BENCHMARK WORKSHOP ON THE OCCURRENCE AND PROTECTION OF VMES (VULNERABLE MARINE ECOSYSTEMS) (WKVMEBM)

VOLUME 4 | ISSUE 55

ICES SCIENTIFIC REPORTS

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ISSN number: 2618-1371

ICES Scientific Reports

Volume 4 | Issue 55

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Recommended format for purpose of citation:

ICES. 2022. Benchmark Workshop on the occurrence and protection of VMEs (vulnerable marine ecosystems) (WKVMEBM).
ICES Scientific Reports. 4:55. 99 pp. http://doi.org/10.17895/ices.pub.20101637

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i Executive summary

The main aim of WKVMEBM 2022 was to develop and document an operational evidence-based procedure for the production of recurrent ICES advice on VMEs.

WKVMEBM recommend the method described at ANNEX 6 be used when ICES provides advice on location and protection of VMEs. The method is consistent on the FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO, 2009). WKVMEBM identified the key data sources along with confidence and limitations in data layers that delineated the distribution of VMEs (indicators, habitats, elements) and fishing activity based on the data types available from the EU and NEAFC. WKVMEBM also defined scenarios for VME protection that differed in the data available, and the VME indicator metrics that could be included in the decision-making process by requesting agencies. The WK recognises that the method will be modified as the science develops and more data, and at a finer resolution, becomes available. These modifications will include improvements to the VME Index, estimation of fishing activity, particularly in the NEAFC area, and criteria for the prioritization of protection scenarios and degree of precaution applied in management. It is anticipated that these improvements will be developed and included in the process on a modular basis. A re-evaluation of the benchmark would be warranted when these improvements may result in changes in the advice being provided by ICES.

Future research should focus on improving the quality of VME and VMS data, developing objective approaches to quantify the confidence in the data layers used in the analyses, investigate methods to assess the risk to VMEs from human activities, and consider the potential for recovery.

ii Expert group information

Expert group name	**Benchmark Workshop on the occurrence and protection of VMEs (vulnerable marine ecosystems) (WKVMEBM)**
Expert group cycle	Fixed term
Year cycle started	2022
Reporting year in cycle	1/1
Chair(s)	Pierre Pepin, Canada – External Chair
	Eugene Nixon, Ireland – ICES Chair
Meeting venue(s) and dates	11 and 28 February 2022 – Postponed
	5-8 April 2022, Hybrid, ICES Headquarters &online 28 April 2022, online

1 Background

Certain habitats and species of deep-sea bottom-living organisms are defined as Vulnerable Marine Ecosystems (VMEs), including seamounts, hydrothermal vents, cold-water coral reefs and aggregations of deep-sea sponges. VMEs have many taxa that can be extremely long lived and are particularly vulnerable to fishing that involves bottom contact gear as they are easily disturbed and slow to recover. VMEs are thus protected from bottom fishing under several international treaties that stem primarily from United Nations General Assembly Resolution 61/105 (UNGA, 2006). In this context, ICES provides recurring annual advice on the occurrence and options for protection of VMEs to NEAFC and the EU.

This Benchmark Workshop on the occurrence and protection of VMEs (WKVMEBM) chaired by Eugene Nixon (ICES Chair, Ireland) and chaired and reviewed by Pierre Pepin (External, Canada) will:

i. Review existing methods used by ICES for the provision of vulnerable marine ecosystems (VMEs) advice;
ii. Based on this review (TOR a) develop and document an operational evidence-based procedure for the production of recurrent ICES advice on VMEs.

Benchmarking is an intense evaluation and peer review of the ICES advisory process used when responding to specific recurring advice requests, in this case advice on the occurrence and protection of vulnerable marine ecosystems (VMEs). Benchmarks occur outside of the annual advice period and changes to procedures agreed to are incorporated in subsequent advisory processes. ICES has been using benchmarks for recurring advice on fishing opportunities for the past decade or more and this is the first benchmark for non-fisheries advice. Benchmarked methods can be expected to be valid for some time because the recurring advice respond to basically the same request year after year. The list of participants is show in Annex 1.

