25.5%, n = 1155). A total of 31 Norwegian Campell trawls were submitted as point data, but have start and end points with an average transect length of 1.5 km ± 212 m (range = 1.2 km – 2.1 km). Overall transect length ranges from 0 m to 763.1 km. All transects with length equal zero were bottom trawls and were submitted by the Vigo Oceanographic Centre (n = 1091), Marine Scotland Science (n = 11), and the Polar Scientific Research Institute of Fishery and Oceanography (n = 1667). After removing any line length < 0, transect lengths ranged from 3.8 m - 763.1 km (Figure 5). Outliers in transect length can be visually identified across a variety of survey methods, but primarily bottom trawls (Figure 5.5). Using interquartile ranges to identify outliers in a standardised way within each survey method, a total of 463 lengths were flagged as outliers (range = 290 m – 763.1 km; Figure 5.5). These data flagged as outliers were submitted by the Spanish Oceanographic Institute (n = 156), Institute of Marine Research (n = 3), Joint Nature Conservation Committee (n = 8), Marine Institute (n = 7), Marine Scotland Science (n = 15), and Polar Scientific Research Institute of Fishery and Oceanography (n = 274).

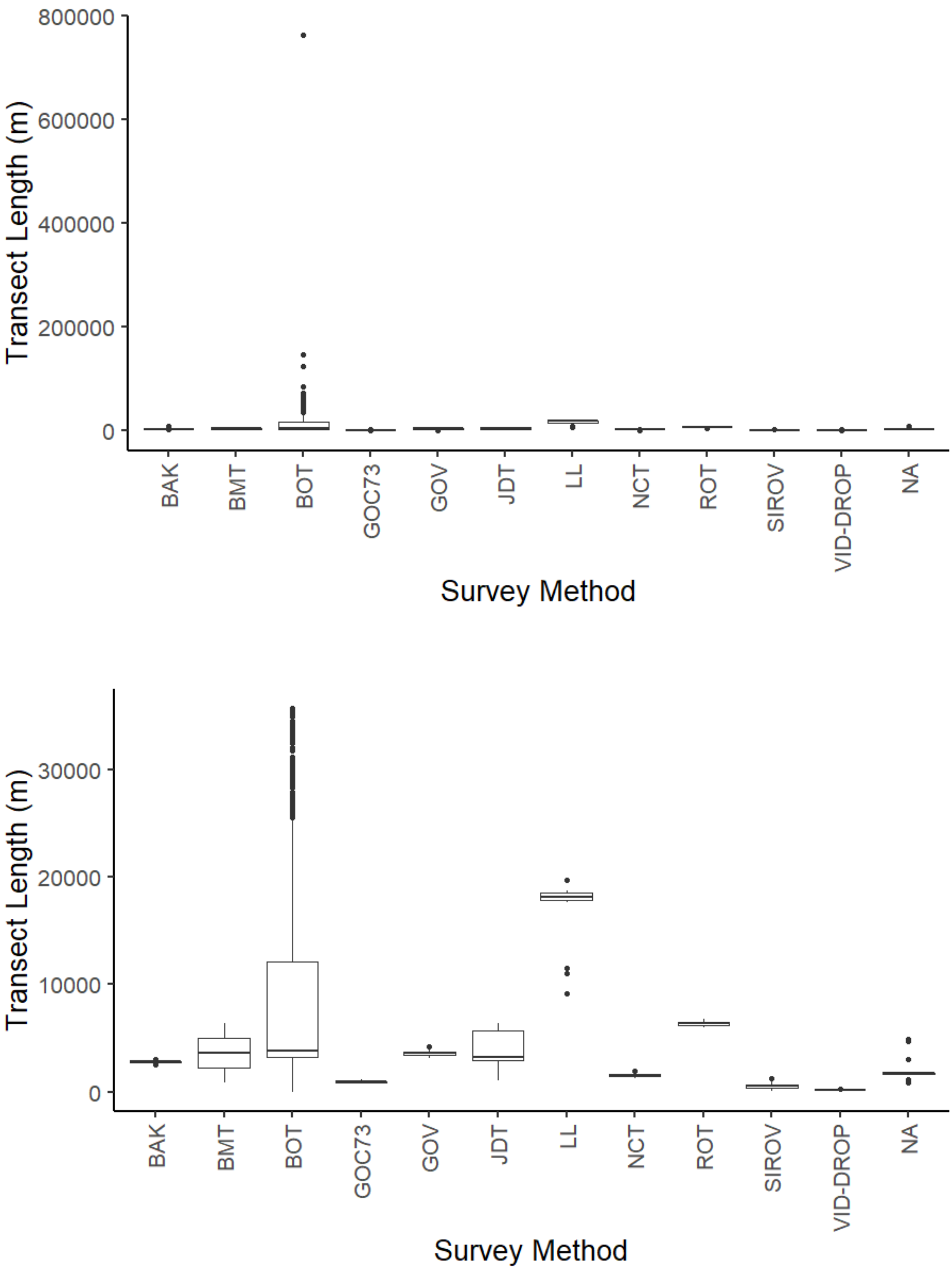

Figure 5.6: Line lengths (>0 m) calculated from the provided start and end points from 4327 absence observation transects (upper panel) and after removing outliers using the interquartile range method (lower panel).

On account of the geographical scope of the errors identified by stakeholders and the need for corrected data to be included for the 2024 ICES VME advice to the European Commission, records arising within the Celtic Seas ecoregion that were submitted by the Marine Directorate of the Scottish Government (formerly Marine Scotland Science) and the Marine Institute (Ireland) have been checked and where necessary corrections have been made to the data held within the ICES VME database.

A total of 1529 records from 14 Marine Scotland Science (MSS) scientific surveys undertaken between 2006 and 2019 were examined for positional accuracies in response to ToR c. All positions from ten of these surveys were confirmed to be correct. Positional errors, of varying degrees, were corrected for 93 VME indicator records arising from 28 sampling events (bottom trawl tows) across 4 MSS surveys in the ICES VME database. One station (0412S_144) that had two records associated with it (1 dead Lophelia pertusa 112g and 280 Funiqulina quadrangularis) was removed from the database as the original positional data was also erroneous. One VME habitat record from 1 sampling event was also corrected for the Marine Institute (MI) data (SeaRover18_540). These corrections are presented in Annex 3.

6 TOR D: Framework for a future workshop on the occurrence of VMEs in the NE Atlantic region

6.1 Background

In 2014, ICES WGDEC initiated the development of a Multi-Criteria Assessment (MCA) method to weight the reliability and significance of Vulnerable Marine Ecosystem (VME) indicator records in support of advice on bottom fishing closures (ICES, 2014). In its first iteration, the MCA method considered four criteria to score VME likelihood: Survey method, weight of material, date of observation and whether specimens were dead or alive. The method was deemed moderately successful, maps were more readily interpreted than previous maps based on expert opinion but some caveats were also highlighted (ICES, 2015). Among those caveats were the fact that the weighting algorithm was mixing measures of likelihood (e.g. weight of material) with measures of uncertainty of that likelihood (e.g. survey method). Data from visual surveys were outweighed because records from visual surveys provide numbers of specimens, not weight. The system also did not account for the taxonomy of the VME indicator records and their likelihood of forming a VME. Finally, the MCA method was scoring individual records but not spatially aggregating evidence.

In 2015, WGDEC redeveloped the approach to provide a single measure evaluating the likelihood of VME occurrence and an additional measure of the uncertainty associated with this score (ICES, 2015). These two indexes were further refined during the 2016 WGDEC meeting (ICES, 2016a) and was further published in the peer-reviewed literature (Morato *et al*, 2018). The new MCA method first discriminates between *bona fide* VME habitats, which are records for which there is unequivocal evidence for a VME (such as video imagery of a cold-water coral reef from a remotely operated vehicle survey), and VME indicators, which are records that suggest the presence of a VME with varying degrees of uncertainty (such as VME bycatch from a fishing trawl). The VME index and the confidence index were developed only for records of VME indicators. The VME index took into account the vulnerability and the abundance of the VME indicators. The VME indicators were grouped into the 12 VME indicator types updated during the 2015 workshop on the VME database (ICES, 2016b). In order to compute a vulnerability score, VME Indicator types were first assigned a score for each of the five Food and Agriculture Organization (FAO) criteria for VMEs, based on expert judgement. These FAO-criteria scores were then averaged to calculate a vulnerability score, ranging from 4.4 for stony coral, to 1.6 for soft corals. The abundance score was based on weight thresholds and these thresholds defined according to encounter rules as applied by North East Atlantic Fisheries Commission (NEAFC) (i.e. > 200 kg for sponges, half the NEAFC encounter rule, and > 30 kg for corals). The VME index was the sum of the vulnerability score, given a weight of 0.9, and the abundance score, given a weight of 0.1. The results of the VME index were then aggregated to a 0.05 degree grid cell. For each cell, the maximum VME index score was taken as the overall value for that cell. The final outcome was presented as three nominal categories of 'VME index' scores (high, medium, low), indicating the likelihood of encountering a VME in the assessed grid cells. The confidence index took into account the type of survey (i.e. visual surveys, physical sampling and indirect methods, by increasing order of uncertainty), the number of surveys, the time span range of surveys undertaken in years, and how recent was the last survey. These scores were also aggregated by 0.05 grid cells, and only the scores of the records giving the highest VME index score were considered.

The implementation of the VME Index in support of advice for NEAFC and the EU highlighted some limitations of both the VME Index and the confidence Index. For NEAFC, only VME habitats are considered. For both NEAFC and EU advice, the confidence Index has not been implemented. Three main concerns have been raised from their development (ICES, 2018) to their implementations (ICES, 2019a, 2021, 2022):

- The relevance of VME abundance thresholds for sponges and non-sponge taxa has been questioned (ICES, 2018). The thresholds are derived from encounter rules in the NEAFC area and thus apply to by-catches in commercial trawls. The ICES VME database used to calculate the Index however holds data from a variety of sources, including a large number of scientific surveys characterised by shorter tows than commercial trawls, and for which the thresholds may not be relevant (ICES, 2022). NEAFC thresholds also only apply to sponges and corals. The coral threshold of 30 kg has been expanded to all non-sponge VMEs, which was felt to be too high for some species such as seapens or black corals (ICES, 2018).
- The vulnerability component in the VME Index scores how 'well' the indicator meets the VME designation criteria (FAO, 2009). However, a list of what constitutes a VME already exists, and there may be no need to value different types of VMEs again in the index as any of the criteria allow designation of a VME. Different types of VMEs may require different types and levels of protection, and this is likely to be related to the FAO criteria (e.g., fragility and recovery potential), but these differences would need to feed into the management measures implemented once a VME has been detected (ICES, 2021). Under the FAO guidelines, vulnerability is assessed through evaluation of the potential for fishing to cause significant adverse impacts (SAI). SAIs are those that compromise ecosystem structure or function and will be specific to the interaction of the fishing gear used, the timing, intensity and frequency of the disturbance, and the species composition of the VME. This is appropriate as it assesses each VME in its ecological setting and evaluates impacts against specific gear interactions (ICES, 2022).
- The effect of the passage of time in the confidence score: ICES (2019) expressed concern that historic VME information was down-weighted in the confidence index. Given the longevity of many of the VME indicator taxa, the threshold for down-weighting may not be meaningful. Hence the weighting algorithm used and its impacts on the results should be investigated further.

Considering the limitations of the current VME Index and suggestions for improvements raised in previous reports, WGDEC has been tasked to draft a resolution for a workshop to improve the VME Index.

6.2 Expectations and challenges of a VME likelihood index

Recommendations on ways to improve the VME index were made by the Workshop on EU regulatory area options for VME protection (WKEUVME) and the Benchmark workshop on the occurrence and protection of vulnerable marine ecosystems (WKVMEBM), among which the fact that the new VME Index should focus on assessing the likelihood of VME occurrence (ICES, 2021), independently of the relative vulnerabilities of VME indicators, but making full use of trawl catch surveys (ICES, 2022). In doing so, clarity about the nature of the indicator ('concreteness') would be vital for acceptance of outcomes by managers and stakeholders (ICES, 2021).

It was agreed during WGDEC 2024 that the vulnerability score was introducing a ranking that is independent from the likelihood of a VME to occur but rather relates to the risk of significant adverse impact. The method may make sense when the intensity of the pressure is unknown but should be avoided when the intensity of the pressure can be quantified independently, such as for towed fishing gears. Regarding the use of trawl bycatch, some caveats were underlined. Scientific trawl surveys were considered more reliable than commercial ones, and for the latter, the presence of an observer on board would be an important criterion to assess the reliability of the records. Scientific trawl surveys however are less likely to provide information on occurrences of VMEs. These surveys are generally repeated at the same sites each year, and any apparent encounter with a VME would be likely to result in a change in the sampling plan. The catchability of VME indicator species was also mentioned as a major source of uncertainty.

To designate VMEs based on imagery, Baco et al. (2023) listed a set of criteria along a decision tree that included habitat types (e.g. reef, chemosynthetic ecosystem), size/age of VME taxa, functional role, presence of threatened taxa, threshold in VME taxa richness, and threshold in VME taxa density. The spatial extent of VME taxa aggregations was also mentioned as a key criterion. Some of these criteria could be similarly used in a MCA approach to develop a VME likelihood index. Additional lines of evidence that could be added in the MCA are VME elements from high-resolution bathymetry, which were already listed in the very first iteration of the MCA (ICES, 2014), and species distribution models (see ToR G).

A main constraint for the development of a VME likelihood index for the purpose of ICES advice is that the index has to be developed from existing data available in the ICES VME database. Some criteria, such as the size/age of VME taxa or functional role cannot be considered because such information is not present in the database but the volume and quality of records has significantly increased over the last 10 years and a synthesis of the contents of the database was deemed necessary.

6.3 The ICES VME database

For the purpose of transparency and reproducibility, the VME index shall be calculated based on data held by the VME database, managed by the ICES Data Centre. As the content of the ICES VME database is growing every year with higher QA/QC in place, the amount and quality of data available should have improved since 2015, when the current VME Index has been developed. As of May 2023, the database was holding 73380 records (Table 6.1), compared to 8000 records when development of the multi-criteria assessment was initiated in 2014. Occurrences of VMEs are classified either or both according to Habitat types or VME Indicators. In its 2015 report, WGDEC clarified that Habitat types should only be used for *bona fidae* records of VME habitats, such as from ROV transects; while VME Indicators should refer to occurrences of VME indicator taxa, such as from a longline or trawl bycatch. Records of habitat types represent about 14% of the total number of records (Table 6.1). A third of these records are from trawl bycatch (Table 6.2). Those trawl records are from scientific surveys in NAFO area where the delineation of VME habitats was further supported by kernel density analyses and spe-cies distribution models (Kensington et al., 2016). Those records were thus deemed representative of VME Habitats (ICES, 2018).

This is particularly true for Deep-sea Sponge Aggregations. Records of VME Indicators are the most common, contributing to 78.8% of all records (Table 6.1), mostly based on evidence from imagery and trawl bycatch data (Table 6.3). Regarding trawl bycatch, 5.5% of the records come from commercial trawls. For less than 2% of the records, neither the Habitat type or the VME indicator is given although for a thousand records the VME indicator could still be inferred from the VME taxa. Finally, 7.68% of the records hold no information on either VME habitat, VME Indicator or VME taxa, reflecting absence data.

Table 6.1. Number of records in the ICES VME database providing evidence for the presence or absence of VME habitats, VME Indicators and VME taxa.

	Nb records	% Total
All records	73380	100
Habitat types	9902	13.49
VME indicators only	57842	78.83
VME taxa only	1121	1.53
No information (absence)	5636	7.68

Table 6.2. Number of records of Habitat types according to gear types (note that indirect or irrelevant gears are excluded, i.e. MBES, CTD, divers).

Habitat types	Imagery	Trawls	Grabs
Anemone aggregations	25	-	-
Bryozoan patches	4	-	-
Cold seeps	14	1	-
Cold-water coral reef	1934	-	3
Coral Garden	1606	388	-
Deep-sea Sponge Aggregations	1685	1806	-
Hydrothermal vents/fields	9	-	-
Mud and sand emergent fauna	4	-	-
Seapen fields	1392	825	-
Stalked crinoid aggregations	4	-	-
Tube-dwelling anemone aggregations	126	-	-
Xenophyophore aggregations	47	-	-

Table 6.3. Number of records of VME indicators according to gear types (note that indirect or irrelevant gears are excluded, i.e. MBES, CTD, divers).

VME indicators	Imagery	Trawls	Dredges	Grabs	Long Lines
Anemones	2075	54	-	-	-
Black coral	1637	290	20	-	8
Chemosynthetic species	-	-	-	11	-
Cup coral	249	464	20	-	35
Gorgonian	7260	1656	49	-	2
Sea-pen	7161	5143	195	2	29
Soft coral	89	672	120	3	40
Sponge	11752	15404	59	1	25
Stony coral	2309	408	95	6	38
Stylasterids	25	19	13	-	3
Xenophyophores	12	-	-	5	-

A major challenge in constructing a VME likelihood index is to define criteria and thresholds to be applied to VME indicator records in order to rank the likelihood that these records are evidence of VMEs. Quantitative criteria to designate VMEs may include density or biomass thresholds and/or spatial extent thresholds. In the ICES VME database, number, weight, or the SACFOR scale for abundance (records species in terms of percentage cover or counts S = Superabundant, A = Abundant, C = Common, F = Frequent, O = Occasional, R = Rare) are the three fields providing either quantitative or semi-quantitative data on VME records (Table 6.4). About half of the records hold information on the number of individuals associated with a record, mostly from imagery and trawl by-catch, while 12% of the records provide information on weight, only from trawl and long-line by-catches.

Table 6.4. Number of records with quantitative or semi-quantitative data, either as numbers of individuals (> 0), weight of VME taxa (> 0) or an abundance scale.

Gear types	Number	Weight	SACFOR
Dredge	2	-	-
Grab	6	-	-
Imagery	25474	-	2418
Long lines	10	173	-
Trawls	9720	8535	-
% total records	48%	12%	3%

The numbers and weights of VME taxa show large variations within VME indicator groups (Figure 6.1). However, those variations may prove difficult to interpret without standardisation, which is challenging. Numbers may for example come from a single image, whose size is unknown, or from an ROV transect, whose navigation is unknown. The geometry of ROV transect is provided as a line, with start and end latitude and longitude, while the ROV may have meander in between the start and end of the dive. Weights may vary significantly from one taxa to another within a VME indicator group, for example between glass sponges and demosponges, but over half of the sponge records are identified at phylum level only, preventing further discrimination (Table 6.5). In addition, numbers and weight may have been reported as raw values or may be already spatially standardized.

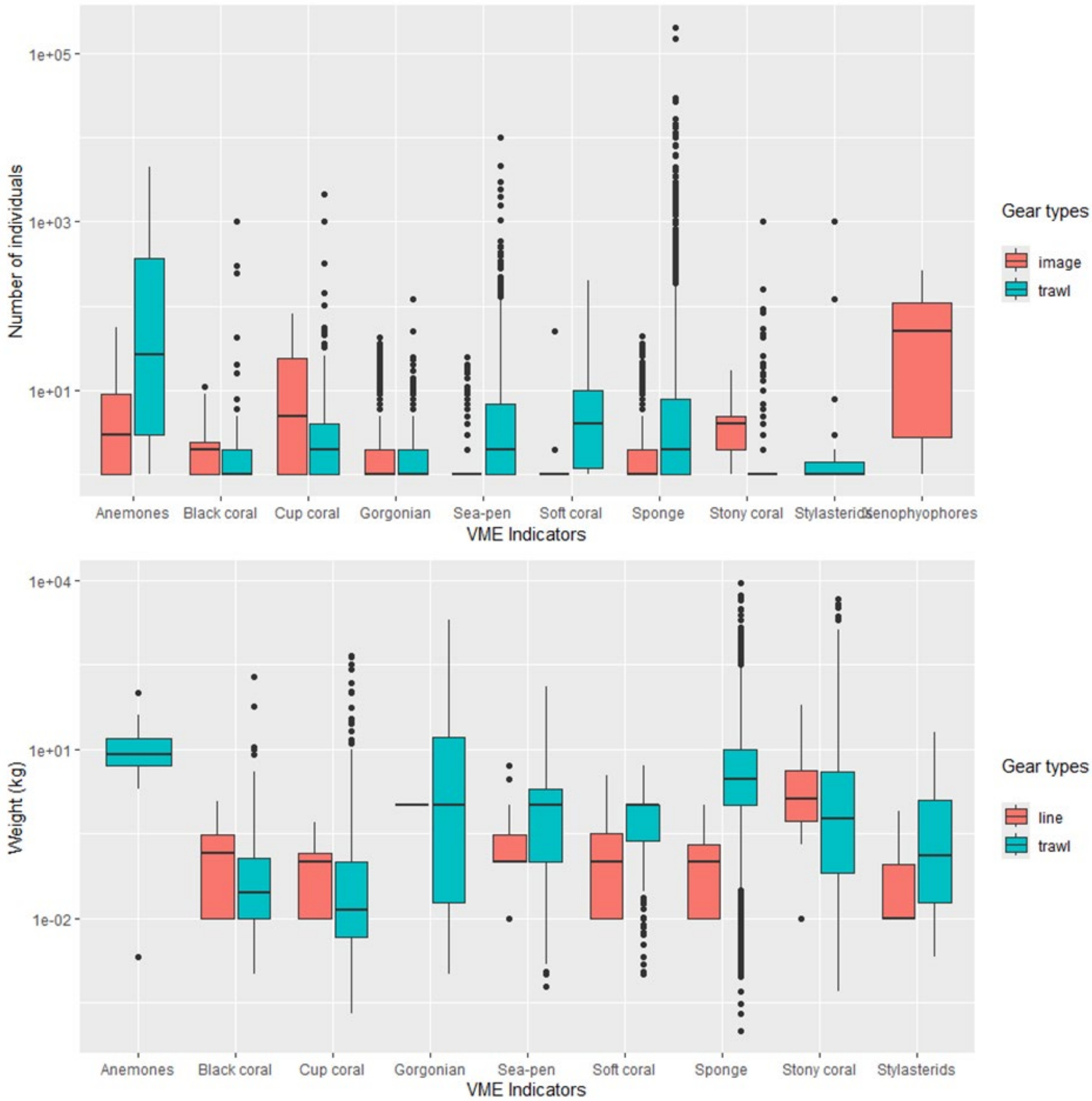

Figure 6.1. Boxplots of the number of individuals (top panel) or weights (bottom panel) in imagery-based and trawl bycatch records grouped by VME Indicators.

Table 6.5. Highest taxonomic resolution of records per VME indicator groups (the taxonomic resolution of records has been extracted from a match with the world register of marine species).

VME Indicators	Phylum	Subphylum	Class	Order	Family	Genus & species
Anemones	-	9	106	316	21	1731
Black coral	-	-	-	532	-	1424
Chemosynthetic species	-	-	-	-	-	11
Cup coral	-	-	-	609	75	805
Gorgonian	-	-	-	1875	139	10561
Sea-pen	-	-	-	5336	28	7544
Soft coral	1	-	2	165	138	697
Sponge	14805	-	114	415	6458	5551
Stony coral	-	-	-	4599	-	2405
Stylasterids	-	-	8	-	33	19
Xenophyophores	-	-	7	-	-	10

In ICES advice, evidence of VME occurrences is provided at the scale of 0.05 C-squares to match fishing effort. Another way to assess the likelihood of VME Indicator occurrences could thus be to sum records per C-square (Figure 6.2). The number of records per square varies according to gear types and is higher for imagery than trawls but for both the median does not exceed 5 records per C-squares. Images as points (i.e. single images) provide the highest number of records per C-squares because each image along a transect is a record, compared to video transects where each line is a record.