The main aim of this VME benchmark is to develop and document for the first time, the full ICES VME advisory process, full ToRs at Annex 2. This includes the work of WGDEC and WGMHM in providing the evidence of the location or likely location of VMEs, VME indicator taxa and VME habitats; the work of WGSFD when producing the swept area ratio (SAR) used to establish the intensity of fishing with mobile bottom contacting gear and the potential of further significant adverse impacts (SAI) resulting from continued fishing with mobile bottom contacting gear.

2 Conduct of the Benchmark

To ensure credibility, salience, legitimacy, transparency and accountability in ICES work all contributors are required to abide by the ICES Code of Conduct. The ICES code was brought to the attention of participants at preparation meetings and the workshop and no actual or potential conflicts of interest were identified by any of the participants. The list of participants is shown in Annex 2 along with their participation in different parts of the benchmark process.

A core group of ICES experts was formed and included the ICES Chair of WKVMEBM, the Chairs of WGDEC, WGSFD, WGMHM, ADGVME, WKEUVME, HAPISG along with ICES experts, and the Secretariat. Access to the online meetings and documentations was provided to the external WKVMEBM Chair and the two reviewers, see Annex 2 for list of participants in the core and review groups. The core group reviewed and documented existing methods used by ICES for the provision of vulnerable marine ecosystems advice (ToR a). The draft review of existing ICES methods to fulfil ToR (a) was uploaded to the SharePoint on 18th January. The core group met on the 11th February 2022 and agreed that the review was appropriate to fulfil ToR (a) and that this would be finalised at the workshop. Annex 3 contains a short note on ToR (a) and in effect this WK report is consider fulfilment of this term of reference.

Based on the ToR (a) review, the core group further documented the VME advisory method to be benchmarked and, on the 16th February indicated to the external Chair that the method as briefly described in Annex 3 was ready for their review. The external review was submitted on 25th February (Annex 4), and concluded that:

> '*the proposed VME Assessment Framework Benchmark is appropriate to address the request for Advice in Tor b. The overall structure reflects careful development of data quality control algorithms and processing in order to provide reliable and repeatable estimation of metrics to be applied in the framework.*
>
> *The delineation of VME closures under the different scenarios for each ecoregion are sound and comprehensive. Addition of the potential effect of missing data and the benefits of use of SDMs could serve to condition application of the outcome of the different scenarios and options in development of the Advice.'*

The full text of the material provided to the external reviewers is not reproduced in the Annex 3 because it could cause confusion with the procedures that were subsequently modified and the text revised as a result of the benchmarking process.

Because of the invasion of Ukraine by the Russian Federation, the hybrid VME benchmark workshop was rescheduled from the 7 to 10th March to the 5 to 8th April. Further informal work was undertaken by the experts prior to the benchmark.

Each morning, the workshop worked in subgroups and met in plenary each afternoon. Three subgroups were formed; one to produce the Advice Template, which will be used to transfer the data, maps and evidence from the working groups to the advice drafting group on VMEs; one to work on VME data and identifying where VMEs are known to occur and on the VME index of where VMEs are likely to occur; the final subgroup worked on VMS data and producing SAR values to establish the intensity of fishing with mobile bottom contacting gear and the potential for further significant adverse impacts.

The list of participants at the hybrid workshop is shown in Annex 1 and the agenda at Annex 5. At the start of the plenary session on the 5th April, the ICES Chair presented background information on the ICES advisory and benchmark process, the ToR for the workshop and the method that was to be benchmarked. The external Chair presented their review and conclusion that the proposed VME Assessment Framework Benchmark is appropriate to address the request for Advice in ToR b. This was followed by presentations from the three subgroups on VMEs, VMS and the advice template including maps.

The workshop made significant progress during the four-day hybrid meeting but did not succeed in finalising and agreeing all aspects of the method to be used by ICES when providing VME advice. The complexity of producing the VME index and the swept area ratios (SAR) for mobile bottom contacting gears and also the application and implications of two scenarios, each with two options, required a considerable amount of discussion to bring the workshop participants to a level of understanding to ensure issues were *thoroughly* examined. The wording of the Scenarios and Options were examined and modified in plenary as reflected in the agreed benchmark method described in Annex 6.

As there were still aspects of the method to be developed and documented, the workshop remained open and agreed to work by correspondence to allow the subgroups to work further on their three topics. It was agreed that the benchmark workshop would reconvene before the end of April 2022 to finalise and agree the final method to be used by ICES when providing VME advice in 2022.

The workshop convened again on the 28 April 2022 and finalised the method for providing advice on VMEs as documented in Annex 6.

3 Data Sources

3.1 Data on Vulnerable Marine Ecosystems

The annual ICES data call receives georeferenced data from ICES member countries on VME habitats and associated representative VME "indicators"1. All data submitted to the ICES VME Database are subject to quality control (QC) standards via the ICES Data Centre and WGDEC. The QC review steps identify outliers in location (e.g., land records) and species identifications against known distributions. Any questionable data are referred back to the data submitters. Data to map the VME elements was obtained from EMODnet seafloor geology, a publicly available georeferenced dataset of geological and biogenic structures such as banks, coral mounds, mud volcanoes and seamounts. Those data were available at a higher spatial resolution than other global sources of public information such as those utilized by WGMHM (Grid Arendal Global Geomorphological maps and the 2019 General Bathymetric Chart of the Oceans (GEBCO) bathymetric datasets) for their first consideration of mapping VME elements.

3.1.1 VME Index and Habitats

The data received from the member states in response to the data calls are collated in the ICES VME Database along with earlier data compiled by WGDEC. The database contains data from multiple sources, collected at different times, through different survey collection methods, and includes older data from the scientific literature. These data are therefore not standardised and cannot easily be compared against each other for data analysis purposes (e.g., there is no information on trawl/video transect distance, duration, trawl width, etc). To resolve this, ICES uses a multi-criteria assessment system to produce the "VME Index", which is based on the presence of VME indicators species and scores the overall 'likelihood' of a VME being present in a C-square as either high, medium or low for each C-square grid cell (0.05 x 0.05 degrees; approximately 3 km x 5 km) (Rees, 2003). Records of C-squares containing VME habitat submitted to the database are, following QC checks, automatically assigned to a 'VME habitat' category as C-squares known to contain VMEs and therefore do not sit on the VME Index 'likelihood' scale.

3.1.2 VME Elements

VME elements represent important geographic features that can provide suitable habitats for VME indicator taxa, despite the possible absence of sampling records in the area. VME elements are defined in the FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO, 2009) as topographical, hydrophysical or geological features, including fragile geological structures, that potentially support VMEs. The VME elements used thus far have been limited to topographic highs (seamounts, banks) as well as small elements spatially well-constrained (coral mounds, mud volcanoes, cold seeps, hydrothermal vents) but may also include steep slopes/flanks (>6.4 degree) and peaks, mid-ocean ridges, knolls and guyots, depending on the availability and accuracy of data.

1 https://www.ices.dk/data/Documents/VME/VMEs%20and%20their%20taxa.pdf

3.2 ICES VMS Data on Fishing Activity and Intensity

The annual ICES VMS/Log book data call receives data for fishing activities in the North East Atlantic and Baltic Sea. The data call asks for VMS and coupled logbook data of fleets in the ICES area that are anonymized and monthly aggregated to the 0.05 x 0.05 degree C-square grid reference (Rees, 2003). All data submissions to the ICES VMS/Log book data call generate a quality report to data submitters and also for review by the ICES Data Centre and the chairs of WGSFD. Feedback on potential data quality issues found during the QC process are referred back to the data submitters for rectifying and resubmission. If data issues cannot be resolved through this iterative process then the data for a member state may not be accepted into the database.