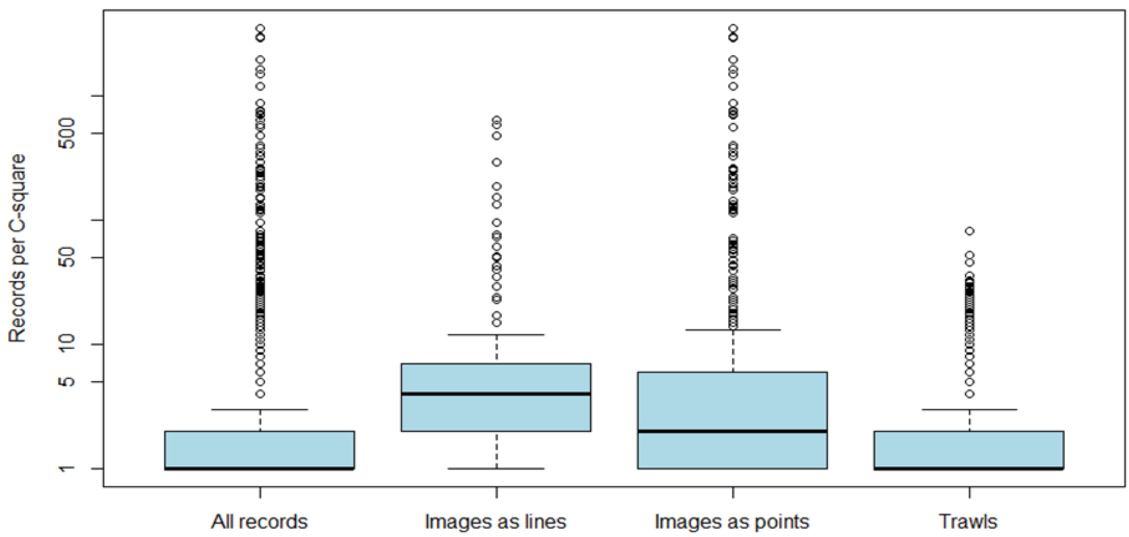

Figure 6.2. Boxplot of number of records per 0.05 C-squares for all records and according to gear types. For records as lines, the middle latitude and longitude have been used.

For records as lines, either from imagery-based transect or trawl bycatch, the middle latitude and longitude of the line have been used in Figure 6.2. However, these lines may cross several C-squares, in particular half of the trawls intersect at least two C-squares (Figure 6.3). In Figure 6.3 the largest outliers, intersecting over 20 C-squares have been removed. As underlined in ToR C, some trawl lengths are unrealistic but it holds also true for some imagery-based surveys.

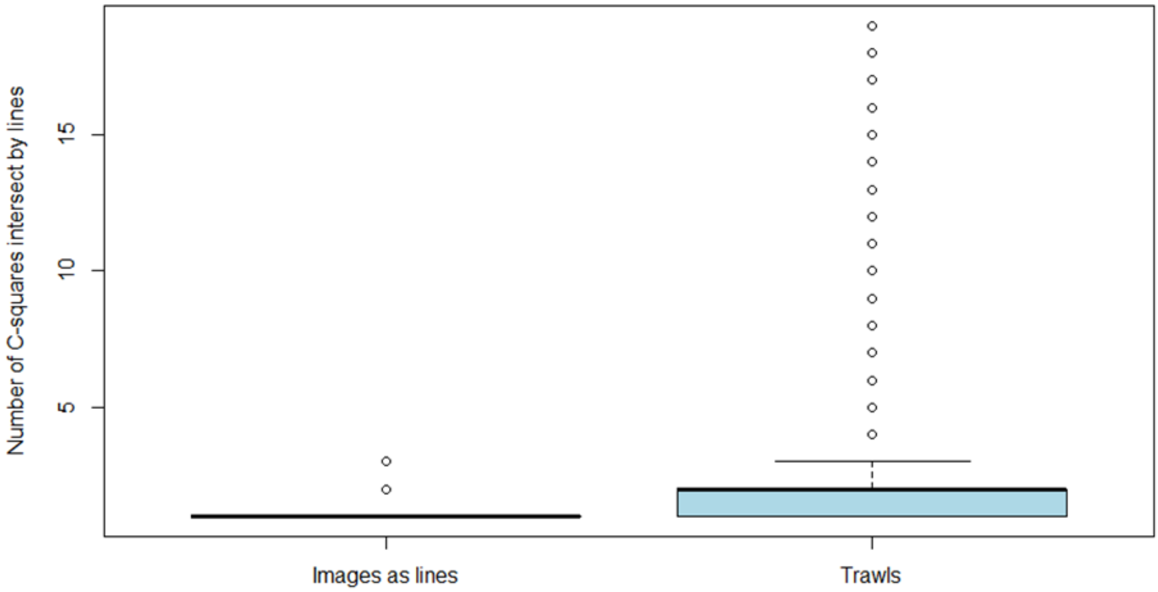

Figure 6.3. Boxplot of the number of 0.05 C-squares intersect by Imagery-based transects and trawls. The most obvious outliers (> 20 C-squares) have been removed.

Overall, the ICES VME database has accumulated a very large number of records over the years, which may support the development of a VME likelihood index based on VME occurrences and abundance. However, as already shown in ToR C, a preliminary analysis of the data underlined some caveats, including errors as well as missing or unstandardised metadata. A core VME data review group would need to be established, in association with ToR C, in order to update the database where it can be or flag dubious records. Beyond data cleaning, the group would provide an overview of the nature and quality of data available in advance of the workshop. The data compilation group would work on a copy of the database and keep track of all changes made in its content. This proposed group should work in coordination with the ICES Data Centre to ensure that changes made are consistent and compatible with ICES data centre data call submission standards.

6.4 Defining thresholds

The ICES VME database provides a suite of variables that may inform on the likelihood of VME occurrence, including taxonomy, abundance, and spatial coordinates of VME indicator taxa. Such data have previously been used to define VME thresholds in support of encounter rules or fishing closures. Two families of methods have been used, either spatially independent or spatially dependent.

Spatially independent methods rely on cumulative catch curves. *South Pacific Regional Fisheries Management Organisation* (SPRFMO) for example uses the 99th percentile of cumulative catch weight to define encounter rules for single-taxon and the 80th percentile for multiple taxon (Cryer et al., 2018). Similarly, in the Northwest Atlantic Fisheries Organization (NAFO) Area, 90% to 97.5% weight quantiles were suggested to define thresholds for large gorgonians and sea pens respectively (NAFO, 2008). However, the choice of a weight percentile is somehow arbitrary and may depend on management objectives (Penney et al., 2008). Alternatively, spatially-dependent methods provide evidence for the local aggregation of VME taxa and a biological basis for defining thresholds (Kenchington et al., 2009). In the NAFO Area, Kernel Density Estimation (KDE), supplemented with species distribution modelling, have been used to identify and map significant concentrations of large-sized sponges, sea pens, small and large gorgonian corals, erect bryozoans, sea squirts, and black corals (Kenchington et al., 2019, 2014). A first attempt at using this method with the ICES VME database, focusing on sea pens on the Rockall Bank, underlined some limitations, particularly in the density of data available (ICES, 2019b). The report concluded that "further work could be done to standardise the data in order to optimise the application of these tools to the data in the ICES VME database. Other spatially-dependent tools for analyzing spatial distributions and patterns, such as hotspot analysis, which look for clusters of data and displays those clusters as hotspots (Getis and Ord, 1992), has been applied to abundance data of marine predators and marine mammals in the Arctic (e.g., Hamilton et al., 2021; Yurkowski et al., 2019). This tool has been preliminary applied to sea pen records in the Celtic Sea ecoregion (ICES, 2021). However, WGDEC noticed that there was not enough time to perform a complete analysis during the meeting.

6.5 The workshop

The workshop will aim at combining multiple lines of evidence from a variety of data sources, including imagery surveys, trawl by-catches, high-resolution bathymetry, and eventually predictive habitat models, in order to propose taxa-specific and a generic all-taxa VME likelihood Index. The index shall rank likelihood as high, medium or low in order to fit with the procedure for the production of recurrent ICES advice on VMEs (ICES, 2022).

The workshop should be scheduled ideally in February 2025, to be reviewed by WGDEC during its annual meeting in 2025, and held at ICES headquarters as the workshop will heavily rely on ICES database managers and coders. We expect the workshop to last for 5 days. A core data group will review and synthetise data in the ICES VME database beforehand and meet by the end of 2024.

We expect the workshop to be attended by about 30 participants, including database and coding support, WGDEC members, experts from other RFMOs with expertise on developing criteria for the identification of VMEs, data providers and regional experts as well taxonomic experts.

Proposed draft terms of reference can be found in annex 2.

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7 ToR E: Review and update advances in knowledge of the life history, connectivity and ecology* of VME indicator taxa in the Northeast Atlantic and identify research priorities.

* refers to reproductive ecology

7.1 Key messages/points

- Moving from individual closures mindset to a network of closures
- Connectivity does not (and should not) undermine other conservation targets or areas, it should reinforce them
- Provide a conceptual framework for management on how connectivity can be implemented (from simple to complex)

7.2 What is connectivity (in a VME context)?

In its broadest sense, connectivity is defined as a flux of material and energy between locations (Cowen and Sponaugle, 2009). To incorporate connectivity in a VME context, we concentrate on ecological spatial connectivity.

Table 7.1. Ecological spatial connectivity and its aspects

Ecological spatial connectivity			
Structural	Landscape (Seascape)		Potential
Functional	Population	Demographic	
		Genetic	Realized
	Community		Potential

Ecological spatial connectivity "*refers to processes by which genes, organisms, populations, species, nutrients, and/or energy move among spatially distinct habitats, populations, communities, or ecosystems*" (Carr et al., 2017) (Table 7.1). Structural connectivity focuses on the structure of the physical environment (seascape) and the spatial configuration of areas/units/closures to be connected. In the marine environment, it is estimated most often with a metric of distance (e.g. least cost path). Functional connectivity focusses on elements of movement (e.g. random dispersal, larval behaviour) and their outcomes (e.g. self-replenishment, stepping stones, population growth and persistence). Functional connectivity can be estimated (i.e. within a generation) at the level of individuals (demographic), communities or ecosystems. Our current methodologies for these organization levels mostly allow us to estimate potential connectivity because of the difficulty in tracking individual propagules. Genetic connectivity operates at the level of genome and is calculated based on population genetic structure; as such it can be considered realized connectivity (at least for benthic organisms) and can quantify connectivity between reproducing adults.

7.3 Why is connectivity important for VMEs?

Including connectivity in the VME closures context will ensure that VMEs persist in the future, by replenishing populations within and outside a VME closure. VMEs are benthic species with a planktonic larval stage, meaning that spatial dispersal is only possible during that life stage that lasts for a relatively short period of time (days/months compared to adults that can live centuries). Therefore, connectivity in VMEs can be achieved in two ways: 1) VME closures are big, including different VMEs that are able to self-replenish the populations within the closure; 2) VME closures are small and close to each other, so they can exchange propagules.

7.4 What connectivity related biological and ecological aspects are implied FAO characteristics?

List of VMEs have been growing since their inception in 2009 (FAO, 2009), including a wide range of species and habitats, making it difficult to evaluate connectivity metrics for each species separately. However, VME characteristics based on biological and ecological aspects of VMEs in general that can underpin connectivity in ICES protocols (Table 7.2).

Overall, VME characteristics point towards the need for long term closures that can and should be evaluated in a network manner to account for connectivity. In the absence of specific data (see next section), a precautionary approach is desirable for placement and sizing of VME closures (examples in Table 7.2). This includes e.g., stepping stones between VME closures and buffer zones around them, serving to reduce the effect of increased suspended sediment concentrations cause by bottom trawling fisheries (Wedding et al., 2013). The largest dimension of VME closure should be at least twice the mean dispersal distance of target species (Botsford et al., 2001; Wedding et al., 2013). Many VME closures could be refugia sites, which is especially important for climate change.

7.5 How can connectivity be measured and estimated?

Connectivity can be measured and estimated in several ways, from very simple with high uncertainty to very complex with lower uncertainty, but high computational and data demands (Calabrese & Fagan, 2004; Metaxas & Saunders, 2009, Wilcox et al., 2023). Table 3 shows different options for estimating and measuring connectivity, with VMEs in mind, start with application of simple rules of thumb (Carr et al., 2017; Balbar et al., 2024) to complex approaches that include biophysical modelling and genetic approaches. The simple answer is that connectivity can be included in VME closures planning if VME indicator species locations (polygons), PLD and current speeds are available. This can give an idea of minimal distances needed between VME closures to ensure connectivity as well as minimal sizes of VME closures to ensure self-replenishment. More complex approaches can be used in cases of species-specific questions, identifying potential and/or realized connectivity between patches of suitable habitat (Ross et al., 2019; Taboada et al., 2023).

Table 7.2. Evaluation of biological and ecological aspects related to connectivity based on FAO (2009) characteristics.

Characteristic	Definition	Comments
Uniqueness or rarity	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include:	Hydrothermal vents/ fields, cold seeps and black corals are VMEs that scored the highest for this characteristic based on expert opinion (Morato et al., 2018; ICES, 2020).
	habitats that contain endemic species;	Endemic species are especially found in hydrothermal vents/fields and cold seeps. Connectivity between VME closures containing these VME indicators can be achieved if there is high local retention of propagules to maintain a population, especially if populations are geographically isolated, or species have very long PLD, where propagules can potentially travel large distances between populations (Baco et al., 2016). Stepping stones between populations (VME closures) are recommended (Breusing et al., 2016). Buffer zone surrounding VME closure is desirable to minimize effect of suspended sediment from bottom trawling on larval dispersal.
	habitats of rare, threatened or endangered species that occur only in discrete areas; or	Discrete areas where these species (e.g., black corals) occur should be included as VME closures. Biophysical modelling should be used to evaluate how are these VME closures connected, which will help identify closures that contribute the most to population connectivity (e.g., black coral patches in Wang et al., 2024).
	nurseries or discrete feeding, breeding, or spawning areas.	VMEs are often used by (but limited to) commercial mobile species (e.g., fish and crustaceans) as feeding, breading and spawning areas. This implies that during planning of VME closures, corridors and stepping stones are critical. As these closures are essential for early life history stages, they should be big enough to ensure survival of the young.

Characteristic	Definition	Comments
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.	Hydrothermal vents/ fields, cold seeps and large sponges are VMEs that scored the highest in this category based on expert opinion (Morato et al., 2018; ICES, 2020). More detailed description of functional significance of a habitat (defined through the species or the ecosystem function/s) can help understand how to approach integrating connectivity in the management of that VME closure. For example, if a VME closure contains a sponge that has an important role in nutrient recycling (Bart et al., 2021) and has very short planktonic larval duration (PLD) (e.g., 24h, Ross et al., 2019), it would be preferable to have a larger VME closure that can self-replenish and grow, thus increasing the magnitude of the ecosystem function and persistence of the population.
Fragility	An ecosystem that is highly susceptible to degradation by anthropogenic activities.	Stony corals and xenophyophores are VMEs that scored the highest in this category based on expert opinion (Morato et al., 2018; ICES, 2020). To help maintain connectivity between VME closures with very fragile VMEs, size of the closure plays an important role; either as big as available or as big as needed to sustain self-recruitment. Additionally, buffer zones could be included as means to ensure that any far-reaching effects of bottom trawling (suspended sediments) are accounted for, as they can cause physiological stress and increase mortality of those VMEs (Grant et al., 2018, Bilan et al., 2023).
Life-history traits of component species that make recovery difficult	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics:	Stony corals, black corals and gorgonians are VMEs that scored the highest in this category based on expert opinion (Morato et al., 2018; ICES, 2020). Climate change impacts (e.g., increase in temperature, reduced downward food availability (Maier et al., 2023)) can have important effects on VMEs life history traits (e.g., fecundity output) that directly affect connectivity. Additionally, early life stages are vulnerable to climate change impacts, probably more than adults. Life history traits of VMEs directly imply that VME closures should be long-term.
	slow growth rates;	For connectivity, growth rates of propagules determine how long they are in the water column, known as planktonic larval duration (PLD) which translates to dispersal distance=PLD [days/months] x current velocity [meters/second] (Hilário et al., 2015). Slow growth rates of adults mean they will have an influence on the number of propagules produced by that VME closure only after a specific amount of time, but surely not within several years.

Characteristic	Definition	Comments
	late age of maturity;	VME closures should include larger/older organisms to maximise larval/gametes supply to other closures, especially considering their slow growth rates (Waller et al., 2014).
	low or unpredictable recruitment; or	VME closures should include suitable habitat for recruits, to maximise survivability of low numbers of recruits. Genetic studies and modelling can help understand the connectivity between closures, to maintain source populations and identify suitable sinks (e.g., Taboada et al., 2023).
	long-lived.	This characteristic implies that if closed for long time in good conditions, VME closures can supply propagules and grow for a long time.
Structural complexity	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.	Stony corals are VMEs that scored the highest in this category based on expert opinion (Morato et al., 2018; ICES, 2020). VME closures containing VMEs that contribute to the structural complexity of the habitat, contain associated species which are usually not targeted in conservation or commercial purposes (e.g., Rueda et al., 2016). In this case, connectivity of those species is incorporated under the VME closures umbrella.

Table 7.3. Summary of approaches, data requirements and feasibility of using them to estimate or measure connectivity for VME closures. For types of ecological spatial connectivity, refer to Table 7.1.

Ecological spatial connectivity type	Approach	Estimate or metric	Data required	Is that data available? If not, proposed data collections	Feasible for VME closures?
Structural	Rules of thumb	Dispersal distance for an VME	VME indicator locations, PLD, current speed	VME locations are available. Mean PLD for eurybathic and deep species is 35 days (Hilário et al., 2015). Current speeds are available from global or regional hydrodynamic models.	Yes
		Dispersal distance for a VME indicator	VME indicator locations, VME indicator specific PLD, current velocity (velocity include speed and direction)	VME locations are available. VME indicator specific PLD is available for some VMEs. In case it is not, PLD of a phylogenetically closest species can be used. Current velocities are available from global or regional hydrodynamic models.	It is possible for most VME indicator species

Ecological spatial connectivity type	Approach	Estimate or metric	Data required	Is that data available? If not, proposed data collections	Feasible for VME closures?
	Biophysical modelling (particle tracking)	Dispersal distance for a VME indicator	VME indicator locations, VME indicator specific PLD or range of possible PLDs, output from a hydrodynamic model (e.g., monthly averages per grid cell), biological parameters for VME indicator (fecundity, larval swimming, time of spawning)	VME locations are available. VME indicator specific PLDs and ranges of potential PLDs are available for some VMEs. Global or regional hydrodynamic models. Biological parameters, including species specific PLD, are difficult to obtain for VMEs, but focused experimental studies and direct observations (plankton studies) along with modelling approaches are ways to improve on this.	It is possible for some VME indicator species
	Biophysical modelling (particle tracking) + graph theory	Connectivity metrics (in/out degree; local retention; betweenness centrality	Same as above	Same as above	Same as above
Functional	Direct measures	Estimates of dispersal based on population genetics (PKG dispersal distance)	VME indicator locations where genetic material was sampled, isolation by distance - based on genetic markers (Baco et al., 2016)	Data is available for few VME indicator species in specific regions	It is possible for few VME indicator species, in specific regions
	Biophysical modelling + graph theory + genetic studies	Connectivity metrics (in/out degree; local retention; betweenness centrality	VME indicator locations, VME indicator specific PLD or range of possible PLDs, output from a hydrodynamic model (e.g., monthly averages per grid cell), biological parameters for VME indicator (fecundity, larval swimming) and genetic similarity between sampled locations (same as above)	Same as above, with the addition of limitations for biophysical modelling and graph theory	It is possible for few VME indicator species, in specific regions.
	Biophysical modelling + graph theory + genetic studies	Same as above, at lease	Same as above, plus habitat suitability models for VME indicator species and climate change scenarios as predicted	Same as above, with the addition of limitations of habitat suitability models outputs and climate change outputs	No

Ecological spatial connectivity type	Approach	Estimate or metric	Data required	Is that data available? If not, proposed data collections	Feasible for VME closures?
	+ habitat suitability models + climate change scenarios		habitat suitability models and predicated hydrodynamic models		

7.6 Challenges:

- VME index now does not include species, which is valuable information. Is it possible to maintain species data within the VME index somehow? – Can we use the VME database and ignore the VME index for connectivity questions?
- *In situ* data collection on propagules (e.g. survival, behaviour); however, this can be overcome by considering outcomes of different scenarios (e.g. for different behaviours, larval duration etc); scenarios can be considered for all approaches from the rules of thumb to complicated biophysical modelling
- Difficulty of setting targets for potential connectivity (how much is enough); easier if the purpose is to preserve specific locations (i.e. VMEs or stepping stones) of limited areas (close in its entirety) or close a size large enough to ensure self-recruitment equal to replacement of individuals; harder to predict on a network scale because this requires knowledge of true estimates of biological parameters (e.g. survival, fecundity, spawning time); for genetic connectivity, one can use the number of migrants to maintain population size based on data on population structure
- Ignoring connectivity can have severe consequences and may undermine closure efforts (loss of larval sources)
- Climate change: Changes in connectivity (in addition to through effects on the biological parameters such as PLD, survival etc) can be manifested through changes in habitat suitability and changes in ocean density structure and circulation; dynamic closures are being considered to account for these types of changes; hard to predict impacts on realized connectivity.
- Evidence from several studies with cold-water coral species (conducted within iAtlantic and not published yet) that PDL is likely to decrease with warming and swimming speed is likely to decrease with ocean acidification. This perhaps can help in the discussion on the large closure vs small closures close to each other.
- Fox et al., 2016 shows how connectivity of Lophelia was quite sensitive to changes in the state of dominant physical forcing modes like the NAO - so it is not just changing water mass properties that change larval connectivity in future, but climate change may in some regions also bring about changes in the circulation pathways and strength of ocean currents, which will also reconfigure connectivity.

7.7 References:

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8 ToR F: Conduct a literature review of the impact of different bottom-contact static gears on VMEs and understand the ecosystem effects of different static gears and begin a preparatory framework for a future workshop aiming to review and assess the impact of different gear types on VMEs across the ICES area.

8.1 Introduction and Background

This section reports on Term of Reference [f] with the aim to address uncertainties highlighted in the ICES advice on areas where Vulnerable Marine Ecosystems (VMEs) are known to occur or are likely to occur in EU waters (ICES, 2023), which stated that *the interaction between static gear and the seabed is variable among gear types (e.g. gillnets, pots, longlines) and is generally not well understood*.

Bottom longlining, particularly in deep-sea areas, is considered to have a lower impact on VMEs than mobile bottom-contact gears, reducing bycatch of cold-water corals and limiting additional damage to benthic communities (ICES, 2024). At the 2024 meeting, WGDEC reviewed available information on the effects of bottom-contact static gears on VME (including differences inherent to regions) to understand the ecosystem effects of different static gears.

8.2 Static fishing gears used in ICES area

The Working Group on Spatial Fisheries Data (WGSFD) have used VMS data as an indicator of static gear fishing activity (ICES, 2022). However, it was noted that, fishing with static gears is often an inshore activity carried out using relatively small vessels, with many of them below the length at which are required to carry VMS equipment or log-books. Additionally, WGSFD found difficulties in the development and application of a speed threshold to determine the location of fishing due that the speeds observed when the gears are deployed overlap with steaming speeds. Therefore, maps produced by WGSFD can be used to highlight locations where fishing with static gears takes place, and have some qualitative information of areas of higher and lower effort, but are not suitable to provide a quantitative assessment of the distribution of fishing effort. Additionally, other parameters such as soaking time, gear length, number of hooks, etc., are needed to have an accurate estimate of the effort of the passive fishing gear. However, the availability of this type of data varies from country to country (ICES, 2022).

From the analysis of fishing effort (MW hours fished) based on VMS for static gear groups by ICES area, for 2019 and 2020, longlines presented the higher effort with around half of the total MW hours fished, followed by nets with 43% of the effort and traps with around 7% (ICES, 2022). When we look at the national fishing fleets using static fishing gears in each ICES ecoregion, we can observe that bottom longlines and entangling nets are commonly used by most of them, followed by traps and bottom handline (https://www.ices.dk/advice/Fisheries-overviews/Pages/fisheries-overviews.aspx).

8.3 Impacts of static fishing gears on VMEs

To date, most studies exploring the impact of fishing gear on the benthic environment have been centered around the impact of mobile fishing gear, in particular bottom trawling and dredging. Due to the fact that static fishing gear is highly selective and relatively stationary, it has generally assumed that cause little damage to benthic communities. However, similarly than with mobile gear, the effects of static gear on benthic habitats will depend on the magnitude and frequency of the impact, the biological community present and the type of gear being used (e.g., Lumsden et al., 2007; Johnson, 2022).