ICES has advised that mobile bottom contact fishing gears (MBCG), which includes bottom otter trawls, bottom seines, dredges, and beam trawls, have a far greater impact on VMEs when compared to other gears (ICES, 2021a). For this reason, and also due to the lack of data on spatial intensity of fishing activity other than MBCG, the current focus of ICES work on VMEs relates to the removal of MBCG from areas that contain or are likely to contain VMEs.

3.3 ICES VMS swept-area ratio (SAR)

The swept area ratio (SAR, also defined as fishing intensity) is the cumulative swept area divided by the surface area of the grid cell. Calculating swept area ratio (SAR) requires information on 1) gear type, 2) gear width or in the absence of gear width vessel length or kW engine power, 3) fishing hours, and 4) fishing speed. For ICES data there is a look-up table defining the gear parameters required to calculate SAR for metier level 6 codes and benthic gear groupings (Eigaard et al., 2016).

3.4 NEAFC VMS data on fishing activity

VMS and catch reports data are received annually by the WGSFD expert group from NEAFC, via the ICES Secretariat, along with authorisation details, and vessel information from the NEAFC fleet registry. The data consists of four files annually linked by a common anonymised vessel identifier field. Fishing activity is inferred from vessel speed profiles, under the assumption that VMS polls recorded at slow speeds represent fishing.

Although the NEAFC VMS data has been used to produce advice on the distribution of fishing activity in the vicinity of VMEs for a number of years, this has relied on the measurement of “hours fished, based on numbers of VMS pings in each grid cell at fishing speeds rather than converting to swept area.

3.5 NEAFC VMS hours fished

Hours fished for NEAFC VMS data is estimated based on the numbers of VMS pings in each grid cell at fishing speeds. However, it does not take account of vessel power and therefore is not a standardised measure of fishing effort in kW hours like the ICES VMS/Logbook data kW fishing hours product. In the absence of gear reported at a trip resolution assumptions are made to produce hours fished raster layers for broad categories of gear (mobile or static).

4 Assessment

4.1 Confidence in VME Data Layers

There is high confidence in the presence of the VME elements used in the benchmark process. Data on other VME elements are available, but not yet used, due to lower spatial resolution and lower confidence in the data. Member states may hold higher-precision bathymetric data (e.g., multibeam) but this has not been used due to restricted access issues and limited coverage. Additional VME element data will be required, especially for deep-sea areas which are under-sampled compared with shallower waters, and therefore rely more heavily on VME elements to infer VME presence.

The mix of data and concepts represented in the VME Index makes it difficult to infer what an index value within a specific location is likely to represent. This is relevant because clarity about the nature of the indicator ('concreteness') is vital for acceptance of outcomes by managers and stakeholders (Rice and Rochet, 2005), and for the appropriate use by scientists. Use of the VME Index as it is now may result in under-representation of certain VME types (e.g., sea pen VMEs) in the delineation of VME polygons as a result of the inherent properties of the index.

The 'likelihood' of VME presence in a given grid cell could be determined using statistical probabilities for cells where multiple records of presence and absence data are available. Otherwise, a simple quantification of the numbers of presence records supporting VME habitats, VME Indicators and VME elements for each grid cell and/or VME polygon would give a perspective on the "confidence" in the VME Index designation.

The VME "confidence" index developed by WGDEC, and previously used by ICES, is not considered a good proxy for evaluating the reliability of the VME data used in the calculation of the VME Index. Two recent ICES workshops (WKREG, WKEUVME) have expressed concerns over the validity of the weighting terms applied to derive the confidence index. The confidence index was therefore not used to generate VME polygons in this benchmark process.

Species Distribution Models

Species distribution models (SDMs) can also be used to provide an evaluation of whether a VME or VME indicator is `*likely to occur*'. When the standards for accepting such models into VME advice are finalized, ensembled SDMs could be used to give a quantitative estimate of associated uncertainty. Work is ongoing in WGMHM and WGDEC to apply and evaluate the recommendations of WKPHM on the standards for predictive models needed for acceptance in ICES advice.