Here, we provide a review of the impacts caused by the main static gears used in the ICES area, such as bottom longline, static nets (which includes gillnets), and traps or pots. Information on handlines is limited but the observed bycatch is small compared to other static gears and therefore the impacts are considered to be negligible (FAO, 2021).

8.3.1 Bottom longline

Longlines and other line fishing methods, including handlines, are used all over the world to catch a wide variety of demersal fish species (Bergstad and Hareide, 1996; Gordon et al., 2003; Clark et al., 2007; Bensch et al., 2009). They are passive capture techniques which are based on attracting fish to baited hooks and, despite variations in design and mode of operation, they are generally simple and easy to operate. The bottom longline gear consists of anchors, nylon line and baited hooks and is fixed to bottom by anchors. Although considered to have lower impact on the benthic environment than trawls (e.g., Chuenpagdee et al., 2003; Lumsden et al., 2007; Jenkins and Garrison, 2013), they may still present negative effects in areas with high fishing intensity (Mortensen et al., 2005; Vieira et al., 2015; Clark et al., 2016), although quantitative information on the impact of bottom longline on the deep sea is scarce (Auster et al., 2011). Longlines are particularly effective in rocky seabed whereas the hard sediments affect the performance of bottom trawls, making these substrates not suitable for fishing with this type of gear.

Impacts on VMEs

Bycatch of different groups of vulnerable marine ecosystem (VME) indicator taxa have been reported in different studies using deep-sea longlines (Table 1). In addition, sponges and corals have been observed broken by longline weights (e.g., Fossa et al., 2002; Mortensen et al., 2005; 2008), or cut by the mainline while moving laterally during fishing or hauling (Welsford and Kilpatrick, 2008). However, little is known on the mortality rates of organisms that remain damaged on the seafloor (Kilpatrick et al., 2011), longline selectivity and the overall level of impact of longline operations for benthic communities.

Bavestrello et al. (1997) concluded that the major cause of mortality in *Paramuricea clavata* on the Portofino Promontory was damage to the colonies by fishing line, followed by the attachment of numerous epibionts. Some of the colonies could be detached due to a single physical event such as an anchor dragging. Whereas in other cases, the fishing line can cause abrasion of the tissue which can allow epibiont organisms to settle on the stripped branches, forming large aggregations. The burrowing activity of some of them can result in a weakening of the skeleton, which is then more likely to break, resulting in the detachment of the colony. Mortensen et al. (2005) found colonies damaged by longline colonized by parasitic zoanthid anemones.

Rates of coral by-catch is highly variable between studies. Krieger (2001) found the gorgonian *Primnoa* and other corals species caught on 0.11% of hooks that were fished during the sablefish longline survey in the Gulf of Alaska and Aleutian Islands. Whereas, Mortensen et al. (2005) found that 4% of observed gorgonian corals with video surveys were impacted by longline, although they observed broken or tilted corals along 29% of the transects carried out. Mortensen et al. (2008) found corals in 24% of the sets with longline in the Mid-Atlantic Ridge. Duran-Muñoz et al. (2011) provided values of catch per unit effort (kg/1000 hooks), funding that the largest biomass of catch was for stony corals with values between 9.3 and 0.1 kg per 1000 hooks. Through the use of interviews with fisherman, Sampaio et al. (2012) reported an occurrence of 15.2% of fishing trips surveyed that landed coral specimens, being most of them complete colonies, although a 28% were damaged or fragments. Data collected from accidental coral catches during an experimental longline fishing survey in the Mediterranean Sea using two different hook sizes showed a 72% of occurrence rate of cold-water corals (Mytilineou et al., 2014), compared to 55% occurrence reported by D'Onghia et al (2012) in the *Lophelia* banks off Santa Maria di Leuca, also in the Mediterranean Sea.

Pham et al. (2014) reported different levels of bycatch and in situ damages by bottom longlines for two cold-water species with contrasting morphological complexities. The unbranched whip coral (*Viminella flagellum*) was significantly less abundant in the bycatch compared to the branched gorgonian (*Dentomuricea* aff. *meteor*) despite being equally abundant in the area surveyed. Most of the samples (96%) of the unbranched whip coral included intact or bent organisms, whereas almost half of the samples of the branched gorgonian included damaged (44%), displaced (1%) or dead colonies (3%). The authors suggest bottom longlines to have an unbalanced impact on benthic communities with potential long-term shifts in community structure. The study concluded that deep-sea bottom longline fishing has little impact on vulnerable marine ecosystems, reducing bycatch of cold-water corals and limiting additional damage to benthic communities. It stated that slow-growing vulnerable species are still common in areas subject to more than 20 years of longlining activity and estimate that one deep-sea bottom trawl will have a similar impact to 296–1,719 longlines, depending on the morphological complexity of the impacted species.

Understanding the impacts of static gears such as longlines is difficult because the extent of the area disturbed cannot be easily determined using existing methods (Auster and Langton, 1999). In a longline survey in the southern hemisphere, Welsford and Kilpatrick (2008) recorded the interactions between the main line and the benthos during setting and hauling with a video camera. They estimated that up to 0.122 km^2 of seafloor was swept by the line while it was being retrieved. They also provided evidence that VME indicator taxa could fall off the longline hooks before reaching the surface and therefore the surface observations of VME taxa bycatch are likely to underestimate of the real level of interaction.

Numerous studies have highlighted the significant impacts of abandoned, lost, or otherwise discarded fishing gear (ALDFG) from longline activities on marine environments (e.g., Van den Beld et al., 2017; Melli et al., 2017). While lost traps and nets may continue to catch fish and larger mobile invertebrates, lost longlines and ropes predominantly interact with sessile epibenthic organisms (Vieira et al., 2015). Instances of entanglement have been recorded across various species, including reef-building corals, octocorals, black corals, and sponges (Orejas et al., 2009; Pham et al., 2013; Bo et al., 2014; Angiolillo et al., 2015; Enrichetti et al., 2019; Otero and Marin, 2019; Betti et al., 2020). Lost (or discarded) longlines have been found snagging coral branches or resting on vulnerable cold-water coral species, further exacerbating damage (Cau et al., 2017; Dominguez-Carrió et al., 2020). Gorgonians, habitat-forming sponges, hydrocorals, and reef-building corals are especially susceptible to damage from lines and ropes (Pham et al., 2013; Oliveira et al., 2015; Angiolillo et al., 2015; Rodríguez and Pham, 2017; Consoli et al., 2018). Entanglement in derelict fishing lines is also considered to cause severe harm to corals, resulting in evident tissue damage and epibiosis by fouling organisms, often leading to high mortality rates (Asoh et al., 2004; Yoshikawa and Asoh, 2004).

8.3.2 Static nets

Static nets are assumed to have a smaller footprint than that of trawling (Ragnarsson et al., 2016), the degree of damage from individual static net fishing operations is likely to be lower than for trawling (Fosså et al., 2002), and biological features are likely to have lower susceptibility to impacts from static nets compared to mobile gears (Grabowski et al., 2014). However, cumulative damage from static nets may be significant. Stakeholder surveys undertaken by Chuenpagdee et al. (2003) found that bottom gillnets, a type of static net, were deemed as having a high degree of impact, and Fuller et al. (2008) found that stakeholders in Canada considered bottom gillnets to have second highest severity of habitat impacts after bottom trawls.

A number of variables affect the impacts caused by static nets, including the length of demersal static nets, gear set up (e.g. rope strength), the depth in which it is deployed, and the area where it is deployed, both in terms of the environmental conditions (currents, weather), the physical habitat (reef height) and the biodiversity (DFO, 2010). Abrasion on the seabed arises due to the anchors at each end of the net (these can weigh 20-120kg; Baer et al., 2010), the weighted footrope, and the net itself (Clark and Koslow, 2007; DFO, 2010). Active set gillnets can move with any near-bottom-currents or when meshed fish try to escape, causing the nets to be pushed onto the seabed (Buhl-Mortensen et al., 2013; Clark and Koslow, 2007; High, 1998). The hauling of set nets can also result in impacts, which can be exacerbated by the use of mechanical net haulers or power blocks (Munro et al., 1987, cited in Jennings and Kaiser, 1998).

Fisheries using static nets can also target locations which are unsuitable for trawling, that may host coral or sponge habitats (Ragnarsson et al., 2016; Fernandez-Arcaya et al., 2024). Site specific difference in VME density are likely to affect the extent of any impact. For example, Shester and Micheli (2011) suggest that if set gillnets are placed in areas with higher abundances of biogenic habitats, or in areas of high biological importance, the relative impacts to species abundance or ecosystem functions would be greater. Effects may therefore be significant if static gear activity is localised in relatively small areas with communities of long-lived species (Jennings and Kaiser, 1998).

Impacts on VMEs

Species that are caught or become entangled in static nets, such as gillnets, can be left damaged on the seabed, or be 'plucked', or torn loose from the seabed during hauling and brought to the surface (Buhl-Mortensen et al., 2013; Fosså et al., 2002; ICES, 2010; Mortensen et al., 2005; OSPAR, 2010; Shester and Micheli, 2011; Wareham and Edinger, 2007; DFO, 2010). Static nets can also cover and choke benthic communities, and coral colonies can be abraded by net meshes during fishing operations (Bo et al., 2014).

In Fisheries Observer Program data from Canada, bycatch of soft corals, seapens, cup corals and gorgonians were recorded in gillnet fisheries from areas deeper than 125 metres (Edinger et al., 2007). The rate of coral occurrence in gillnets (from fisheries observer program data for all directed species) was 7%, and the percentages of gillnet sets containing corals per 20x20km grid cell peaked at 38.4% during the study period. Frequencies of coral bycatch were driven by fishing effort and the spatial distribution of corals (Edinger et al., 2007). In another study off Canada, the Fisheries Observer Program recorded 150 occurrences of coral bycatch in gillnets over a two-year period (Wareham and Edinger, 2007), including seapen species. Edinger et al. (2007) noted that coral bycatch occurred in all gear types deployed in areas of peak coral abundance and was not specific to a certain gear type or directed species, however Wareham and Edinger (2007) found that bycatch in gillnets did occur at a lower frequency than otter trawls.

In a study off Portugal, 85% of bottom-set gillnet deployments caught cold-water corals, 45% of which were entire colonies (Dias et al., 2020). Twenty-two different coral species were recorded as bycatch. Coral bycatch was higher when the nets were deployed on or nearby areas where rocky substrate is known to occur. The average coral Catch per Unit Effort (CPUE) was 0.92 per day with a 100 m net length (31.1 corals per set), however this increased to 13.02 over rocky substrates.

A study by Enrichetti et al. (2019) investigated the impact of trammel nets, another type of static net, on rocky reefs in the NW Mediterranean Sea. Authors reported that 40% of the structuring anthozoans at the study site showed signs of impacts. Entanglement was found to be the most common impact, involving 30% of the structuring anthozoans on average, but other impacts included the presence of necrotic portions and overgrowth of epibiotic organisms. Three gorgonian species had the highest percentage of impacted colonies and were more epibionted/necrotic, whilst the red coral *Corallium rubrum* had the lowest percentage of impact. The non-commercial organisms representing the highest percentages of benthic discards from the trammel net fishing were cnidarians (32%), bryozoans (22%), echinoderms (17%), and macroalgae (15%). Sponges represented 6%, with high levels of diversity amongst these sponge discards. Calcarous bryozoans showed the highest average catch rate, followed by flexible gorgonians. Of the bycaught gorgonians showing living tissue, 16% were entire colonies and 84% were fragments. Trammel nets collected a high-proportion of biogenic detritus, mainly comprised of long-term dead fragments of bryozoans (41%) and corals (54%, including red coral branches, solitary corallites, and gorgonian skeletons).

Another study in coastal waters in Baja California (Pacific Ocean) found that on average 16.8% of gorgonian corals were damaged or removed within 1m of set gillnet paths (Shester and Micheli, 2011). Of 22 coral interactions with set gillnets, 36.4% resulted in full removal of the coral, 40.9% in partial damage and the remaining 22.7% had no visible damage. Sponges were also recorded as bycatch in the set gillnets.

Limited evidence was available on specific impacts on sponge aggregations, anemones, stylasterids, stalked crinoids, bryozoans, chemosynthetic species and xenophyores (Table 1). Free-living species, such as anemones and stalked crinoids, may be able to free themselves and move away to avoid becoming entangled in nets, however (Ballesteros et al., 2018).

In intensively fished areas, the rate of gillnet gear loss could be high (Ragnarsson et al., 2016). Ghost fishing impacts from these lost static nets will depend upon the size, shape, location and length of time of the net in the ocean (Gerrodette et al., 1987). A study in Canada by Gerrodette et al. (1987) found that pieces of derelict gillnet collapsed down from their original active fishing configuration fairly rapidly due to the weighted leadline (for example, nets less than 100m collapsed in less than a day). If buoys are attached, this could keep the net open for longer, or if large animals become entangled it could collapse sooner. Nonetheless, these collapsed gillnets are still capable of entangling species.

Lost static nets are known to provide suitable artificial substrates for benthic species to settle, for example anemones and stalked crinoids (Ballesteros et al., 2018). However, entanglement of branching corals is considered to have negative effects. For example, Grehan et al. (2004) observed lost tangle nets on the Porcupine Bank filled with coral bycatch and lost rope from static nets entangling corals, including *Desmophyllum pertusum* (formerly *Lophelia pertusa*), suggesting snagging had occurred. In Norway, lost gillnets have been observed covering parts of *D. pertusum* coral colonies (Baer et al., 2010). Resulting damage can include fragmentation, fresh tissue loss, and tissue loss with algal grown (Ballesteros et al., 2018). In a study by Ballesteros et al. (2018), 67% of corals underneath lost gear (mostly nets) showed damage compared to control sites (18%). Once nets settle on the seabed, they can also become sediment traps, submerging corals underneath, restricting movement and their ability to clean themselves of sediment, and resulting in mortality.

8.3.3 Traps

Traps or pots are passive gear types that rely on bait to attract the target species. They are one of the most commonly used types of fishing gear, especially in fisheries for crabs, lobsters, shrimp, crayfish, fish, whelks, and conchs (Stevens, 2021). They can be used in a wide range of habitats and depths and are deployed by a wide range of vessel sizes. In shallow waters traps can be individual with just one buoy, but fisheries that occur in deeper water, often employ strings of traps (often called "trawls", "fleets", or "rigs") attached to a single ground line with one buoy line at each end (Stevens, 2021). When fishing in areas subject to powerful waves and/or tidal currents, anchor-weights are usually attached to the ends of the string to prevent it dragging. Once pots have been baited and deployed for fishing, they are generally left to 'soak' for 1–3 days before harvesting (Coleman et al., 2013).

Impacts on VMEs

Traps can have different impacts, ranging from those involving the captured organisms, such as the bycatch of target and non-target commercial species, and those affecting the environment, including impacts to habitats, epifauna, or mobile species (Lumsden et al., 2007). In the seamounts of Alaska, emergent epifauna like corals and sponges are home to king crabs (Stevens, 2002). In general, traps can damage bottom habitats in three different manners (Bacheler, 2024; Stevens, 2021): traps can crush some benthic organisms when landings on the seafloor (Lewis et al., 2009; Schweitzer et al., 2018), but other groups of benthic epifauna can withstand the weight of traps or pots by bending or supporting the trap weight, resulting in less damage (in particular in soft sediments) (Sutherland and Jones, 1983; Eno et al., 2001; Marshak et al., 2008; Shester and Micheli, 2011; Grabowski et al., 2014; Schweitzer et al., 2018). The total footprint or swept area of most traps is also very small (Kopp et al., 2020). Secondly, under the influence or waves, tidal currents or due to bad weather and storms, traps can move on the seafloor, as well as during trap retrieval (Sutherland and Jones, 1983; Lewis et al., 2009; Coleman et al., 2013; Uhrin et al., 2014), which results in a larger footprint that can cause more significant epibenthic damage (Schweitzer et al., 2018). Thirdly, traps can sometimes be connected to one another via ground lines, and these lines can drag along the bottom and damage benthic epifauna (Stone and Shotwell, 2007; Schweitzer et al., 2018).

Studies reporting impacts of fishing traps on vulnerable marine ecosystem (VME) indicator taxa (Table 1) showed different degrees of impact level. Eno et al. (2001) reported minimal impacts on sea pens by commercial crab traps consisting of a three-trap line in UK waters. Stephenson et al. (2017) reported similar findings and reported minimal disturbance of a single trap to rock reef habitats in UK waters. However, Schweitzer et al. (2018) studied the impacts of a multi-trap line on benthic habitat within the Mid-Atlantic Bight. They found that during trap retrieval where traps are dragged along the ocean floor, 50% of the traps came into contact with emergent epifauna damaging or breaking corals and running over other epifauna such as sponges, bryozoans, and anemones.

Lost traps can represent between 10 to 20% per year (Stevens et al., 2021). Despite the number of studies that focus on the impact of lost traps to captured organisms (e.g., Stevens et al., 2000; Butler and Mattheus, 2005; Arthur et al., 2014), few studies have examined the impact of traps on benthic habitats and ecosystems. Sutherland and Jones (1983) did not find visual evidence that traps killed or injured corals or sponges on the reef of the south-Florida. However, Chiappone et al. (2002) found that remnants of lobster traps accounted for 64% of the stony corals impacted, 22% of gorgonians, and 29% of sponges in the Florida Keys.

In general, traps are fishing gear that has a low impact on benthic epifauna when compared to trawling. However, this can only be realized when traps are deployed independently, no traps are lost, sensitive habitats are avoided, and traps are retrieved vertically without dragging (Eno et al., 2001; Marshak et al., 2008; Shester and Micheli, 2011; Kopp et al. 2020). Nonetheless, the frequency with which traps are deployed, and come into contact with benthic habitats, is suggested to be much greater than for trawls in some areas (Auster and Langton, 1999).

Table 8.1. Studies reporting bycatch or impacts of static gears on VME indicator taxa.

	Sponges	Anemones	Black corals	Cup corals	Gorgonians	Sea pens	Soft corals	Stony corals	Stylasterids	Stalked crinoids	Bryozoans
Longline											
Bavestrello et al. (1997)[2]					X						
Benedet (2017)[1]	X	X	X	X	X	X	X	X	X	X	X
Breeze et al. (1997)[2]					X						
Brewin et al. (2021)[1]	X	X	X		X	X	X	X	X	X	X
Chiappone et al. (2005)[2]	X				X			X			
Chimienti et al. (2020)[2]											
D'Onghia et al. (2012)[1]			X					X			
Duran Muñoz et al. (2011)[1]	X		X	X	X	X	X	X	X		
Edinger et al. (2007)[1]				X	X	X	X				
Fossa et al. (2002)[2]								X			
Gass and Willison (2005)[1]					X						
Heifetz et al. (2009)[2]											
High (1998)[2]					X			X			
Krieger (2001)[2]					X						
Mortensen et al. (2005)[1][2]					X						
Mortensen et al. (2008)[1][2]			X	X	X			X			
Mytilineou et al. (2014)[1]			X	X	X	X					
Orejas et al. (2009)[2]								X			
Parker and Bowden (2010)[1]	X	X			X			X			
Pham et al. (2014)[1]	X	X	X	X	X		X	X	X		
Reed et al. (2002)[2]								X			
Sampaio et al. (2012)[1]			X		X			X	X		
Valeiras et al. (2023)[1]		X		X	X	X		X			
Witherell and Coon (2001)[1]					X						X
Nets											
Dias et al. (2020)[1]			X		X			X			
Edinger et al. (2007)[1]				X	X	X	X				
Enrichetti et al. (2019)[2]	X			X	X		X				X
Fossa et al. (2002)[1]								X			
Gass and Willison (2005)[1]					X						
Grehan et al. (2004)[2]								X			
Shester and Micheli (2011)[1]	X				X						
Traps/pots											
Chiappone et al. (2002)[1]	X				X		X	X			
Edinger et al. (2007)[1]				X	X	X	X				
Eno et al. (2001)[2]	X				X	X					X
Lewis et al. (2009)[2]	X				X			X			
Schweitzer et al. (2018)[2]	X	X			X			X			X
Sheridan et al. (2005)[2]	X				X			X			
Shester and Micheli (2011)[1]	X				X						
Stone (2006)[2]								X			
van der Knaap (1993)[2]	X				X			X			

[1]Bycatch; [2]Impacts observed on bottom

8.4 Ecosystem effects of static gears

Coral and sponge assemblages and other VME indicator taxa provide several ecosystem functions and services. They contribute significantly to benthic biomass and vertical relief which increase the availability of microhabitats. Increasing complexity provides feeding and spawning sites, refugia from predators, and shelter from high flow regimes (e.g., Saxton, 1980; Reed, 2002; Freese and Wing, 2003; Colloca et al., 2004; Etnoyer and Morgan, 2003; Etnoyer and Warrenchuk, 2007; D'Onghia, 2019). In general, these habitats represent biodiversity hotspots for invertebrates (e.g., Bett and Rice, 1992; Smith et al., 2000; Klitgaard, 1995; Mortensen and Buhl-Mortensen, 2005; Henry and Roberts, 2017), and can support a high abundance of fish (e.g., Bradstock and Gordon, 1983; Koenig, 2001; Husebø et al., 2002; Krieger and Wing, 2002; Rooper et al., 2019). Additionally, they play a vital role in benthic-pelagic coupling (e.g., Griffiths et al., 2017; Leys et al., 2018), facilitating nutrient cycling (e.g., Perea-Blázquez et al., 2012; Maldonado et al., 2020), and modifying biochemical regimes (e.g., Kaufmann and Smith, 1997; Soltwedel and Vopel, 2001).

Sponges, are identified as nutrient providers for the marine environment, recycling organic matter into various forms of bioavailable nutrients such as ammonium and nitrate (Li et al., 2016; Dunham et al., 2018; Rooks et al., 2020; Bart et al., 2021). Biologically mediated habitat service is the profit derived from habitats formed by marine organisms (such as reef formation and sponge grounds that provide nursery grounds, breeding spaces, refugia from predators and surfaces for feeding (Beaumont et al., 2007). This service is the building block of many other services (La Bianca et al., 2023). Cold-water corals reef structures are one of the best- examples of biogenic habitat that forms complex structures and support biodiversity (Fosså et al., 2002, Henry and Roberts, 2017) and ecosystem functioning in the deep sea (Bongiorni et al., 2010; Thurber et al., 2014), including commercially valuable fisheries in some regions (Armstrong et al., 2014; Henderson et al., 2020).

Deep-sea sponges and their associated bacteria and fungi are a potential novel source of bioactive metabolites for biotechnological applications such as anti-tumour, antibacterial, antiviral, toxin inhibitors and anti-inflammatory metabolites (Rateb and Ebel, 2011; Batista-García et al., 2017)

Increasing mortality of VME indicator species due to the impact of static gears will weaken all the functions that they provide. The indirect impacts of the static gears may cause changes in rates of reproduction, feeding or growth, genetic selection, or predator-prey relationships, as well as loss of habitat structure that supports hiding, feeding, or mating refugia (Stevens, 2021). For example, in the case of sponge-dominated ecosystems, Pham et al. (2019) found that due to the large amount of seawater filtered daily and the organic carbon consumed through respiration, any removal would likely affect the delicate ecological equilibrium of the deep-sea benthic ecosystem and a shift towards low oxygen or anoxic scenarios could occur. In another study, De Clippele et al. (2020) found that the Mingulay Reef Complex in the Hebridean sea off the west coast of Scotland overturned between three to seven times more carbon than a soft-sediment area at a similar depth, showing the importance that two dominant ecosystem engineers (the coral *Desmophyllum pertusum* and the sponge *Spongosorites coralliophaga*), have in the carbon cycling. For example, the decomposition of organic material by viruses in deep-sea sediments is estimated to contribute to the releasing of ~37-50 megatons of carbon per year that represent an important source of labile organic compounds in deep-sea ecosystems (Dell'Anno et al., 2015). Thus, virus decomposition is considered to provide an important ecosystem function that plays a crucial role in nutrient cycling within the largest ecosystem of the biosphere (Dell'Anno et al., 2015).

In order to assess the effects that static gears can have in the ecosystem, it is important to understand the fishing effort carried out with these gears, the area of seafloor impacted, gear selectivity and damage or mortality rates associated to each type of static gear.

8.5 Preparatory framework for a future workshop

In light of the reviewed information, WGDEC recommends a future workshop aiming to review and assess the impact of different gear types on VMEs and to understand the ecosystem effects of different fishing gears. Suggested Terms of Reference that a dedicated workshop could usefully address to inform ICES advisory process are found in annex 2.

8.6 References

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9 ToR G: Recommend next steps for a future incorporation of species distribution models in consultation with WGMHM into the ICES VME advice framework.

9.1 Background

ICES provides advice annually to NEAFC and the European Commission on areas where VMEs are known or are likely to occur and could be at risk from significant adverse impacts from mobile bottom contacting fishing activity. This advice is currently based on VME habitat and indicator data submitted to the ICES VME database, which is used to develop maps of confirmed VME (habitats), and high, medium and low likelihood VME at c-square resolution (0.05 x 0.05 degree); and modelled data on VME physical elements. Over the last few years, WGDEC have also been reviewing the potential to use Species Distribution Models (SDMs) and Habitat Suitability Models (HSMs), herein referred to as predictive habitat models (PHMs), to support understanding of the likely presence of VMEs and VME indicators in North-East Atlantic waters.

Following work by the Working Group on Marine Habitat Mapping (WGMHM) in 2019 to develop a roadmap for the use of PHMs in ICES advice (ICES, 2019), and a decision by WGDEC in 2020 to identify a set of criteria to review new and existing PHMs against (ICES, 2020), an ICES Workshop on the Use of Predictive Habitat Models in ICES Advice (WKPHM) was held in Feb 2021 (ICES, 2021a). This workshop formulated this list of criteria, and these were then tested by WGMHM in 2021 by reviewing a set of peer-reviewed PHMs of VMEs and VME indicators against the criteria to identify if models existed that could meet them (ICES, 2021b). As no existing PHMs fulfilled all criteria (although many fulfilled most), it was agreed by WGMHM and WGDEC (2021) that a further review was needed to establish a more prioritised list of criteria and which might be considered the 'deal-breakers'. WGDEC 2021 also detailed the need for a more extensive assessment of how models could be applied in ICES advice, suggesting this could be established through a second workshop where models were trialled in theoretical advice giving. The group therefore proposed a set of next steps for additional work and draft ToRs for a second workshop (see Section 8.5, ICES, 2021b).

Since this meeting, in 2022, the ICES Benchmark Workshop on the Occurrence and Protection of Vulnerable Marine Ecosystems (WKVMEBM) again proposed that PHMs be considered as a mapping tool that could be used to determine areas where VMEs/VME indicators are 'likely to occur' (ICES, 2022). No further work was carried out on this topic in 2023, due to other ICES priorities. However, at the WGDEC 2024 meeting, a refresh of the topic was brought to the table and further ideas were collated to establish best next steps.

9.2 Further consideration of the use of PHMs within ICES advice

Within current ICES advice, the available evidence on areas where VMEs are known to occur or likely to occur are currently provided as: C-squares with confirmed VMEs (VME habitat); C-squares with VME indicator taxa (high, medium, or low VME index); and seabed topographic features potentially supporting VMEs (VME physical elements). This method means that a single point observation of VME or VME indicator can be assigned to a full c-square, thus inflating the mapped extent of known data. However, PHMs offer the opportunity to assess how likely it is that the surrounding area (whole c-square) is suitable habitat for VME, providing a potential level of refinement in advice in certain areas. Furthermore, the use of PHMS could enable a potential move away from the use of VME elements. VME elements are essentially a model for VME likelihood that make much broader and unquantified assumptions about links between physical geomorphological units and VME occurrence than PHMs do. They are therefore much coarser in resolution and thus bring a lower level of confidence.

The use of PHMs also offers the opportunity to explicitly consider demersal trawling effort (when available as a GIS layer) in the assessment of likelihood of VME occurrence, through inclusion of demersal trawling effort as a predictor variable in PHM model development. PHMs, used appropriately, therefore potentially offer some significant advances and refinements in the quality of ICES advice on VME occurrence.

WGDEC 2024 also discussed the need to consider model suitability for use in advice giving, continuing the WGDEC 2021 proposed idea for a second workshop to consider further criteria, such as spatial scale (e.g. underlying data resolution) and data richness. These criteria would need to be understandable to a broad audience and any ranking system equally understandable (e.g. a simple traffic light system).

9.3 Next steps

WGDEC 2024 agreed with the 2021 conclusion that a second workshop is needed to review the application of PHMs to the provision of ICES scientific advice and to establish a framework for the inclusion of PHMs within such advice in future. This workshop will build on the outputs of WKPHM and, specifically, the list of criteria for assessing PHMs, as well as the assessment of models against the criteria undertaken by WGMHM.

The workshop will firstly review and refine the criteria derived by WKPHM to identify the potential ‘deal breakers’ and higher priority criteria. This may need to be done inter-sessionally so that criteria can be established before PHMs are requested and reviewed against the criteria. Using the list of models assessed by WGMHM as a starting point, the workshop leads will put out a call for any new models developed since this assessment and request the support of WGMHM in assessing these new models against the revised criteria. The workshop will then collate suitable PHMs to use in a series of case studies, based around historical advice given by ICES, to understand the ways in which models can add to, and potentially refine, that advice by providing high resolution maps in certain areas where these types of model are available.

Having established which models are useful for delivering what type of advice, models then need to be brought together in a geographic information system for undertaking the case studies. Consideration needs to be given to the method of thresholding used to turn model output values of likelihood of VME (or VME indicators) presence into binary maps. Different thresholding techniques place different emphasis on either a) sensitivity or b) specificity and the group needs to consider what are suitable threshold(s) in the context of discriminating areas of likely habitat suitability for VME (or VME indicators).

The bulk of the workshop will then be focused on using PHMs together with the VME index and VME elements to propose areas of likely VME occurrence through re-visiting historic advice-giving scenarios as case studies. Workshop participants will work through questions that arise in the practical application of PHMs to advice-giving. Such questions could relate to the type and weighting of PHM evidence where multiple models are available, and the development of a ‘weight of evidence’ framework to ICES VME advice-giving. In working through examples and considering use of PHMs in the context of advice-giving, consideration will be given to the benchmarked ICES VME advice-giving process to provide feedback and suggestions for any future refinements to allow the inclusion of PHMs.

Draft terms of reference were prepared by WGDEC 2021, which were further refined by WGDEC 2024. The proposed draft terms of reference for a future workshop on incorporation of species distribution models can be found in annex 2.

9.4 References

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ICES. 2021b. Working Group on Deep-water Ecology (WGDEC). ICES Scientific Reports. 3:89. 162 pp. http://doi.org/10.17895/ices.pub.8289

Annex 1: List of participants

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Ana de la Tor-riente	IEO	Spain
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David Stirling	Marine Science Scotland	UK
Kerry Howell	Plymouth University	UK
Anna Metaxas	Dalhousie University	Canada
Chris Pham	IMR	Norway
Neil Golding	Aquarius Survey Mapping	UK
Felicia Keulder-Stenevik	IMR	Norway
Jorge Arteaga	IPMA	Portugal
Natasha Murphy	Marine Institute	Ireland
Laura Grady	JNCC	UK
Caroline Alibert-Deprez	European Commission	Other (observer)
Javier Murillo-Pe-rez	Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia	Canada
José Manuel Gon-zález Irusta	IEO	Spain
Peter Auster	Marine Sciences	US
Ohiana Revuelta	IEO	Spain
Marina Carreiro-Silva	University of the Azores	Portugal

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Steinunn Hilma Ólafsdóttir	Marine and Freshwater Institute (Hafogvatn)	Iceland
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Sebastian Val-anko	International Council for the Exploration of the Sea (ICES)	Denmark

Annex 2: Draft resolutions for potential future workshops

As prompted by WGDEC 2024 tor d (see section 6) - Draft terms of Reference for a future **workshop on the occurrence of VMEs in the north-east Atlantic region**:

a) Review the spatial and non-spatial statistical approaches to map aggregations and define thresholds, highlighting their merits and limits including data requirements.
b) Within the range of approaches reviewed in ToR A, and considering data availability, identify and apply the most suitable methods per taxa and data source; propose metrics, including weight, abundance or record thresholds, to assess the likelihood of VME occurrence.
c) Assess the ecological relevance and the consistency of metrics across the taxa / data-source matrix, as well as the relative confidence among metrics.
d) Combine lines of evidence per taxa into taxa-specific likelihood indices and a generic all-taxa VME likelihood index; test the indices in the framework of NEAFC and EU advice.

As prompted by WGDEC 2024 tor f (see section 8) – Draft terms of reference for a future **workshop aiming to review and assess the impact of different gear types on VMEs and to understand the ecosystem effects of different fishing gears.**

a) Review existing definitions of, and ongoing work to define, bycatch of VMEs.
b) Review VME data based on reported bycatch, observer data, commercial and scientific surveys, using static gears. [It is recommended that ICES issues a data call ahead of the workshop].
c) Assess fishing effort and analysis of available satellite (AIS, VMS, iVMS) and logbooks data, including under 10m vessels. [It is recommended that ICES issues a data call for logbooks ahead of the workshop, which would be made available, analysed and interpreted by the Working Group on Spatial Fisheries Data (WGSFD)].
d) Analysis of historical changes in fisheries to provide an indication of changes in behaviour and fishing grounds [this could be done in collaboration with WGSFD and other relevant working groups].

As prompted by WGDEC 2024 tor g (see section 9) – Draft Terms of Reference for a future **workshop on incorporation of species distribution models**

a) Considering the use of PHMs in ICES advice, review and refine the criteria derived by WKPHM, to decide on the relative importance of each criterion, identify potential 'deal breakers' and identify those criteria which, if not met, could constitute a fundamental flaw in model use.
b) Select a set of published models that meet the above criteria and undertake case studies on select areas to test how predictive models could add to and refine existing ICES advice on VME closures, and identify limitations for model use.
c) Based on these case studies and expert knowledge, develop a model specification assessing model suitability for use in advice giving and develop a simple matrix system, understandable to end users, to classify the range of appropriate uses of models within ICES advice.

d) Provide recommendations, aimed at PHM modellers and advice requesters, on i) the type of thresholding to be used in models relevant to ICES advice, ii) model standards and iii) types of models needed for use in future ICES advice.

e) Establish a weight of evidence framework for the application of PHMs in ICES advice on areas where VME are known and likely to occur.

Annex 3: ToR C database corrections/resubmissions on account of positional data errors in the VME database

A total of 1529 records from 14 Marine Scotland Science (MSS) scientific surveys undertaken between 2006 and 2019 were examined for positional accuracies in response to ToR c. All positions from ten of these cruises were confirmed to be correct. Positional errors, of varying degrees, were corrected for 93 VME indicator records arising from 28 sampling events (bottom trawl tows) across 4 MSS surveys in the ICES VME database. One station (0412S_144) that had two records associated with it (1 dead *Lophelia pertusa* 112g and 280 *Funiqulina quadrangularis*) was removed from the database as the original positional data was also erroneous. One VME habitat record from 1 sampling event was also corrected for the Marine Institute (MI) data (SeaRover18_540). Below, these corrections are presented in Table A3.1 and depicted in Figures A3.1 – 3.8.

Table A3.1 Summarising the old and new positions for those data resubmitted in response to ToR c

Org	Station	N	VME	New.Start.x	New.Start.y	New.Mid.x	New.Mid.y	New.End.x	New.End.y	Old.Start.x	Old.Start.y	Old.Mid.x	Old.Mid.y	Old.End.x	Old.End.y
MSS	0412S_144	2	Sea-pen, Stony coral	-	-	-	-	-	-	-14.399	57.297	-14.371	56.905	-14.343	56.513
MSS	1212S_439	2	2 Sea-pen	-9.858	56.068	-9.882	56.093	-9.905	56.117	-9.858	56.082	-9.882	56.100	-9.905	56.117
MSS	1212S_440	4	Black coral, 2 Gorgonian, Stony coral	-9.635	56.195	-9.646	56.166	-9.657	56.136	-9.635	56.195	-9.646	56.170	-9.657	56.144
MSS	1212S_443	3	Gorgonian, Sea-pen, Sponge	-10.519	55.005	-10.523	55.003	-10.527	55.001	-10.504	55.005	-10.515	55.003	-10.527	55.001

Org	Station	N	VME	New.Start. x	New.Start. y	New.Mid. x	New.Mid. y	New.End. x	New.End. y	Old.Start. x	Old.Start. y	Old.Mid. x	Old.Mid. y	Old.End. x	Old.End. y
MSS	1212S_445	6	Black coral, 4 Cup coral, Sea-pen	-10.467	54.967	-10.486	54.960	-10.505	54.953	-10.467	54.967	-10.485	54.959	-10.504	54.950
MSS	1212S_446	3	Gorgonian, 2 Sea-pen	-10.169	55.132	-10.163	55.153	-10.158	55.173	-10.169	55.132	-10.165	55.162	-10.161	55.192
MSS	1212S_447	2	2 Sponge	-9.343	56.189	-9.343	56.214	-9.343	56.239	-9.396	56.189	-9.369	56.214	-9.343	56.239
MSS	1213S_313	2	Gorgonian, Sea-pen	-9.874	56.114	-9.860	56.088	-9.846	56.061	-9.874	56.114	-9.444	56.088	-9.014	56.061
MSS	1213S_314	3	Gorgonian, 2 Sponge	-9.364	56.236	-9.383	56.210	-9.401	56.183	-9.364	56.236	-9.185	56.210	-9.007	56.183
MSS	1213S_316	2	Cup coral, Sea-pen	-10.320	55.195	-10.327	55.183	-10.333	55.171	-10.320	55.195	-10.163	55.183	-10.006	55.171
MSS	1213S_317	8	Gorgonian, 3 Stony coral, Cup coral, 2 Stylasterids, Sponge	-10.194	55.229	-10.203	55.211	-10.212	55.193	-10.194	55.229	-10.099	55.211	-10.004	55.193

Org	Station	N	VME	New.Start. x	New.Start. y	New.Mid. x	New.Mid. y	New.End. x	New.End. y	Old.Start. x	Old.Start. y	Old.Mid. x	Old.Mid. y	Old.End. x	Old.End. y
MSS	1213S_318	3	Sponge, Black coral, Sea-pen	-10.295	55.295	-10.313	55.281	-10.330	55.267	-10.298	55.315	-10.152	55.291	-10.006	55.267
MSS	1213S_325	3	2 Gorgonian, Cup coral	-10.078	56.079	-10.042	56.049	-10.005	56.018	-10.078	56.079	-10.039	56.049	-10.000	56.018
MSS	1213S_326	5	Gorgonian, 3 Cup coral, Sea-pen	-9.870	56.110	-9.855	56.084	-9.840	56.057	-9.870	56.110	-9.442	56.084	-9.014	56.057
MSS	1213S_327	3	2 Cup coral, Gorgonian	-9.622	56.109	-9.628	56.142	-9.634	56.175	-9.622	56.121	-9.316	56.148	-9.011	56.175
MSS	1213S_329	2	2 Sea-pen	-10.101	56.631	-10.064	56.658	-10.026	56.685	-10.101	56.631	-10.051	56.658	-10.000	56.685
MSS	1213S_330	1	Sea-pen	-9.364	56.820	-9.367	56.793	-9.369	56.766	-9.364	56.820	-9.185	56.793	-9.006	56.766
MSS	1213S_331	1	Cup coral	-9.177	56.782	-9.170	56.757	-9.163	56.732	-9.177	56.782	-9.090	56.757	-9.003	56.732
MSS	1213S_333	1	Sea-pen	-10.020	57.373	-10.010	57.368	-9.999	57.363	-10.015	57.370	-9.515	57.352	-9.016	57.333
MSS	1213S_335	1	Sea-pen	-9.680	57.319	-9.696	57.344	-9.711	57.368	-9.680	57.319	-9.346	57.344	-9.012	57.368

Org	Station	N	VME	New.Start.x	New.Start.y	New.Mid.x	New.Mid.y	New.End.x	New.End.y	Old.Start.x	Old.Start.y	Old.Mid.x	Old.Mid.y	Old.End.x	Old.End.y
MSS	1213S_338	1	Gorgonian	-10.184	57.584	-10.187	57.609	-10.189	57.634	-10.184	57.584	-10.094	57.609	-10.003	57.634
MSS	1213S_339	6	2 Sponge, Cup coral, Gorgonian, Soft coral, Sea-pen	-9.972	57.624	-9.963	57.609	-9.953	57.593	-9.972	57.624	-9.494	57.609	-9.016	57.593
MSS	1213S_340	2	Soft coral, Sea-pen	-9.874	57.648	-9.870	57.623	-9.865	57.598	-9.874	57.648	-9.444	57.623	-9.014	57.598
MSS	1213S_343	9	4 Sponge, 2 Gorgonian, Soft coral, 2 Cup coral	-10.737	58.151	-10.718	58.161	-10.698	58.170	-10.737	58.151	-10.374	58.161	-10.012	58.170
MSS	1213S_344	10	2 Sponge, Cup coral,	-9.734	58.470	-9.730	58.495	-9.726	58.520	-9.734	58.470	-9.373	58.495	-9.012	58.520

Org	Station	N	VME	New.Start. x	New.Start. y	New.Mid. x	New.Mid. y	New.End. x	New.End. y	Old.Start. x	Old.Start. y	Old.Mid. x	Old.Mid. y	Old.End. x	Old.End. y
			Soft coral, 3 Sea-pen, 2 Black coral, Gorgo-nian												
MSS	1213S_345	2	Cup coral, Sea-pen	-9.661	58.456	-9.666	58.443	-9.670	58.430	-9.661	58.456	-9.336	58.443	-9.011	58.430
MSS	1213S_349	5	2 Sponge, Cup coral, 2 Stony coral	-10.033	59.368	-9.994	59.353	-9.954	59.338	-10.033	59.368	-9.524	59.353	-9.016	59.338
MSS	1413S_368	1	Gorgo-nian	-15.066	55.912	-15.103	55.892	-15.140	55.872	-15.066	55.912	-15.469	55.892	-15.872	55.872
MI	SeaRover18_540	1	Coral Garden	-15.164	55.676	-15.161	55.674	-15.154	55.674	-15.415	55.674	-15.289	55.675	-15.164	55.676

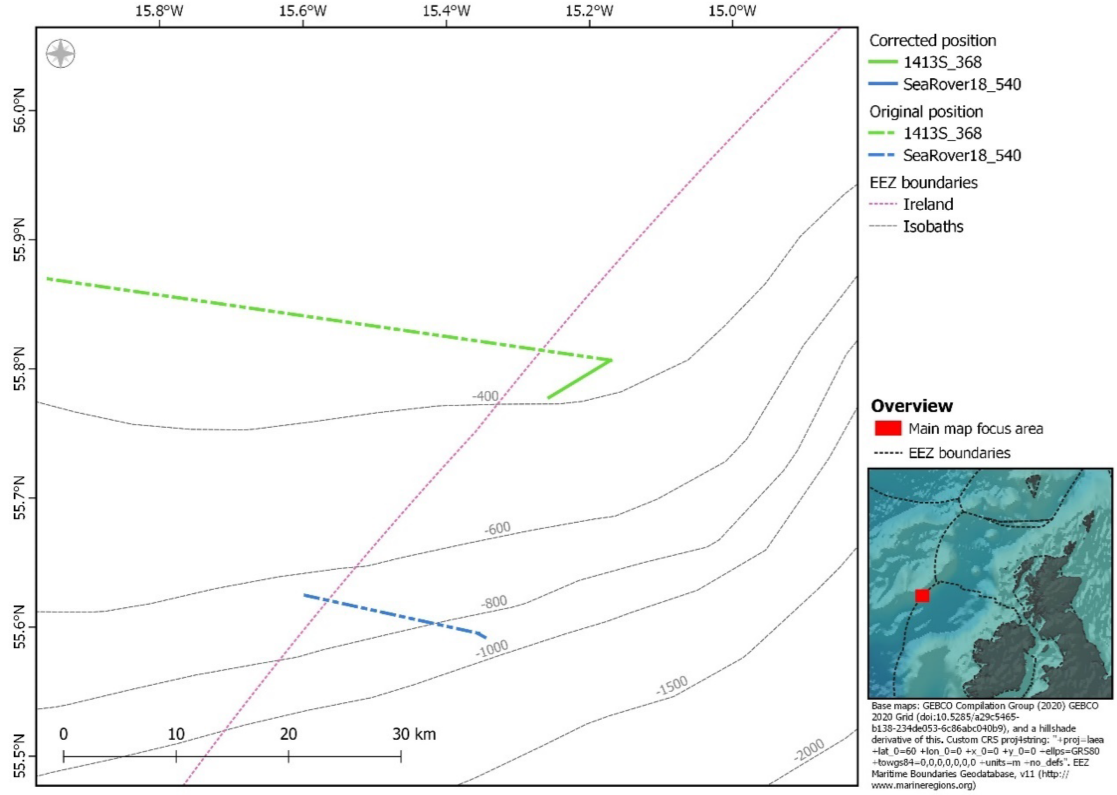


Figure A3.1 Showing the original and corrected positions for stations 1413S_368 and SeaRover18_540

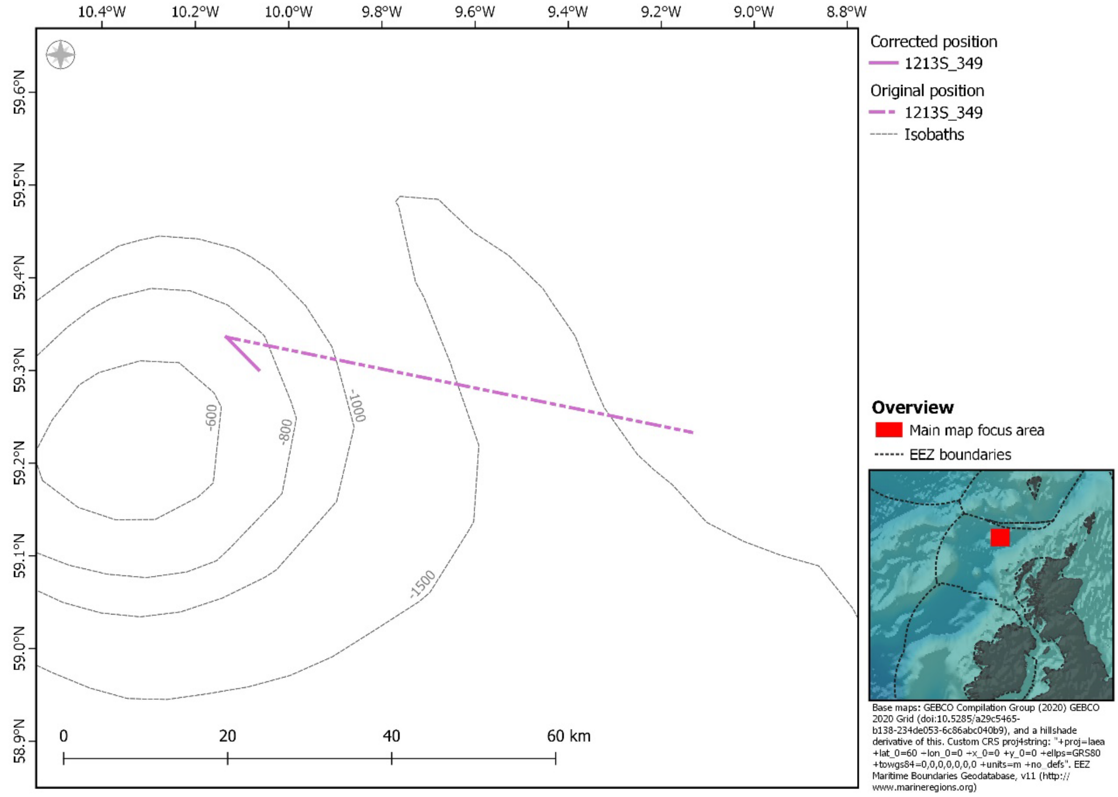


Figure A3.2 Showing the original and corrected positions for station 1213S_349

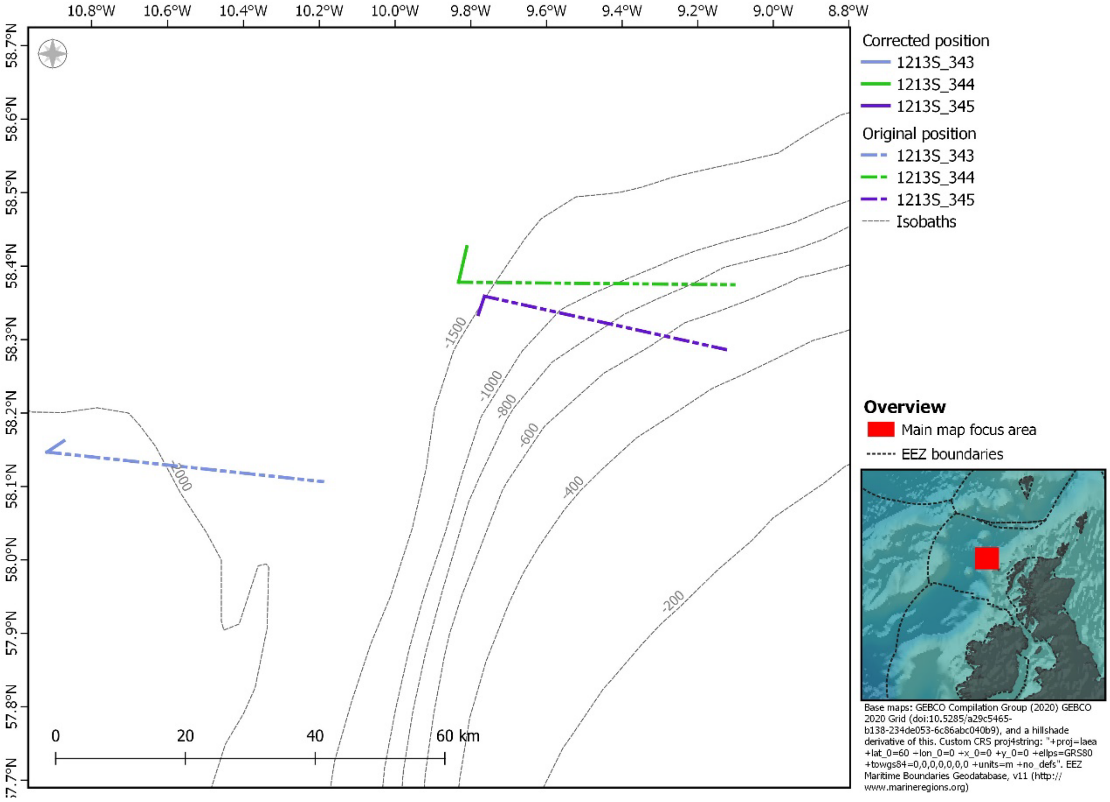


Figure A3.3 Showing the original and corrected positions for stations 1213S_343-345