4.2 Confidence in fishing activity data layers

4.2.1 Confidence in ICES VMS Data Layers

There is high confidence in the SAR values as a relative measure of intensity for mobile bottom contacting gears fishing activity of the vessels included in the member states submissions. The ICES VMS/Logbook data call requires member states to resubmit all data years to each annual data call as amendments and improvements are made to the R codes for VMS/Logbook data processing and submission periodically. In practice, not all member countries submit data in all data call years or for all data years to each call, additionally some countries data may not pass the QC process and not be accepted into the database. As a result, the data in each data call year varies in comprehensiveness and data products may rely on a mix of recent data and older data from previous data call submissions for particular member states who have not resubmitted.

The ‘completeness’ of the VMS data could be determined based on historic proportions of cumulative SAR by member states however it would not be possible to attribute this completeness to individual C-squares without information on the missing member states fishing distribution.

VMS systems are only required for vessels > 12 m in length therefore the fishing intensity products are likely to be underestimates of total fishing intensity. Member states may have vessels (of all sizes) carrying other electronic technologies that are collecting higher spatio-temporal resolution data capable of identifying fishing activity with greater certainty and associated confidence. There are yet to be agreed standardised data formats for electronic technology/monitoring data and as such it is not currently accepted into the ICES VMS/Logbook data call process.

4.2.2 Confidence in NEAFC VMS Data Layers

While the NEAFC VMS data are useful for highlighting the distribution of fishing activity in a relative sense, confidence in the use of generated data layers as a measure of fishing intensity is low. Not all vessels present in the catch reporting table are present in the VMS data despite demersal species being reported in catches therefore there is some uncertainty over the completeness of the VMS data provided. Vessels are believed to spend extended periods fishing in the NEAFC regulatory area which gives rise to greater instances where a vessel may be travelling at slow speeds for reasons other than fishing (e.g., fuel conservation, undergoing maintenance, crew rest periods). Therefore, the use of speed profile derived thresholds may be over estimating the occurrence of fishing activity. The vessel parameters associated with the VMS data are categorised into quite broad groupings of vessel length and power therefore calculating kW hours fished taking either a lower or upper value of the category can result in a marked difference. Around a quarter of fishing activity in the VMS data is also from vessels with unknown length and power.

4.3 Combining VME and fishing activity data layers

The present analysis to identify VME polygons performed under the Scenario 2 options (see Table 4.1) takes into account the historic and present-day fishing effort to determine the likely extent and location of VMEs. The Scenario 2 options rely on either including into VME closure advice C-squares which are subject to low levels of fishing effort with MBCG (Option 1) and are therefore not likely to have experienced significant adverse impacts (SAI), or conversely to exclude all C-squares with high levels of fishing effort (Option 2) as VME is unlikely to be found in such highly-fished areas. The number of C-squares that are either included or excluded from the analysis to identify VME polygons under Scenario 2 is therefore dependent on the SAR SAI threshold applied. An understanding of how sensitive the analysis is to changes in the SAR value is therefore important when estimating the confidence of the results, see section 4.4.1.

4.4 Management options and prioritization

The benchmark process has established a framework for the presentation of options to protect VMEs based on the relationship between mobile bottom contact gear (MBCG), fishing intensity (SAR) and destruction of VMEs (SAI), drawing on trawling impact literature and empirical observations on similar VME indicators made in the Northwest Atlantic Fisheries Organization Regulatory Area ((NAFO, 2022). VME management option Scenarios (Table 4.1) were originally produced in response to an advice request to propose a set of regulatory area options using available ICES data, and were used to develop interactive maps of VME polygons for use by ecosystem and fisheries managers. The options shown in Table 4.1 offer different levels of protection to areas where VME are known or likely to occur, in some cases considering knowledge on the spatial extent and intensity of fishing activities. The options can be combined (specifically Scenario 1 Option 2 with Scenario 2 Option 1) to produce enhanced protection outcomes as described in the combined scenarios in Table 4.1.