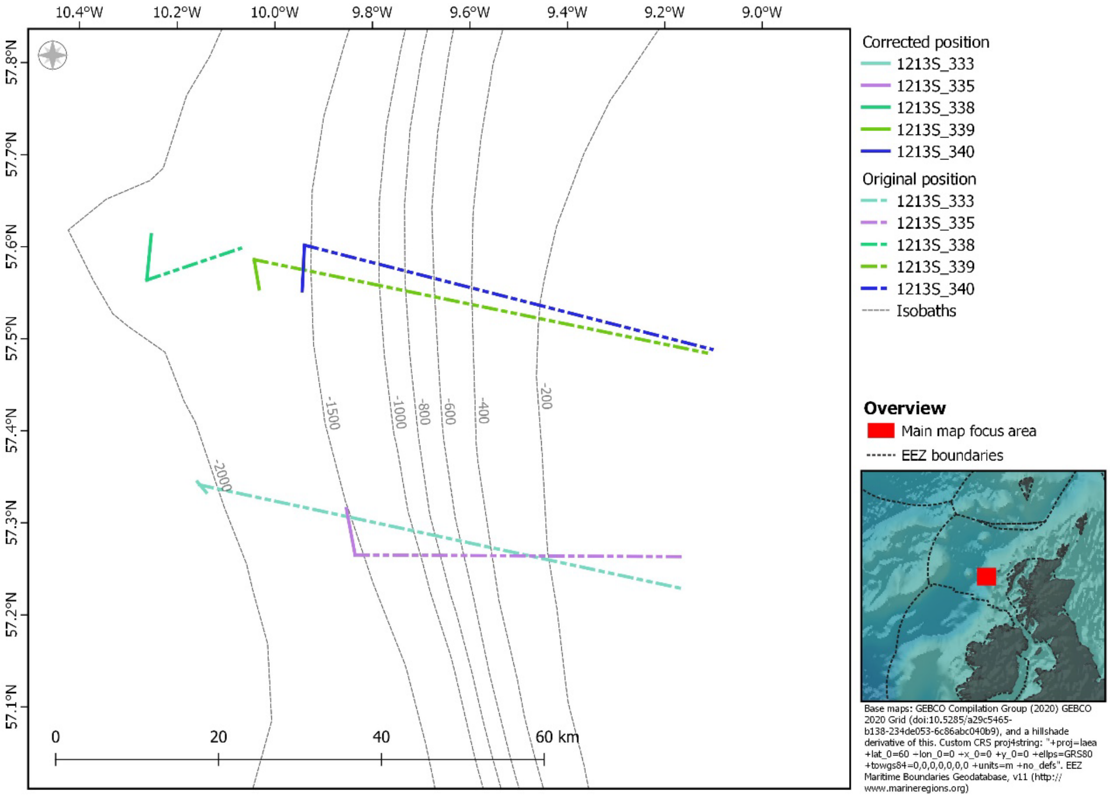


Figure A3.4 Showing the original and corrected positions for stations 1213S_333, 335, 338 – 340

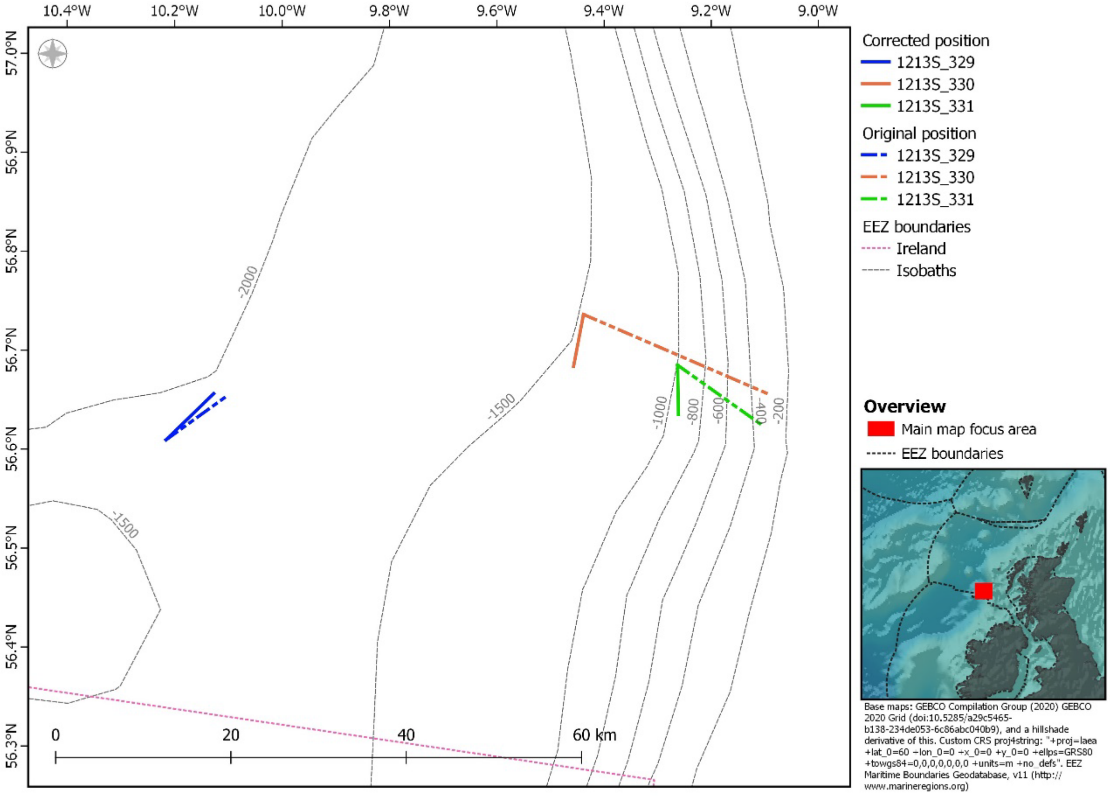


Figure A3.5 Showing the original and corrected positions for stations 1213S_329 – 331

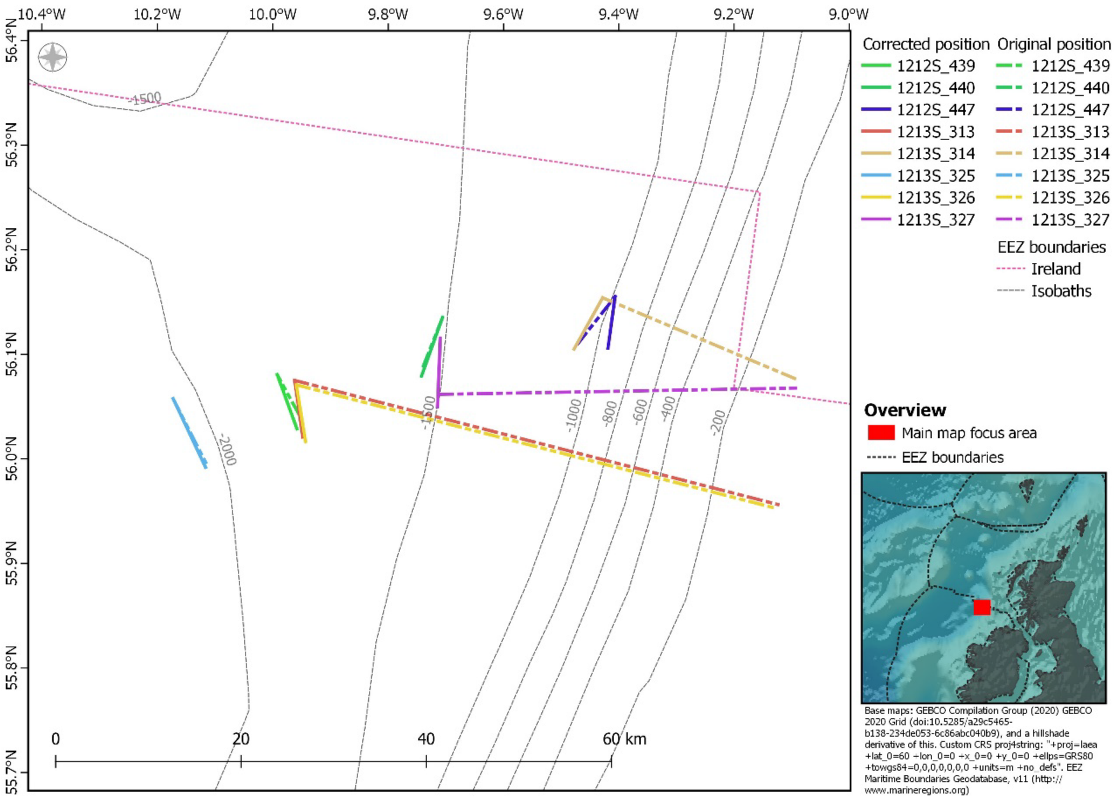


Figure A3.6 Showing the original and corrected positions for stations 1212S_439/440/447, and 1213S_313/314/325/326 & 327

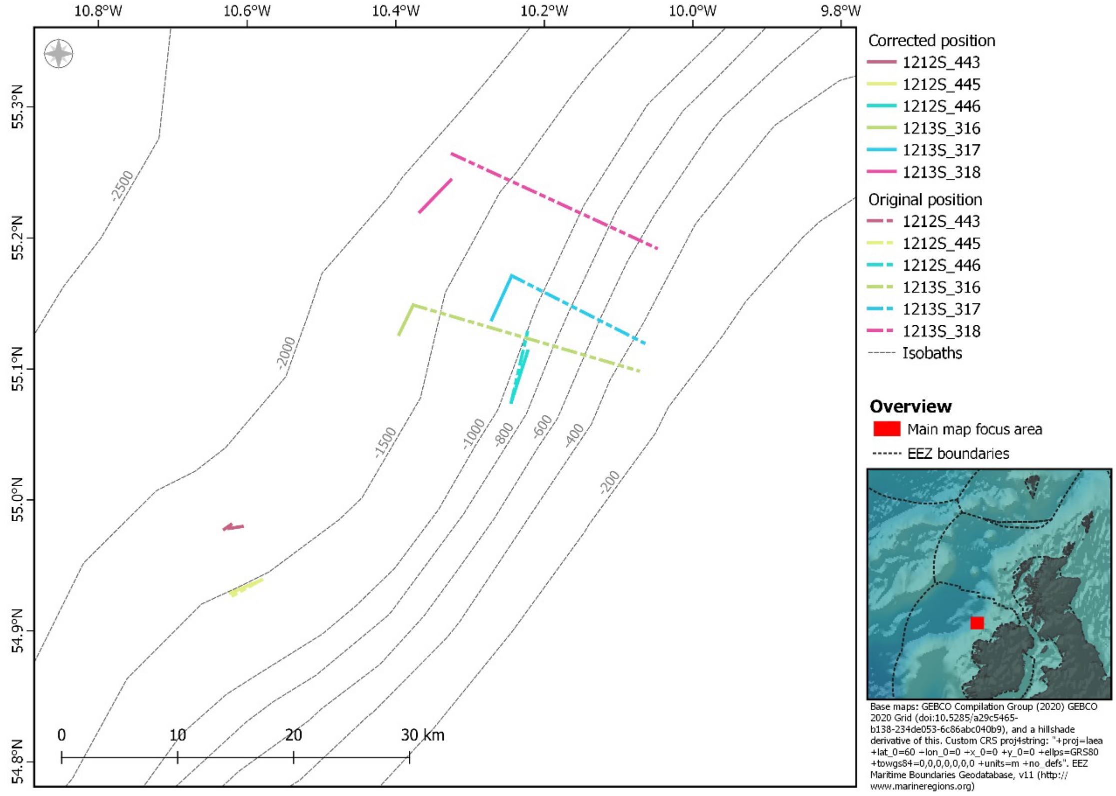


Figure A3.7 Showing the original and corrected positions for stations 1212S_443/445/446, and 1213S_316 – 318

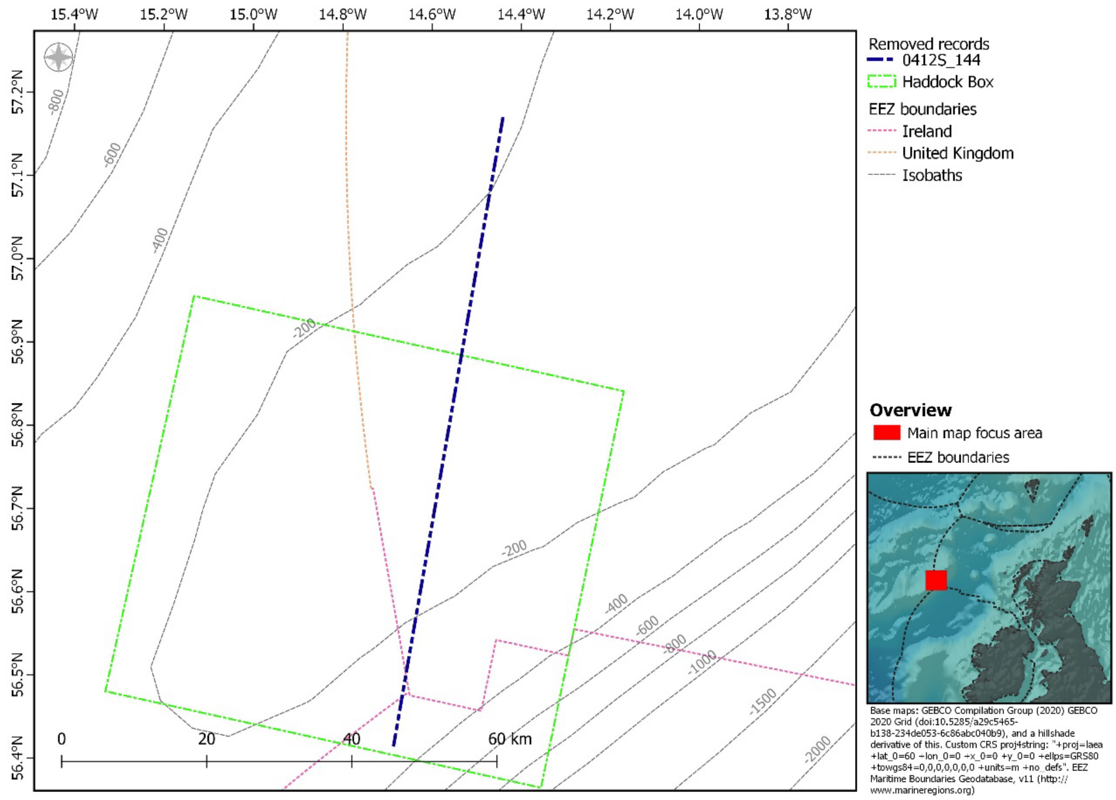


Figure A3.8 Showing stations 0412S_144 which was removed from the ICES VME database

Annex 4: Report of the EU VME assessment group to the ICES ADGVME

This document was prepared with inputs from: Ana Colaço; David Stirling; Rui Vieira; Lenaick Menot; Karin, Peter Auster, Natasha Murphy, Jose Irusta.

Preamble from WGDEC chairs

- The Joint ICES/NAFO Working Group on Deep-water Ecology (WGDEC) met in a hybrid format at ICES HQ, Copenhagen from 25-29 March 2024 to, *inter alia*:

  a) Collate, validate and QA/QC-check new information on the occurrence and distribution of vulnerable marine ecosystems (VMEs), VME indicator taxa and VME elements in the North Atlantic and adjacent waters, archive appropriately using the ICES VME Database, and disseminate via the Working Group report and ICES VME Data Portal. [ToR a]
  b) Review, validate and update new information on the occurrence and distribution of VMEs, VME indicator taxa and VME elements in the NEAFC Convention Area, including subareas of the Regulatory Area that are closed to fishing for other purposes than VME protection, and in EU waters in relation to the EU deep-sea access regulation. In addition, evaluate whether the EU VME advice needs to be updated, based on the criteria suggested by WGDEC in 2023 (ToR c) and agreed in dialogue with ACOM leadership. [ToR b]
  c) Conduct a review of historical records included in ICES VME Database. [ToR c]

- WGDEC was unable to meet to address the completion of the VME assessment in EU waters.

- To address this, Chairs of WGDEC and ICES Secretariate agreed to undertake the assessment with a pool of available experts. As such, this assessment does not represent the expert opinion of WGDEC and its members as a whole.

- Chairs of WGDEC recommend that, in order to ensure timely and thorough VME advice, processes are synchronised throughout the various ICES data calls and workflows. This would allow engagement of WG members and ensure a timely delivery of generic ecoregion-specific assessments in the future requests, as well as specific advice, based on regional expert knowledge.

- Chairs of WGDEC also consider that implementation of the recommendations provided by Working Group experts (ICES WGDEC 2022) would facilitate the completion of the draft assessment in a timely manner to ensure production of the best possible advice.

- It should also be noted that unless it was for the correction of positional errors identified for some of the VME records, the assessment group does not consider that the volume and position of new data submissions since the last assessment (2022/2023) are sufficient to trigger an update to the VME advice provided in 2023.

Assumptions for the application of the benchmarked process for the assessment and provision of VME advice (e.g. "*what are we advising for*")

- The 2022 benchmarked assessment procedure (WKVMEBM 2022, Annex 6) provides the technical guideline for formulating advice on the occurrence and protection of vulnerable marine ecosystems.
- In line with the outcome of WKVMEBM, assessment(s) presented for consideration of ICES ADGVME-2 are based on a framework for the presentation of options to protect VMEs based on the relationship between mobile bottom contacting gears (MBCG), fishing intensity (SAR) and potential significant adverse impacts on VMEs.
- For the benefit of the end-users of this advice, the expert group considers important that advice clearly states that it is based on the framework of the benchmarked assessment procedure (WKVMEBM, 2022) and therefore is **only applicable to mobile bottom contacting gears**, i.e. bottom otter trawls, bottom seines, dredges, and beam trawls.
- Two data flows, VME (including physical elements) and VMS, were combined to assess the spatial overlap between mobile bottom contacting gear fishing and the location of where VMEs occur (verified VME habitats) or are 'likely' to occur (based on VME index), and the potential for significant adverse impacts on VMEs from ongoing fishing activity with mobile bottom contact gears.
- The assessment is summarised in "assessment templates", supplemented by expert interpretation of results, for both ecoregion-specific assessments and the provision of ICES advice.
- We consider that the main purpose of the recurrent advice is mainly additive in nature, i.e., that the identification of VME polygons will primarily be an exercise in identifying additional VME polygons that will be added to those identified in the previous assessment.

- The VME physical elements used here are the following: seamounts, mounds, coral mounds, banks, and mud volcanoes. Within EU waters, EMODnet[1] data is the layer used.
- The only exception are a few very large polygons off the coast of Spain and Portugal, which clearly are not seamounts (according to the IHO definition). These polygons were cropped using modelled seamounts and/or ridges from Harris *et al*. (2014) dataset.
- VME c-squares in the HTML are currently displayed as 'Existing VME c-sq.' and New VME c-sq.' However, existing VME + New VME does not equate to what is currently in the VME database. This is because the existing VME DB is a snapshot from 2020 and the New VME is only those new or updated data submitted since 2020. It would be useful to have a 'current VME C-squares' for all current data holdings in the VME database.
- The VMS workflow was based on the responses to the 2022 ICES VMS and logbook data call. Responses to this data call are summarised in the table below.

Country	Data submission	Country	Data submission
Belgium	y	Lithuania	y
Denmark	y	The Netherlands	y
Estonia	y	Norway	y
Faroe Islands	n	Poland	y
France	y	Portugal	f
Germany	y	Russia	n
Greenland	n	Spain	y
Ireland	y	Sweden	y
Iceland	y	United Kingdom	y
Latvia	y		

y: Suitable data submitted.

n: No data submitted.

f: Data submitted; QC checks not passed.

[1] https://emodnet.ec.europa.eu/en

- The format of the data call changed in 2022 to further address anonymity concerns, and countries were requested to submit data for 2009 - 2021. Due to improvements in data processing, there was an increase in Spanish data included in the aggregated data set. The Portuguese submission did not pass the quality control process in advance of the meeting and has not been included. There are therefore likely to be significant differences in perception of fishing activity between this data set and the one provided for the benchmark (WKVMEBM, 2022).

- The VMS data is gridded to a spatial resolution (c-square) of 0.05 x 0.05 degrees. This is the appropriate scale, given the frequency of VMS polling (a maximum of 2-hour intervals is specified in legislation) and the speeds at which a vessel towing mobile bottom contacting gears is expected to travel (for most gears 2 - 5 knots).

- Swept area ratios (the proportion of the seabed in each c-square which interacts with mobile bottom gears) is calculated, using the gear widths defined in the BENTHIS project (Eigaard *et al*., 2016) for each metier.

Limitations on the provision of VME assessment

- There was limited time to conduct the assessment(s), and it should not be considered an exhaustive process.

- This process is based on the combination of multiple data sources: records of presence of VME habitat and/or indicator species from the ICES VME database and MBCG footprint (from VMS data submitted to ICES for the reference period 2018 to 2022). Both data sources are updated annually as part of the ICES data policy and therefore the VME polygons may change (in both number and size) as part of this process.

- As previous advice in 2022, WGDEC considers that the process of including VMEs located outside the fishable domain (depth range 400-800 m) may increase the size of the polygon because of the buffer zones associated with these VMEs located just outside the depth range. This is not necessarily a problem for VMEs located deeper than 800 m as these are already protected (Deep Sea Access Regs). However, it does not make sense for VMEs located shallower than 400 m as the closures are creating a protection buffer around a VME that is not protected at all. This needs to be corrected where possible. Several examples of this have been identified.

- An area that has been identified as a VME polygon and subsequently been used as a closure cannot be opened unless there is evidence of absence (WKVMEBM 2022). However, if there are errors, updates or other issues in the underlying data that led to the changes in the polygons shape and area there should be a mechanism to address these (for example, discussions with regional experts / WGDEC). This was the case in 2022 for several polygons in the Gulf of Cadiz added to previous advice because of gaps in the VMS data used in the advice and acknowledged during the elaboration of the advice.

- The assessment is broadscale in nature, i.e. ICES ecoregion level. WGDEC was not requested to conduct assessments on a country level. However, experts acknowledge that sub-regions within the ecoregions shall be identified in order to conduct a more thorough assessment (eg. Bay of Biscay and Iberian margin should be divided in bay Biscay, Galicia, and west Iberian coast). Furthermore, in specific areas of interest (e.g. MPAs) where high resolution information is available, conservation efforts should be addressed in finer scale between the EU and nation states by allowing a second round of analysis for these specific areas. This would allow the inclusion of high-resolution information, unavailable for the whole region (and therefore currently unsuitable for this advice), but locally available in these specific areas.

- More information on the data used (years, reference years, resubmissions, corrections) shall be given on the HTLMs for a better interpretation of the results.

- There are issues with the representation of VME physical elements in the map layers.

- Experts acknowledge that the ICES VME database is not the only source of information on VMEs in the NE Atlantic. When compared to the OSPAR database, some physical elements may be missing from the ICES VME database, such as carbonate mounds, seamounts and canyons. Merging both databases would give more holistic information on the distribution of VMEs in the NE Atlantic.

- Experts agreed that the nature of VMS data is a limitation that hampers the ability to identify the exact location of fishing activity, and to assess possible impacts on seafloor and VMEs. We note that this is partly a limitation of the ping rate of the current implementation of the VMS system and partly a feature of the nature of fishing operations with mobile bottom contacting gears. The result is a mismatch of spatial scale between the resolution of a c-square and the VME footprint. A consequence of this mismatch is the creation of large

Polygons that are further enlarged by the pragmatic choice of buffer distance and as such the broadscale nature of this assessment should be again noted. Experts acknowledge that the use of habitat distribution models is expected to improve the resolution.

- Experts acknowledge that spatial resolution of mobile-gear fishing effort (0.05° c-square) does not match the spatial resolution of VME occurrences. VME habitats are mapped from imagery data over 10's to 100's square metres. Low to high VME index records are mapped from blind sampling (e.g. trawls, dredges,...). Both the exact location of the fishing footprint and the spatial extent of VMEs are unknown. The VME polygons under the different spatial management options reflect the encountering of VMEs with mobile contact gears only.

- It is difficult to compare new and existing polygon size and shape in the current configuration of the HTMLs. This could be improved to make interpretation easier. Even if polygons can be identified by an ID number, it is difficult to assess the details or to modify the polygons. Drawing tools and more time with the groups of experts (regional and ICES WGDEC) would be advantageous.

- Several issues and limitations have been identified with the VME index. As the index is used as a product in the VME advice process, these issues are also relevant for the advice based on its use. These issues are centred around three key points and are as follows (ICES, 2021):

  1) Since the VME Index combines information on presence of 'ranked' VME indicator groups and measures of abundance, it is difficult to identify the underlying data that has led to the final Index score when using the final C-square gridded outputs. This makes it difficult to provide further evidence on the nature of the indicator(s) to managers and stakeholders.

  2) The process of ranking the VME indicator groups against the FAO criteria in terms of vulnerability has met some criticism, since definitions of what a VME has already been determined by the FAO guidelines (FAO, 2009). Vulnerability should be assessed in the context of the fishing pressure in a separate step, in what is referred to as an assessment of Significant Adverse Impacts (SAI; FAO, 2009), requiring knowledge of the species and gear interactions.

  3) The use of abundance data, compared to NEAFC move-on thresholds for corals and sponges, means some species, such as sea pens, cannot receive more than a 'Medium'

VME Index score whilst others will always receive a 'High' VME Index score. This led to concerns of the index becoming an index of perceived vulnerability rather than likelihood of occurrence.

- VMS data encompasses millions of GPS data from thousands of fishing vessels across Europe and his analysis is not an easy task. The ICES WGSFD is in charge of analysing these data, establishing quality controls and improving their methods in order to provide the most accurate information on MBCG intensity distribution. These methods as well as the data provided by the different countries are constantly updated, providing better information every year. This can lead to improvements in the MBCG footprint that can generate small differences in SAR distribution and, consequently, small changes in the polygons delineated. This is particularly the case in areas with SAR values close to the threshold of 0.43.

- Experts agreed that it is important to differentiate between changes produced by small changes in SAR as consequence of updates in the VMS data and modifications as consequence of correcting previous errors in fishing footprint. As acknowledge in ICES (2020) and van Denderen et al., (2021) the MBCG footprint using in 2020 advice for the Gulf of Cadiz was inaccurate, severely underestimating trawling activity in the Gulf of Cadiz. This led to the creation of VME closures based on the presence of VME indicator species with high uncertainty in areas of high socio-economic importance. These polygons, which were absent in the advice of 2022 (once the trawling footprint was corrected) and are also absent in the 2024 assessment as they are in areas exposed to high levels of trawling where the low index VMEs records are ignored in scenarios (C, D and E). In the years 2021 and 2022, the Spanish Institute of Oceanography (answering a request of the OPP 80 "Armadores de Punta de Moral") has been surveying these areas using direct (beam trawl) and indirect (photogrammetry sledge) methods, finding no evidence of the presence of VME within these polygons (IEO, 2023).

- At the 2024 meeting, WGDEC provided recommendations and drafts resolutions for a ICES workshop to improve the VME index, taking into consideration the known limitations of the VME Index and the weighting algorithm method for identifying areas where VME are likely to occur in the Northeast Atlantic region.

Generic ecoregion-specific assessments for provision of recurring VME advice

Celtic Seas ecoregion

Difference between 2022 and 2023

New VME data

- A total of 25 new or updated VME C-squares occur in the 400-800 m depth band in the Celtic Seas ecoregion. One of these C-squares is of VME habitat, 7 (28%) are high or medium VME index C-squares, and 17 (68%) are low VME index C-squares.

- The new/updated VME habitat C-square occurs to the northwest of the ecoregion, in the area to the southeast of Rockall Bank. This C-square contains a correction of positional data that had erroneously been in a C-square to the west and explains the change in the 2024 VME polygons compared to those in 2022 (see supplementary material).

- The new/updated high VME index C-squares (6) occur in the centre of the ecoregion in the 400-800 m depth band around Porcupine (5) and in the very south of the ecoregion (1).

- The new/updated medium VME index C-square (1) occurs to the north of the ecoregion in the 400-800 m depth band to the southeast of Rockall Bank. This C-square is due to a correction of the positional data associated with the sample 1413S_368 from a C-square to the west (see supplementary material).

- The new/updated low VME index C-squares (17) occur predominantly in the 400-800 m depth band on the Porcupine Bank to the west of Ireland, but also in the norther parts of the ecoregion.

- The issue outlined above in the 'Limitations on the provision of VME assessment' section, where VME C-squares located just outside the fishable domain (depth range 400-800 m) may increase the size of the VME polygon in the depth band because of the buffer zones associated with these VME c-squares, is also apparent in the Celtic Seas ecoregion. However, while these seem to occur predominantly at the lower depth boundary (800 m), there is one instance where it occurs at the higher boundary (Scenario C - 2024 PolygonID: 114, in the area of southeast Porcupine Bank).

Overlap of new VME records with areas fished by mobile bottom contacting gears

- In total, 84% of the new/updated VME C-squares occurring within the 400-800 m depth band overlap with areas fished by mobile bottom contacting gears (MBCG). Five of the 7 new/updated high and medium VME index C-squares and16 of the 17 low VME index C-squares overlap with fished areas, but the VME habitat C-square does not.

Scenarios and options

In general, the VME polygons from the 2024 assessment are similar to those in the 2022 assessment, with additions in areas of new/updated VME records as expected according to the scenario being considered.

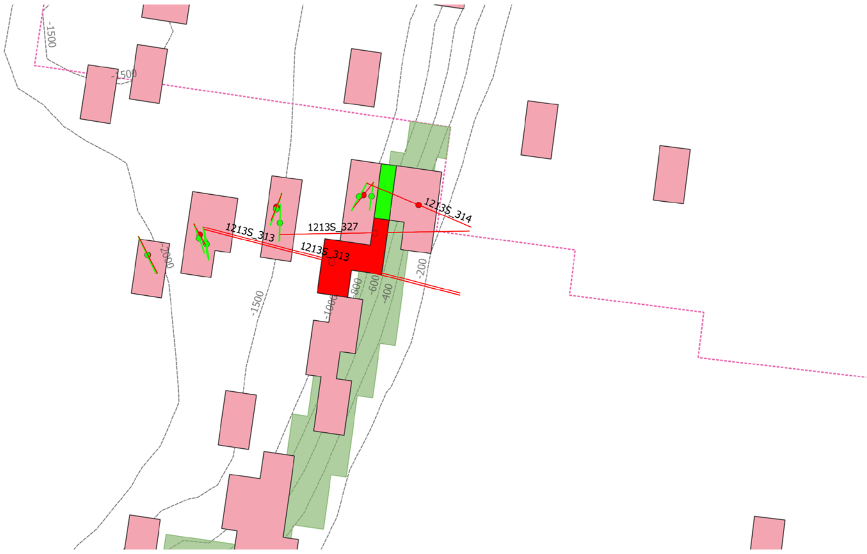
However, there are some notable subtractions/contractions to the VME polygons in the 2024 assessment in some areas. These subtractions are on account of changes (resubmissions/updates) in the VME and VMS data and are described below. These subtractions/contractions occur in 4 main areas of the Celtic Seas ecoregion:

- Area to north of Irish EEZ, on border with UK EEZ
- Area west of Donegal
- Southeast Rockall
- Porcupine (Scenarios C, D & E only – change in VMS data)

Below, a comparison is made between the VME polygons from the 2022 and 2024 assessments for each of these areas and each of the 5 scenarios. Screen grabs of maps from a GIS are used to illustrate the changes (the symbology within the HTMLs makes it difficult to illustrate these differences). The general symbology used here shows in red those areas that were in the 2022 VME polygons, but are no longer in the 2024 VME polygons. New additions to the VME polygons in 2024 that were not there in 2022 are shown in green. Relevant resubmitted VME data records are shown (incorrect previous locations in red (point and line) and corrected positional data in green (point and line). The other polygons (various colours depending on scenario) show the VME polygons that remain unchanged between 2022 and 2024. The 400 – 800 m depth zone is shown in darker green.

Scenario A

- Area to north of Irish EEZ:



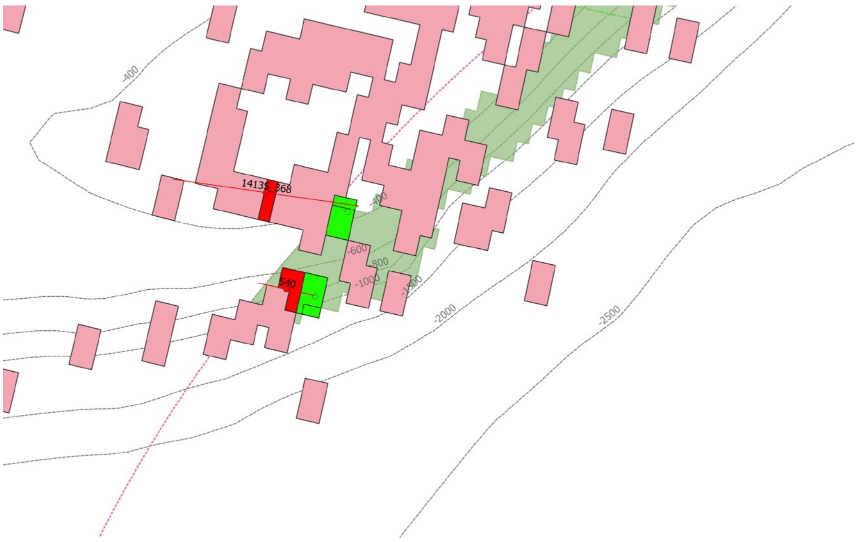
  - Subtractions to 2022 VME polygons in 2024 assessment:
    - An area 121.19 km² was not in the 2024 VME polygons (red polygon above) that had been in the 2022 advice (PolygonID 2022: 231).
      - The midpoint for three samples in the VME database (1213S_313 [2 records], 1213S_326 [5 records] and 1213S_327 [3 records]) changed with the resubmission of the MSS 1213S cruise data.
      - It appears the change in the positional data, in concert with the buffer rules, have caused the geometry of the VME polygons in this area to change.
    - Within the 400-800 m depth band, this subtraction translates to an area of 26 km² (red polygon below):

- Additions to 2022 VME polygons in 2024 assessment:
    - Additions in this area shallower than 400 m due to new data submissions.
    - Additions within the 400 – 800 m and deeper seem to be due to a reconfiguration of the VME polygons and the respective buffers in response to the updated positional data.
    - A VME polygon area of 17.25 km² is added within the 400 – 800 m depth band in this area (PolygonID 2024: 310 & in depth zone: 64).

- Area to west of Donegal

- Subtractions:
  - The VME polygon within this area (PolygonID 2022: 225) is reduced by 71 km^2.
  - This occurred as 2 parts:
    - 1. a shrinking of the VME polygon within the 400 – 800 m depth (a reduction of 35 km^2) (PolygonID 2022: 225, PolygonID 2024: 350 & in depth zone: 68). This is likely due to the change of positional data for samples 1213S_316 and 1213S_317.
    - 2. The splitting of the polygon (PolygonID 2022: 225 into two polygons: PolygonIDs 2024: 348 & 350) in the area deeper than 800 m. This is likely due to the change of positional data for sample 1213S_318.
- Additions:
  - No additions within the 400 – 800 m depth band here.
  - Those additions in the area shallower than 400 m are due to new VME data submissions and those deeper are due to the change in positional data for samples 1213S_316, 1213S_317 and 1213S_318.

- Southeast Rockall



- Subtractions:
  - The VME polygons from 2022 had subtractions in two places within this area in the 2024 polygons:

        - 1. An area within the Irish EEZ was subtracted due to the resubmission of positional data for the sample SeaRover18_540. This resulted in a reduction of 53 km^2 in the area of the 2022 assessment VME polygons (PolygonID 2022: 252).
        - 2. An area of VME polygon within the NEAFC regulatory area was removed due to resubmission of positional data from sample 1413S_368, which translated to a reduction of 35 km^2.
- Additions:
    - Two additions to the VME polygons in this area were made in 2024:
        - 1. A new area of VME polygon of 57 km^2 within the 400 – 800 m due to the resubmission of positional data for the sample SeaRover18_540 (PolygonID 2024: 500 & in depth zone: 11).
        - 2. A new area of VME polygon of 52 km^2 within the 400 – 800 m in the 2024 VME polygons (PolygonID 2024: 407 & in depth zone: 4) due to the resubmission of positional data for the sample 1413S_368.

There are no further subtractions in the VME polygons from 2022 in the 2024 assessment for Scenario A. All further additions are due to new VME data records.

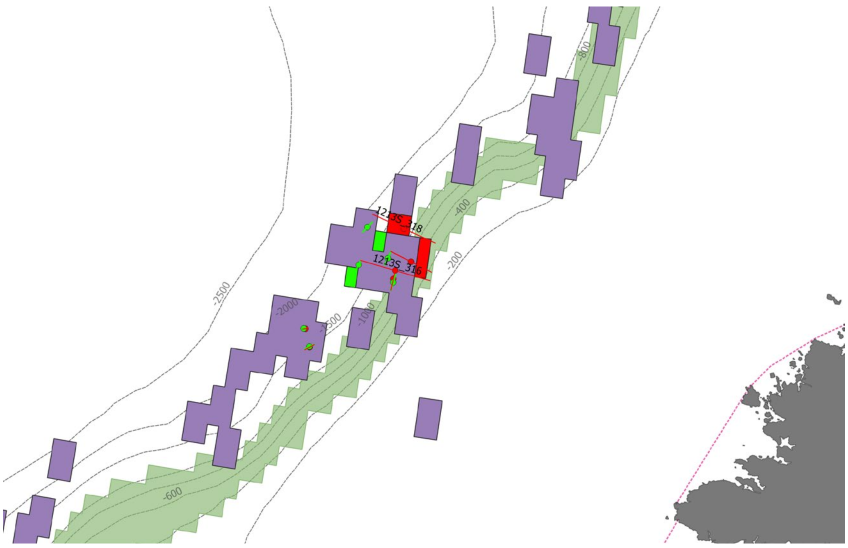
Scenario B

- Area to north of Irish EEZ:

  - Subtractions to 2022 VME polygons in 2024 assessment:
    - An area 121.19 km[2] was not in the 2024 VME polygons (red polygon above) that had been in the 2022 advice (PolygonID 2022: 229).
      - The midpoint for three samples in the VME database (1213S_313 [2 records], 1213S_326 [5 records] and 1213S_327 [3 records]) changed with the resubmission of the MSS 1213S cruise data.
      - It appears the change in the positional data, in concert with the buffer rules, have caused the geometry of the VME polygons in this area to change.
    - Within the 400-800 m depth band, this subtraction translates to an area of 26 km[2] (red polygon below):

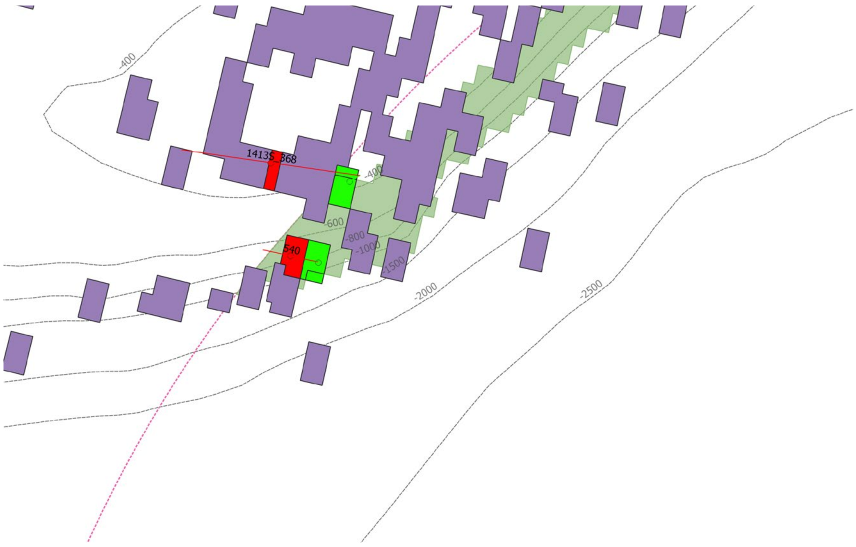
- Additions to 2022 VME polygons in 2024 assessment:
  - Additions in this area shallower than 400 m due to new data submissions.
  - Additions within the 400 – 800 m and deeper seem to be due to a reconfiguration of the VME polygons and the respective buffers in response to the updated positional data.
  - A VME polygon area of 17.25 km² is added within the 400 – 800 m depth band in this area (PolygonID 2024: 306 & in depth zone: 63).

- Area to west of Donegal



- Subtractions:
  - The VME polygon within this area (PolygonID 2022: 224) is reduced by 71 km^2.
  - This occurred as 2 parts:
    - 1. a shrinking of the VME polygon within the 400 – 800 m depth (a reduction of 35 km^2) (PolygonID 2022: 224, PolygonID 2024: 342 & in depth zone: 67). This is likely due to the change of positional data for samples 1213S_316 and 1213S_317.
    - 2. The splitting of the polygon (PolygonID 2022: 224 into two polygons: PolygonIDs 2024: 340 & 342) in the area deeper than 800 m. This is likely due to the change of positional data for sample 1213S_318.
- Additions:
  - No additions within the 400 – 800 m depth band here.
  - Those additions in the area shallower than 400 m are due to new VME data submissions and those deeper are due to the change in positional data for samples 1213S_316, 1213S_317 and 1213S_318.

- Southeast Rockall



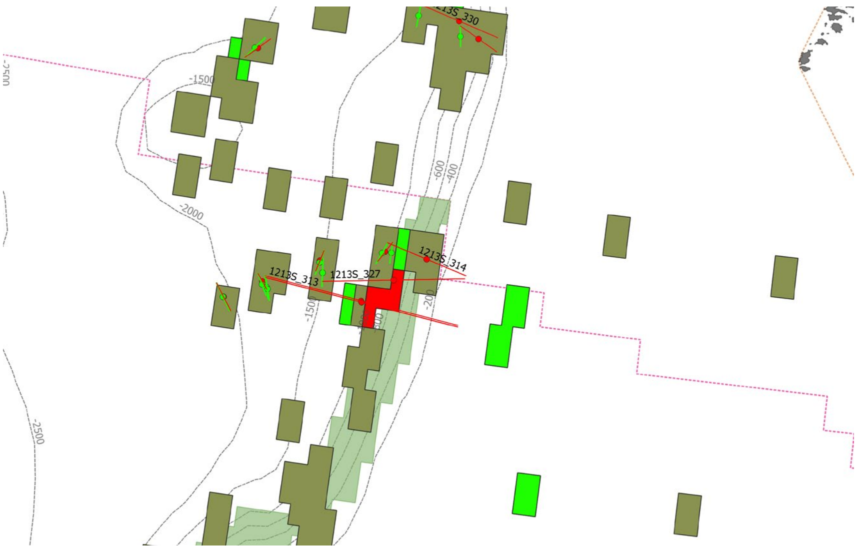
- Subtractions:
  - The VME polygons from 2022 had subtractions in two places within this area in the 2024 polygons:

            - 1. An area within the Irish EEZ was subtracted due to the re-submission of positional data for the sample SeaRover18_540. This resulted in a reduction of 66 km^2 in the area of the 2022 assessment VME polygons (PolygonID 2022: 248).
            - 2. An area of VME polygon within the NEAFC regulatory area was removed due to resubmission of positional data from sample 1413S_368, which translated to a reduction of 35 km^2.
    - Additions:
        - Two additions to the VME polygons in this area were made in 2024:
            - 1. A new area of VME polygon of 57 km^2 within the 400 – 800 m due to the resubmission of positional data for the sample SeaRover18_540 (PolygonID 2024: 488 & in depth zone: 9).
            - 2. A new area of VME polygon of 52 km^2 within the 400 – 800 m in the 2024 VME polygons (PolygonID 2024: 395 & in depth zone: 3) due to the resubmission of positional data for the sample 1413S_368.

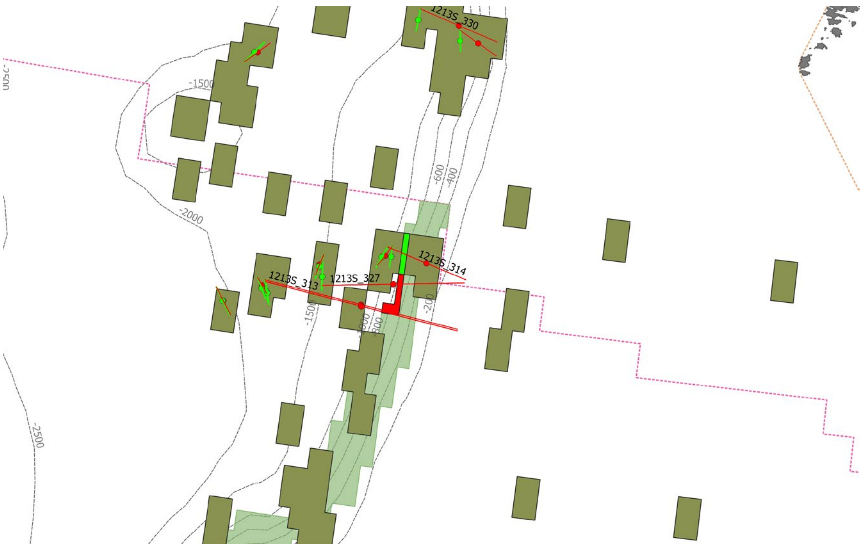
There are no further subtractions in the VME polygons from 2022 in the 2024 assessment. All further additions are due to new VME data records.

Scenario C

- Area to north of Irish EEZ:

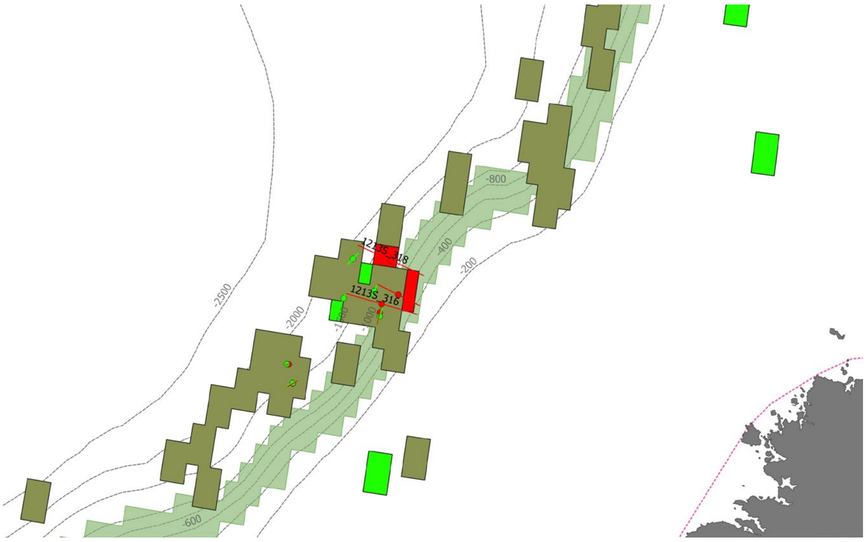


- Subtractions to 2022 VME polygons in 2024 assessment:
  - An area 121.19 km² was not in the 2024 VME polygons (red polygon above) that had been in the 2022 advice (PolygonID 2022: 271).
    - The midpoint for one sample (1213S_327, which contained 3 records) is the only change to the VME data contained within this polygon. However, a further two samples (1213S_313 [2 records], 1213S_326 [5 records]) also change immediately adjacent to this polygon.
    - It appears the change in the positional data, in concert with the buffer rules, have caused the geometry of the VME polygons in this area to change.
  - Within the 400-800 m depth band, this subtraction translates to an area of 26 km² (red polygon below):



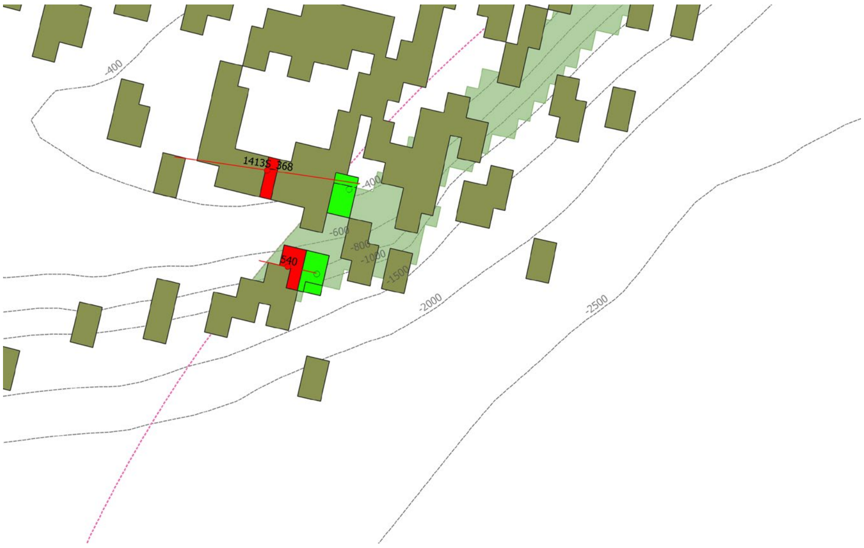
- Additions to 2022 VME polygons in 2024 assessment:
  - Additions in this area shallower than 400 m due to new data submissions.
  - Additions within the 400 – 800 m and deeper seem to be due to a reconfiguration of the VME polygons and the respective buffers in response to the updated positional data.
  - A VME polygon area of 17.25 km² is added within the 400 – 800 m depth band in this area (PolygonID 2024: 957 & in depth zone: 75).

- Area to west of Donegal



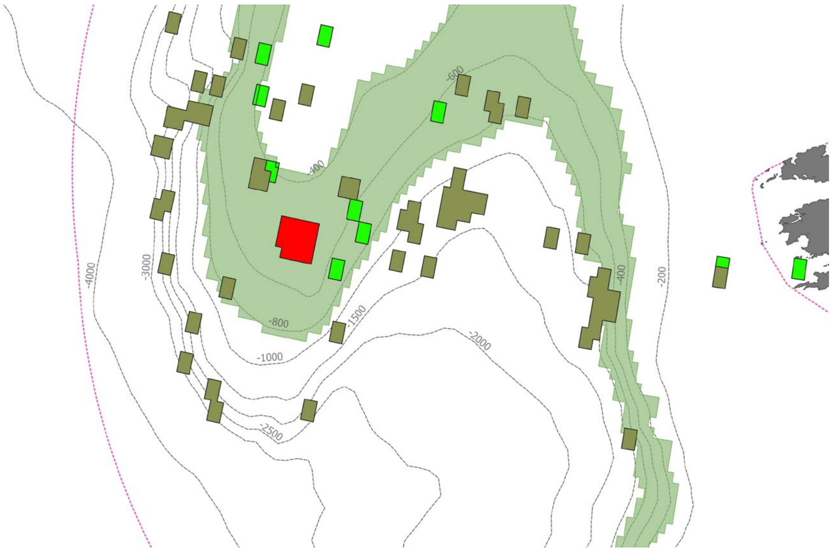
  - Subtractions:
    - The VME polygon within this area (PolygonID 2022: 263) is reduced by 71 km^2.
    - This occurred as 2 parts:
      - 1. a shrinking of the VME polygon within the 400 – 800 m depth (a reduction of 35 km^2) (PolygonID 2022: 263, PolygonID 2024: 1020 & in depth zone: 78). This is likely due to the change of positional data for samples 1213S_316 and 1213S_317.
      - 2. The splitting of the polygon (PolygonID 2022: 263 into two polygons: PolygonIDs 2024: 1017 & 1020) in the area deeper than 800 m. This is likely due to the change of positional data for sample 1213S_318.
  - Additions:
    - No additions within the 400 – 800 m depth band here.
    - Those additions in the area shallower than 400 m are due to new VME data submissions and those deeper are due to the change in positional data for samples 1213S_316, 1213S_317 and 1213S_318.

- Southeast Rockall



  - Subtractions:
    - The VME polygons from 2022 had subtractions in two places within this area in the 2024 polygons:
      - 1. An area within the Irish EEZ was subtracted due to the re-submission of positional data for the sample SeaRover18_540. This resulted in a reduction of 66 km² in the area of the 2022 assessment VME polygons (PolygonID 2022: 296).
      - 2. An area of VME polygon within the NEAFC regulatory area was removed due to resubmission of positional data from sample 1413S_368, which translated to a reduction of 35 km².
  - Additions:
    - Two additions to the VME polygons in this area were made in 2024:
      - 1. A new area of VME polygon of 57 km² within the 400 – 800 m due to the resubmission of positional data for the sample SeaRover18_540 (PolygonID 2024: 1223 & in depth zone: 10).
      - 2. A new area of VME polygon of 52 km² within the 400 – 800 m in the 2024 VME polygons (PolygonID 2024: 1102 & in depth zone: 4) due to the resubmission of positional data for the sample 1413S_368.

- Porcupine:

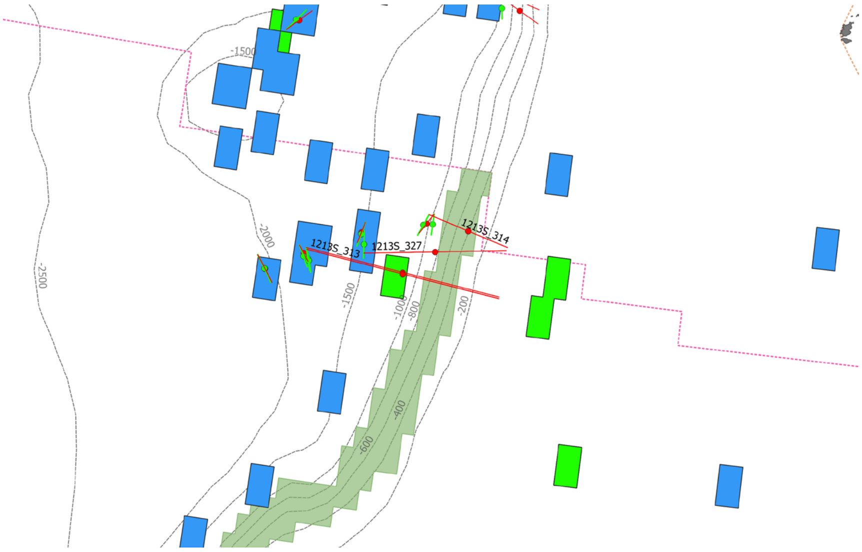


- Subtractions:
    - The VME polygon in the area south of Porcupine Bank from the 2022 assessment (PolygonID 2022: 219, 445.4 km2) containing sea pen VME indicator records, is removed from the 2024 assessment.
    - This is presumably due to changes in the VMS SAR data layer as no VME resubmissions were made in this area. From the HTMLs, it appears the SAR has increased within and immediately surrounding this polygon (particularly to the west and southwest).

There are no further subtractions in the VME polygons from 2022 in the 2024 assessment. All further additions are due to new VME data records and their interaction with MBCG fishing activity.

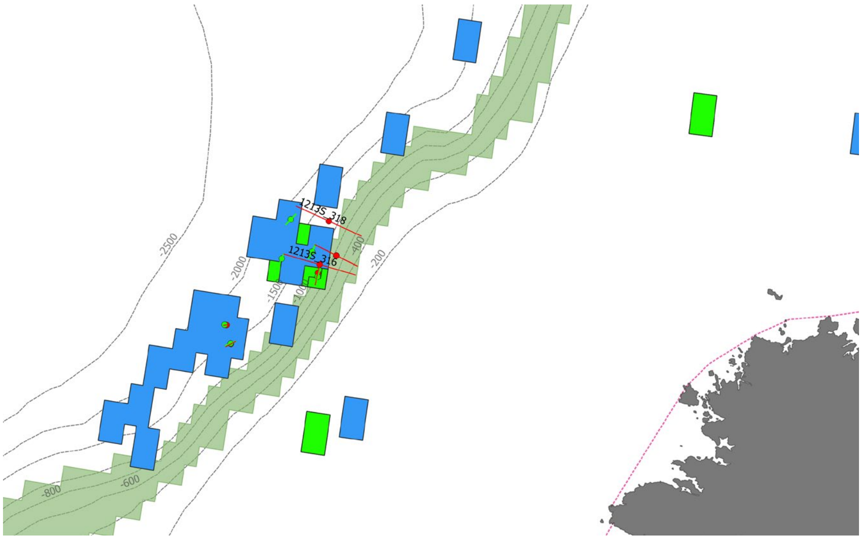
Scenario D

- Area to north of Irish EEZ:



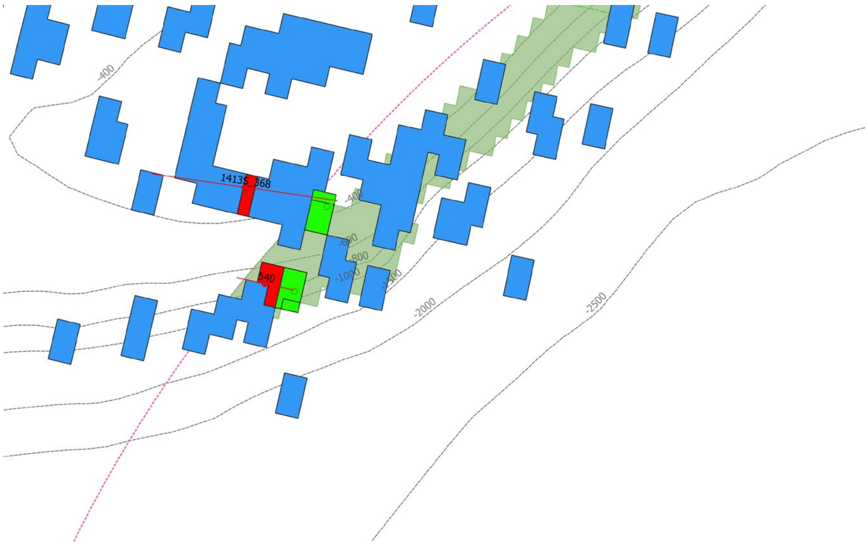
  - There were no changes within the depth zone for this scenario in this area

- Area to west of Donegal



- There were no subtractions of VME polygons within this area for this scenario
- Additions:
  - PolygonID 2022: 239, increased in size on account of the change of positional data for samples 1213S_316 and 1213S_317. This is PolygonID 2024: 990 & in depth zone 70. The portion of this polygon (PolygonID 2024 in depth zone: 70) within the depth zone from this increase in size equates to an area of 17.7 km2.
  - Those additions in the area shallower than 400 m are due to new VME data submissions and those deeper are due to the change in positional data for samples 1213S_316, 1213S_317 and 1213S_318.

- Southeast Rockall

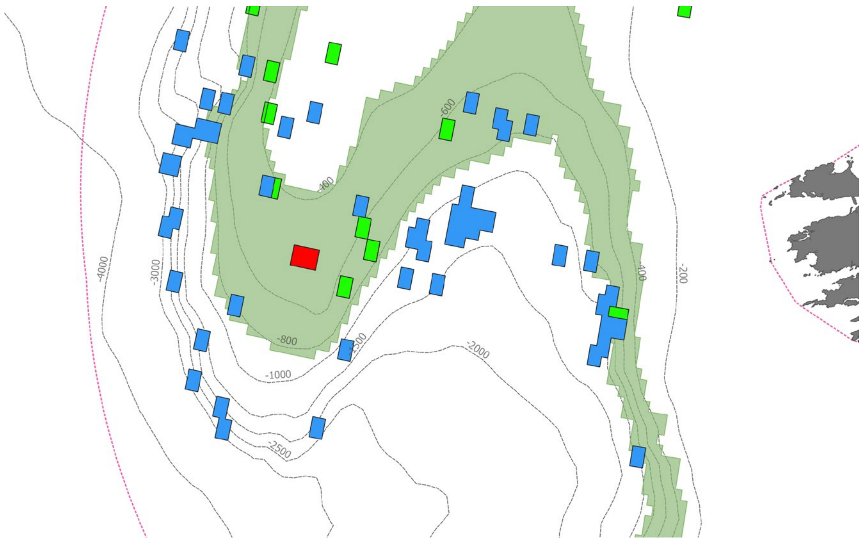


- Subtractions:
  - The VME polygons from 2022 had subtractions in two places within this area in the 2024 polygons:
    - 1. An area within the Irish EEZ was subtracted due to the resubmission of positional data for the sample SeaRover18_540. This resulted in a reduction of 66 km^2 in the area of the 2022 assessment VME polygons (PolygonID 2022: 268).

- 2. An area of VME polygon within the NEAFC regulatory area was removed due to resubmission of positional data from sample 1413S_368, which translated to a reduction of 35 km².

  - Additions:
    - Two additions to the VME polygons in this area were made in 2024:
      - 1. A new area of VME polygon of 57 km² within the 400 – 800 m due to the resubmission of positional data for the sample SeaRover18_540 (PolygonID 2024: 1187 & in depth zone: 12).
      - 2. A new area of VME polygon of 52 km² within the 400 – 800 m in the 2024 VME polygons (PolygonID 2024: 1168 & in depth zone: 9) due to the resubmission of positional data for the sample 1413S_368.

- Porcupine:



- Subtractions:
  - The VME polygon in the area south of Porcupine Bank from the 2022 assessment (PolygonID 2022: 198, 154.9 km2) containing sea pen VME indicator records, is removed from the 2024 assessment.
  - This is presumably due to changes in the VMS SAR data layer as no VME resubmissions were made in this area. From the HTMLs, it appears the

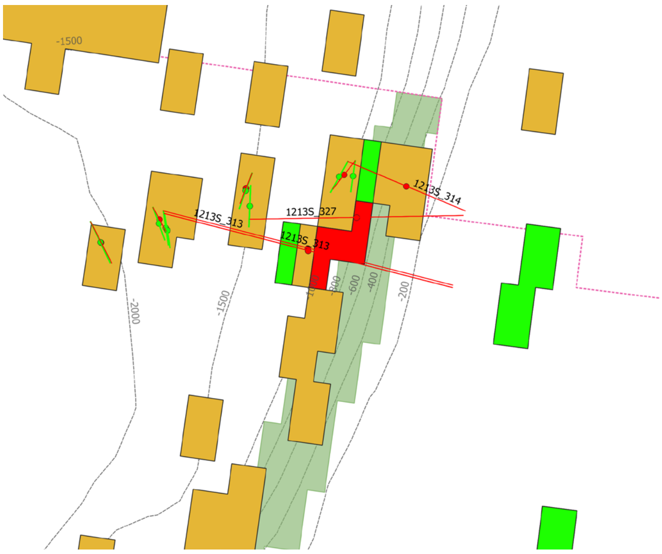
SAR has increased within and immediately surrounding this polygon (particularly to the west and southwest).

There are no further subtractions in the VME polygons from 2022 in the 2024 assessment. All further additions are due to new VME data records and their interaction with MBCG fishing activity.

Scenario E

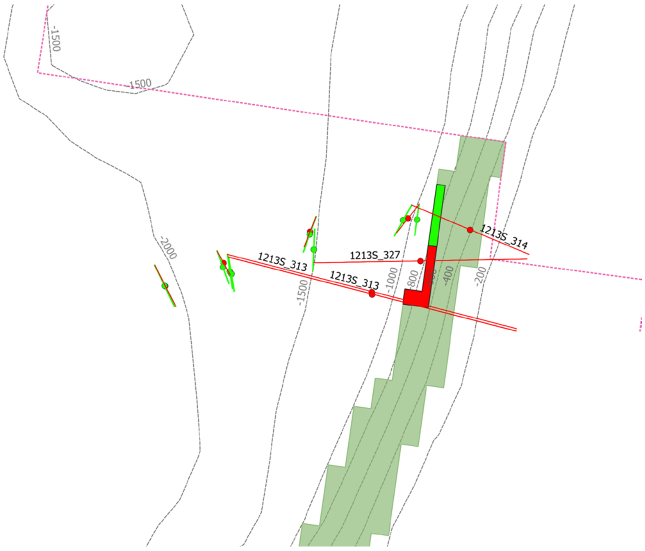
Note: No previous/2022 version of the VME polygons for this scenario in the HTMLs (assessment or advice). The below analysis is based on the polygon shapefiles on the SharePoint.

- Area to north of Irish EEZ:



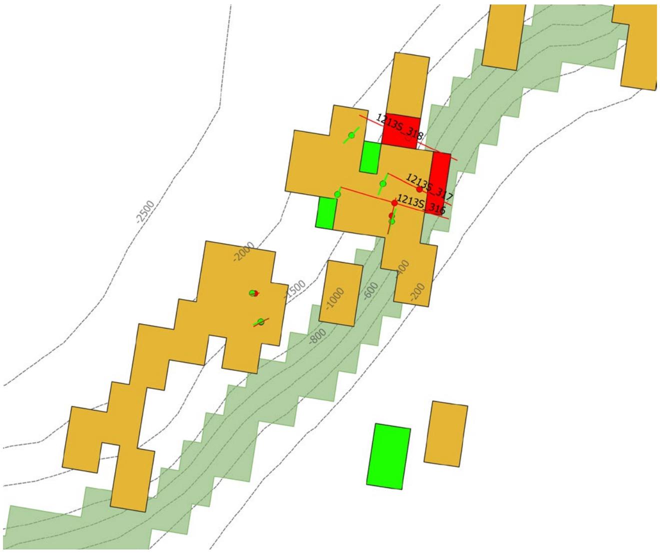
  - Subtractions to 2022 VME polygons in 2024 assessment:
    - An area 86.5 km² was not in the 2024 VME polygons (red polygon above) that had been in the 2022 advice (PolygonID 2022: 270).
      - The midpoint for one sample (1213S_327, which contained 3 records) is the only change to the VME data within this polygon.
      - It appears the buffer rules may have caused the geometry of the VME polygons in this area to change.

- Within the 400-800 m depth band, this subtraction translates to an area of 26 km^2:



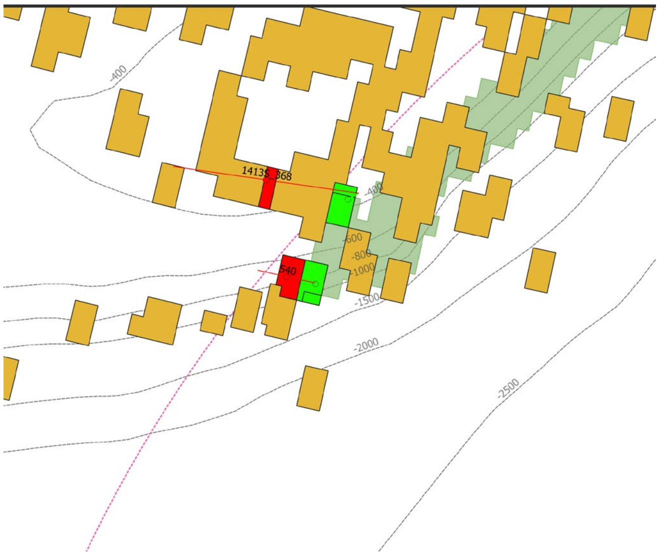
- Additions to 2022 VME polygons in 2024 assessment:
    - Additions in this area shallower than 400 m due to new data submissions.
    - Additions within the 400 – 800 m and deeper than seem to be due to a reconfiguration of the VME polygons and the respective buffers.
    - A VME polygon area of 17.25 km^2 is added within the 400 – 800 m depth band in this area (PolygonID 2024: 952).

- Area to west of Donegal



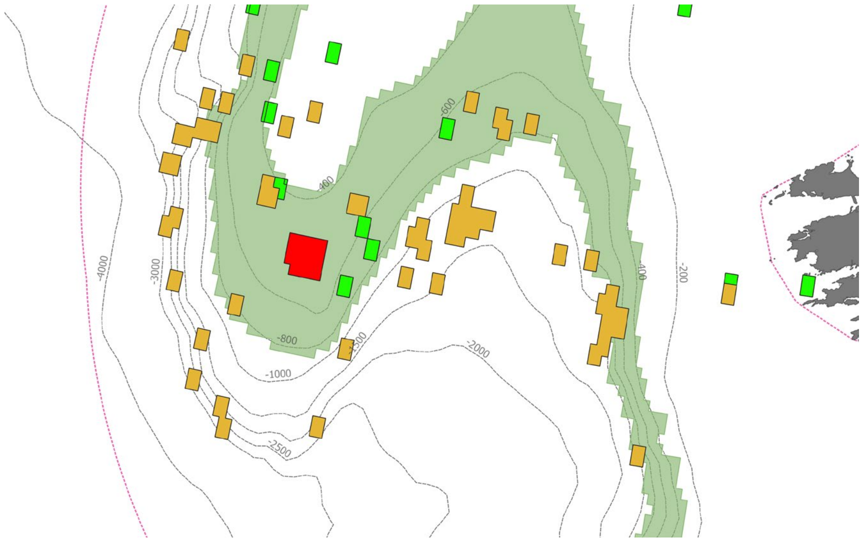
- Subtractions:
  - The VME polygon within this area were reduced by 70 km².
  - This occurred as 2 parts:
    - 1. a shrinking of the VME polygon within the 400 – 800 m depth, which translates into a reduction of 35 km² within the depth band (PolygonID 2022: 262). This is likely due to the change of positional data for samples 1213S_316 and 1213S_317.
    - 2. The splitting of the polygon in the area deeper than 800 m. This is likely due to the change of positional data for sample 1213S_318.
- Additions:
  - No additions within the 400 – 800 m depth band here.
  - Those additions in the area shallower than 400 m are due to new VME data submissions and those deeper are due to the change in positional data for samples 1213S_316, 1213S_317 and 1213S_318.

- Southeast Rockall



  - Subtractions:
    - The VME polygons in 2022 had subtractions in two places within this area:
      - 1. An area within the Irish EEZ was subtracted due to the re-submission of positional data for the sample SeaRover18_540. This resulted in a reduction of 66 km² in the area of the 2022 assessment VME polygons (PolygonID 2022: 291).
      - 2. An area of VME polygon within the NEAFC regulatory area was removed due to resubmission of positional data from sample 1413S_368, which translated to a reduction of 35 km².
  - Additions:
    - Two additions to the VME polygons in this area were made:
      - 1. A new area of VME polygon of 57 km² within the 400 – 800 m due to the resubmission of positional data for the sample SeaRover18_540 (PolygonID 2024: 1209).
      - 2. A new area of VME polygon of 52 km² within the 400 – 800 m in the 2024 VME polygons (PolygonID 2024: 1088) due to the resubmission of positional data for the sample 1413S_368.

- Porcupine



- Subtractions:
  - The VME polygon in the area south of Porcupine Bank from the 2022 assessment (PolygonID 2022: 82(from advice HTML), 445.4 km2) containing sea pen VME indicator records, is removed from the 2024 assessment.
  - This is presumably due to changes in the VMS SAR data layer as no VME resubmissions were made in this area. From the HTMLs, it appears the SAR has increased within and immediately surrounding this polygon (particularly to the west and southwest).

There are no further subtractions in the VME polygons from 2022 in the 2024 assessment for this scenario. All further additions are due to new VME data records and their interaction with MBCG fishing activity.

Update to advice text issued in 2022/2023 for the Celtic Seas ecoregion

In comparison with existing EU closures for VMEs protection and previous (2021 & 2023) VME polygons, the most notable change in 2024 is the removal (in scenarios C, D and E) of a large previous (2021 & 2022) VME polygon (and existing EU closure) on top of Porcupine Bank (Figure 1 and map CS1). This VME polygon is associated with Low VME Index squares and its removal in 2024 is linked to the updated VMS data and average SAR values exceeding 0.43. In all scenarios, there are also minor contractions and a few additions and extensions of VME polygons to the north of the ecoregion, along the Irish continental shelf margin and around Porcupine and south Rockall in 2024. New additions and extensions reflect the inclusion of new VME data in the assessment, while small contractions are linked to updated and resubmitted evidence of VME occurrence in response to the 2024 WGDEC ToR c work and corrections of positional data associated with some records in the ICES VME database. In the area to the west of Donegal, Mayo and Galway, this results in some of the existing EU closures and previous VME polygons no longer being supported by the evidence base.

In 2024, for scenarios A, B, C and E there is a slight addition at the very north of the ecoregion (on the border with the UK EEZ) that unifies two previous (2022) VME polygons across the 400 – 800 m depth zone. There is also a slight subtraction in this area for all scenarios apart from D. Similarly, in the area to the west of Mayo and Galway and to the north of Porcupine Bank, there is a contraction of a polygon in the 400 – 800 mm depth zone, with the addition and subtraction of further small areas deeper than 800 m. For all scenarios, there is a contraction (as compared to 2022) of the VME polygon in the 400 – 800 m depth zone in the area to southeast Rockall Bank, with an addition of a C-square immediately adjacent to this subtraction and an expansion of the VME polygon just north of the area of the subtraction (map ref?).

Between 9.1% (scenario D) and 12.2% (scenario C) of existing EU deep-sea fishing areas in the Celtic Seas ecoregion were identified as VMEs protection polygons in 2024 (Table CS2). The total areal extent of new/updated VME polygons ranges from 4559 km^2 (in scenario D) to 5896 km^2 (in scenario C). Between ~70% (scenarios C, D and E) and ~75% (scenarios A and B) of the updated VME polygons area overlaps with the existing EU closures for VMEs protection. This indicates a 13% to 15% increase in the total area identified for VMEs protection in the ecoregion based on data up to and including 2024.

Scenarios C and E based on evidence of both VMEs and MBCG fishing result in higher total VME polygons area (5896 km^2 and 5810 km^2, respectively), average areal extent of large polygons (373 km^2), and proportion of existing deep-sea fishing areas identified as VME polygons (12.2% and 12.1%, respectively). Scenario C generates one less polygon (62) compared to scenario E (63), and has the largest average polygon areal extent (95 km^2) among scenarios. Both scenarios C and E protect all VME habitat records observed in c-squares overlapping the 400-800m depth zone within the ecoregion (cold-water coral reef, coral garden, deep-sea sponge aggregations, sea pen fields and tube-dwelling anemone aggregations) and identical, highest proportions of VMEs indicator records. Scenarios C and E would also maximise protection of sea-pen records, relative to other scenarios (Table CS3).

Scenarios A and B which are based solely on evidence of VMEs result in comparable outcomes due to the limited occurrence of physical VME elements in c-squares overlapping the 400-800m depth zone within EU waters of the Celtic Seas ecoregion. Scenario A generates fewer (57) and on average larger (91.6 km^2) VME polygons than scenario B (58 and 88.5 km^2, respectively), and yields a slightly larger total polygons area (5220 km^2 compared to 5134 km^2 in scenario B). Both scenarios protect all VME habitat records and identical proportions of VMEs indicator records in c-squares overlapping the 400-800m depth zone within the ecoregion. However, scenarios A and B would protect a lower proportion (34.6%) of sea-pen records compared to scenarios C and E.

Scenario D, which is based on evidence of both VMEs and MBCG fishing, results in on average smaller VME polygons (77 km^2) and large VME polygons (259 km^2), and a smallest total area identified as VME polygons (4559 km^2). Scenario D has the lowest proportional overlap with existing deep-sea fishing areas (9%), and lowest proportions of protected VME habitat and indicator records in the EU waters of the ecoregion. Scenario D based on 2024 data would generally reduce proportions of VME habitat and indicator records currently protected under the existing EU closures.

Bay of Biscay and Iberian coast ecoregion

New VME data

There was no new VME data submitted in 2022, 2023, 2024.

Comparison of VME polygons between the 2022 and 2024 assessments for the Bay of Biscay and Iberian Coast ecoregion

Due to updated VMS data, there are changes in the 2024 assessment compared to the 2022 assessment across Scenarios C, D and E (i.e. those that consider MBCG fishing activity). This has caused an increase/new VME polygons in 2024 compared to 2022.

Below, a comparison is made between the VME polygons from the 2022 and 2024 assessments for each of the 5 scenarios. Screen grabs of maps from a GIS are used to illustrate the changes (the symbology within the HTMLs make this difficult). The general symbology used here shows new additions to the VME polygons in 2024 that were not there in 2022 in green. The other polygons (various colours depending on scenario) show the VME polygons that remain unchanged between 2022 and 2024.

Scenario A

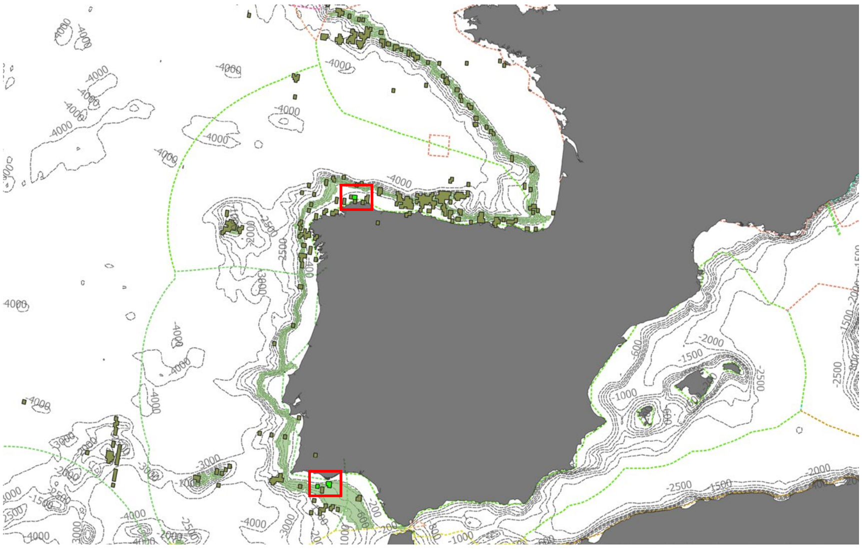
No change between 2022 and 2024 VME polygons

Scenario B

No change between 2022 and 2024 VME polygons

Scenarios C & E

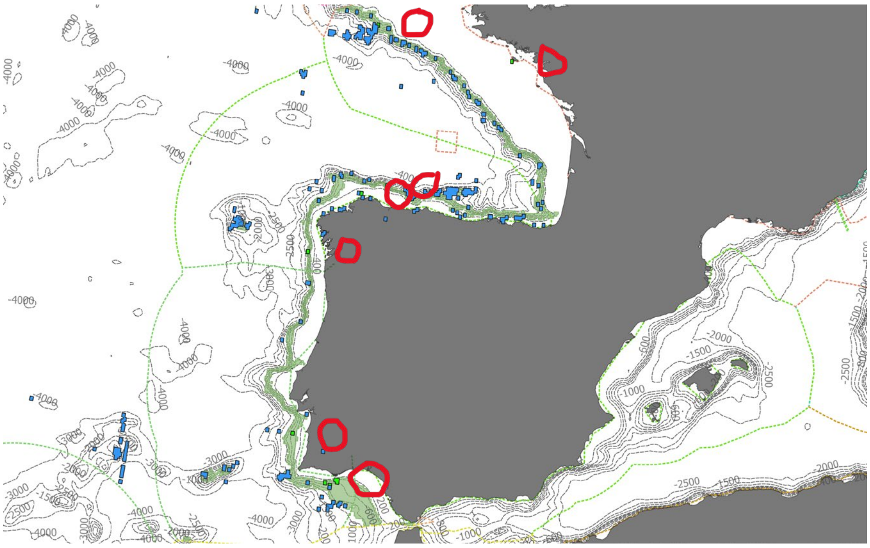
New VME polygons in 2024:



- There are new VME polygons in two areas of the BOBIC ER, to the north of Spain and in the Gulf of Cadiz.
- There were no new VME data, so these new polygons are a result of a reduction of SAR in this area.
- New VME polygons / extension to 2022 VME polygons (from north to south):
  - PolygonID 2022: 90 has increased in size in 2024 (PolygonID 2024: 1116), but is shallower than 400 m
  - PolygonID 2024: 1300 & in depth zone: 69 is a new VME polygon in 2024. It has an area of 80.5 km^2 in the depth zone.
  - PolygonID 2024: 1268 & in depth zone: 65 is a new VME polygon in 2024. It has an area of 167 km^2 in the depth zone.

Scenario D

New VME polygons in 2024:



- There are new VME polygons in seven areas of the BOBIC ER.
- There were no new VME data, so these new polygons are a result of a reduction of SAR in this area.
- Among the new polygons, two are extending already existing ones, which are located within EU-established VME areas. The VME areas may have driven a reduction in SAR at their periphery.
- New VME polygons / extension to 2022 VME polygons (from north to south):
  - PolygonID 2022: 141, is extended (PolygonID 2024: 1018 & in depth zone: 46) by 62.3 km2 within the depth zone
  - PolygonID 2024: 845 (area 84.1 km2) is a new VME polygon, but is shallower than 400 m
  - PolygonID 2022: 79 increased in size (PolygonID 2024: 1033 & in depth zone: 48) by 44.5 km2 within the depth zone
  - PolygonID 2022: 75 increased in size (PolygonID 2024: 1079, shallower than depth zone) by 89.3 km2
  - PolygonID 2024: 1232 & in depth zone: 60 is a new VME polygon. Area in depth zone is 68.7 km2.
  - PolygonID 2024: 1322 & in depth zone: 67 is a new VME polygon. Area in depth zone is 97.7 km2
  - Cluster of three furthest south in Gulf of Cadiz (from east to west)
    - PolygonID 2024: 1257 & in depth zone: 64 is a new VME polygon. Area in depth zone is 80.5 km2

- PolygonID 2022: 6 is extended in 2024 (PolygonID 2024: 1246 & in depth zone: 63) by 49.5 km2
- PolygonID 2024: 1225 & in depth zone: 59 is a new VME polygon. Aea in depth zone is 167 km2

Update to advice text issued in 2022/2023 for the Bay of Biscay and Iberian Coast ecoregion

In comparison with previous (ICES 2023) VME polygons, there are very limited changes and these are due solely to updates to the VMS data (SAR values) used in the assessment. No new VME records were received for this ecoregion since the last ICES advice (2023) was issued.

In 2024, there are additions of VME polygons due to a reduction of SAR in areas within the 400 – 800 m depth zone to the north of Spain and west of Portugal (scenario D) and in the Gulf of Cadiz (scenarios C, D and E). In both aeas, the new VME polygons extend already existing VME polygons (ICES 2021, 2023), which are also located within EU-established VME areas. These established VME area (due to the management restrictions in place) may have driven a reduction in SAR in the periphery of the established areas, causing the expansion of these as presented here in the 2024 assessment.

Between 12.3% (scenario D) and 18.9% (scenario E) of existing EU deep-sea fishing areas in the Bay of Biscay and Iberian Coast ecoregion were identified as VMEs protection polygons in 2022 (Table BI2). The total areal extent of new/updated VME polygons ranges from 5422 km2 (in scenario D) to 9619 km2 (in scenario E). Between 37.8% (scenario B) and 50.7% (scenario D) of the total polygons area currently overlaps with the existing EU closures for VMEs protection.

Scenarios C and E, which are based on evidence of both VMEs and MBCG fishing, continue to result in a higher total number of VME polygons (64 and 62, respectively), total polygons area (9005 km2 and 9619 km2), and proportion of existing deep-sea fishing areas identified as VME polygons (18.4% and 18.9%).

Scenarios including VME physical elements without and with fishing information (scenarios B and E, respectively), continue to result in the highest average areal extent of individual polygons (166 km2 and 155 km2, respectively) and large polygons (777 km2 and 759 km2). Three VME physical elements contribute to increasing the total area of VME polygons in scenarios B and E: Le Danois Bank, Galicia Bank and Gorringe Bank. Differences in the criteria for the inclusion of low VME index c-squares in VME polygons among scenarios, explain that ten polygons protected under scenario E are not protected under scenario B (including 2 polygons in the Bay of Biscay, 3 in northern Spain, and 5 in the Gulf of Cadiz). It also explains that the three large polygons encompassing each of the Le Danois, Galicia and Gorringe Banks VME physical elements in scenarios B and E, are split into five smaller polygons in scenario C.

Scenario A, which is based solely on evidence of VMEs, continues to result in intermediate outcomes in terms of number and size of VME polygons and is the same as that presented in the 2022 advice (ICES 2023) as there are no new VME records. Scenario D, which is based on evidence of both VMEs and MBCG fishing, continues to result in the lowest average size of polygons (111 km^2), average size of large polygons (323 km^2), total area identified as VME polygons (6422 km^2), and fraction of existing EU deep-sea fishing areas identified as VME polygons (12.3%).

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Annex 5: Report of the Reviewers

Summary of review

The goal of this review is to provide objective feedback on the suitability and validity of data and methods, alternative approaches, appropriate interpretation of results and raise potential further work to address unresolved issues. The work of the WCDEC presented in documents, figures and tables was reviewed through this lens. Specific questions that were addressed in the review include:

1) Is the analysis technically correct?
    a. The analyses essentially follow the processes and recommendations of the benchmark assessment approach developed in 2022 and adopted by WKVMEBM.
    b. The work adhered to the established and technically correct methods
2) Are the scope and depth of the science appropriate for the request?
    a. The science was limited by the incremental addition of new data from a few ICES participating nations, despite a consistent call for contributions as part of the advisory process.
    b. Part of the problem is the annual call is not answered consistently, so annual or biennial requests for updates to the advice are inconsistent with the commitment of member nations to update the information. Incremental data contributions were also a problem in the review of WGDEC activities by RGVME conducted in 2023.
    c. One recommended solution to this problem is that ICES only carry out revisions to the VME assessments on a 3-5 year cycle, and that in the interim WGDEC concentrate on methodological and QA/QC concerns to improve provision of advice and the processes to facilitate efficient analyses.
3) Does the analysis contain the knowledge to answer the request for advice?
    a. The assessment was undertaken by limited pool of available experts in a limited amount of time, and therefore was not exhaustive nor does it represent the expert opinion of the WGDEC and its members as a whole. This can potentially represent an important limitation and criticism of the evidence used in development of the advice.
    b. The revised analyses, based on the preamble from the Chairs, have resulted in only incremental changes to the information available to regulatory bodies. As a result the recommendations from WGDEC is that no changes to the 2023 advice are warranted. A conclusion that the review group believes is warranted.

Based on our review of the material provided, the technical work done by the experts is at a sufficient standard for ICES to base its advice on.

Terms of reference:

The terms of reference for the WCDEC in their provision of data and analysis for consideration in providing ICES advice were:

a) Collate, validate and QA/QC-check new information on the occurrence and distribution of vulnerable marine ecosystems (VMEs), VME indicator taxa and VME elements in the North Atlantic and adjacent waters, archive appropriately using the ICES VME Database, and disseminate via the Working Group report and ICES VME Data Portal. [ToR a]

b) Review, validate and update new information on the occurrence and distribution of VMEs, VME indicator taxa and VME elements in the NEAFC Convention Area, including subareas of the Regulatory Area that are closed to fishing for other purposes than VME protection, and in EU waters in relation to the EU deep-sea access regulation. In addition, evaluate whether the EU VME advice needs to be updated, based on the criteria suggested by WGDEC in 2023 (ToR c) and agreed in dialogue with ACOM leadership. [ToR b]

c) Conduct a review of historical records included in ICES VME Database. [ToR c]

Activities and analyses by WCDEC to address the ToR:

- New VME information was submitted by Ireland, Norway and Scotland. These VME records were submitted for the Barents Sea Ecoregion (including NEAFC area) and the Celtic Sea Ecoregion. There were no new VME records submitted for the Bay of Biscay and Iberian Coast Ecoregion.
- These VME data were cleaned, QA/QC'd and added to the data portal.
- The new VME locations were mapped, presences added to the VME weighting algorithm and the updated VME index calculated (with no accompanying estimate of uncertainty).

- New VMS data was submitted for 2023 by 16 countries.
- Updated/corrected VMS data were submitted for the EU waters (Celtic Seas Ecoregion and the Bay of Biscay and the Iberian Coast regions) and NEAFC waters.
- The VMS data were cleaned, QA/QC'd and processed, although some data from Portugal had not passed the evaluation process at the time of the report.
- The new VMS data was used to map fishing intensity in 2023 and to update SAR calculations.

- New and updated VME index polygons were plotted for the EU Seas. Where VME and/or VMS data were added/updated, scenarios A-E were also updated providing modified VME polygons based on the new information.
- The new VMS data from 2023 was plotted with the VME closures by gear type (mobile, static, unspecified) and the corresponding (updated if new data were available) VME index was plotted and compared.

Results of analyses:

- Changes in VME polygons were noted in the Celtic Seas area and Bay of Biscay and the Iberian Coast by the assessment group. There were modifications to VME polygons due to both new VME and corrected/updated VME and VMS observations in the Celtic Seas Ecoregion and from corrections/updates to VMS data in the Bay of Biscay and the Iberian Coast.

- In the Celtic Seas, there were overall increases in the area of VME polygons through a combination of new observations of VME, updated positions of VME observations and updated positions of VMS data (leading to reductions in SAR).
- In the Celtic Seas there were also reductions some in specific VME c-squares due to updated VMS data resulting in higher SAR values (exceeding the 0.43 threshold).
- In the Bay of Biscay and Iberian Coast Ecoregion new/updated VMS data resulted in expansions to some VME polygons and two new VME polygons due to a reduction in SAR for these areas.

- Comparisons were made between the spatial overlap of new VME observations in the Barents Sea and the Celtic Sea and updated VMS data.
- It was concluded that no further modifications of existing closure boundaries was needed based on the new information.

Key pieces of science advice from the analysis:

- The changes/corrections of existing data that were made did not result in significant changes in the resulting VME polygons in EU Seas that would necessitate a revision to the 2023 advice.
- The new information provided for the NEAFC area in 2023 does not necessitate revision of the 2023 advice.

Additional reviewer comments

One good aspect in this assessment is that WGDEC carried out a proper evaluation of the changes to the information relative to previous reports. This is a strong point of the efforts of WGDEC relative to past reports, even though the outcome indicated that no substantive changes to the advice were required. Even if there is nothing to report, for good record keeping this should be stated not only for the ease of reviewers, but as documentation that it was looked at for future reference.

After going through the documents, we noted growing concerns that the work of WGDEC is being impeded by the lack of contribution of new data for the assessments. The frequency of requests for advice coming from the EU and NEAFC, are not consistent with the actions/contributions from member nations. As a result, the outcome essentially represents an incomplete re-assessment of the information previously reported on and used in the development of advice developed by the Advice Drafting Group. This is related to our recommendation above to push toward revising the work process/timing so that ICES only carry out revisions to the VME assessments on a 3-5 year cycle and that in the interim WGDEC concentrate on methodological and QA/QC concerns. Reviewers suggested that 3 years might be a bit long for risk assessment, but 5 years might be needed to allow accumulation of significant new information, so 4 years could represent a balanced approach between risk and new information acquisition.

As reviewers were not involved in the WCDEC process, it was a bit difficult to see how these individual pieces fit together without reference to a large body of information from prior work by ICES WGs and workshops. The ToR and recommendations were not easily put together and the rationale for the current advice (in this case no new advice to be given) was not always easy to discern. We would recommend a more standard approach to the reporting/provision of materials for the review process. Our understanding is that there are currently two separate processes for conducting assessments for the NEAFC and EU waters. This leads to some disjointed aspects of the results that then appear to be missing from the analysis (e.g., NEAFC VME polygons). In the future use of the EU VME methods (from the benchmark workshop report) for both clients would be more efficient and allow for easier comparison of results across areas.

Reviewers also noted some improvements and additional information provided in the 2024 work, such as the addition of (and validation) of fishing activity using the speed histograms in Figure 4.9 (one minor suggestion would be to add a horizontal line where the fishing/not fishing cutoffs were located in each panel). Reviewers noted their agreement with the comment from the Chairs that the maps on the HTML and document were very difficult to read (sometimes having incomplete keys or having legend keys that did not occur on the maps). It might be better to provide the information on VME observations via ArcGIS layers or some other format that could be more efficiently manipulated and visualized.

Reviewers also recognized the comment from the Chairs on the validity of the VME database, but if we understand it correctly indicates that those records submitted in 2020 and prior are retained in the database, even if they have since been updated or removed. If this is the case, it would be useful to have some versioning of the database to both maintain the "current" versions of VME and to have some record of "historical" VME records that were removed or modified. If updated assessments were completed on a more periodic basis (3-5 year cycle), it might allow more time for database improvements as well.

Reviewers note the following statements from WGDEC and their potential consequences to the evidence-base for development of advice:

- "WGDEC considers that the process of including VMEs located outside the fishable domain (depth range 400-800 m) may increase the size of the polygon because of the buffer zones associated with these VMEs located just outside the depth range. This is not necessarily a problem for VMEs located deeper than 800 m as these are already protected (Deep Sea Access Regs). However, it does not make sense for VMEs located shallower than 400 m as the closures are creating a protection buffer around a VME that is not protected at all. This needs to be corrected where possible. Several examples of this have been identified."
- "Experts agreed that the nature of VMS data is a limitation that hampers the ability to identify the exact location of fishing activity, and to assess possible impacts on seafloor and VMEs. We note that this is partly a limitation of the ping rate of the current implementation of the VMS system and partly a feature of the nature of fishing operations with mobile bottom contacting gears. The result is a mismatch of spatial scale between the resolution of a c-square and the VME footprint. A consequence of this mismatch is the creation of large Polygons that are further enlarged by the pragmatic choice of buffer distance and as such the broadscale nature of this assessment should be again noted. Experts acknowledge that the use of habitat distribution models is expected to improve the resolution."

Both of these statements highlight the limitations in the use of C-squares to evaluate the overlap between VMEs and fishing activities in the eastern Atlantic. The reviewers agree that efforts should be directed toward the development of species distribution models appropriate for the assessment of the potential risk of significant adverse impact on VMEs and associated habitats.

In the future, it would seem that further efforts should be made to determine the source of unreported gear types. If the unreported gear types are in fact mobile bottom contacting gear, then there may be reason for concern in some areas. For example the no specific gear type had significant overlap with the Medium VME index areas on Josephine Seamount, which influences the assessment of the potential impact of bottom contact gear. A somewhat similar comment on static gears in that future efforts should be made to include static gears in the calculations. The intensity of static gears was high in some areas, for example on Rockall Bank, and although they did not appear to overlap VME closures, future work should try to assess static gear impacts in a more quantitative way.