Bias in the advice may differ among ecoregions as a result of completeness in reporting of the occurrence of VMEs from member states, and the extent of and gaps in survey coverage. Incomplete reporting in data sources is likely to result in an underestimation in the distribution of VMEs, and therefore may necessitate application of precaution in delineating VME polygons and establishment of protective actions..

Table 4.1. Description of management scenarios and options presented by WKEUVME with associated management implications for the protection of VMEs and general impacts to fisheries. The Combined Scenarios has been added to the table by WKVMEBM.

Scenario	Option	Description of C-square closures	Management implication
1	1	C-squares with VME habitats as well as C-squares with high and medium VME indices, regardless of fishing activity. C-squares with a low VME index only included if adjacent to C-squares with medium to high VME indices.	Prioritizes identification of VME polygons where they "are known to occur", and where they "are likely to occur", regardless of fishing activity.
1	2	Scenario 1–Option 1 + C-squares that contain selected VME physical elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME indicator species records.	Prioritizes identification of VME polygons where they "are known to occur" and "are likely to occur", as well as elements that are known to frequently contain VMEs, regardless of fishing activity.
2	1	As Scenario 1–Option 1 but includes low VME index C-squares if MBCG fishing pressure is also low (SAR < 0.43). This option preferentially includes Low Index C-squares where these occur outside the more highly fished areas.	Prioritizes identification of VME polygons where they "are known to occur" or " are likely to occur", and includes C squares with low VME index where cumulative fishing activity is also low and SAIs by past fishing are less likely, this therefore offers potential VME protection at low cost to the fishery and highest potential protection of VMEs in the fishing footprint.
2	2	C-squares including all VME habitats, high, medium and low VME Index C-squares but excluding C-squares with high cumulative MBCG fishing pressure (SAR > 0.43). This option effectively only considers VME Index (of any category) in areas outside of relatively high fishing effort areas.	Prioritizes identification of VME polygons where they are known or likely to occur, but excludes areas that have been intensely fished and where VMEs are therefore potentially damaged by past trawl fishing. By leaving heavily fished areas open, there is reduced impact on fishing activities.
Combined scenarios		Scenario 1 option 2 and Scenario 2 option 1: C-squares with VME habitats as well as C-squares with medium and high VME indices and low VME index if MBGC fishing pressure is low (SAR < 0.43), + C-squares that contain selected VME physical elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME indicator species records.	Prioritizes identification of VME polygons where they "are known to occur" or " are likely to occur", and includes C-squares with low VME Index where cumulative fishing activity is also low and SAIs by past fishing are less likely, this therefore offers potential VME protection at low cost to the fishery and highest potential protection of VMEs in the fishing footprint, as well as elements that are known to frequently contain VMEs, regardless of fishing activity.

Recognizing that advice on which Scenario is most precautionary may be required, WKVMEBM has identified Scenario 2 Option 1 as being more precautionary than Scenario 2 Option 1 as it captures the 'low' VME Index C-squares that are not heavily fished (SAR <0.43) and retains all VME habitats and high and medium Index C-squares. Depending on the fishing patterns Scenario 2 Option 1 may not differ much from Scenario 2 Option 2.

Scenario 2 does not take into account VME elements, therefore, for areas where VME elements are the predominant source of information, such as deep-sea areas, Scenario 1 Option 2 would be the more precautionary. However, the process requires that inclusion of VME elements is supported by VME Indicator data records, which limits the application of this approach to data-poor areas where only data on VME elements is available. For data poor areas with limited VME Indicator data records, the removal of this requirement would allow incorporation of data on VME elements independent of associated VME Index or habitat data records.

Overall, the combination of Scenario 1 Option 2 with Scenario 2 Option 1 (Combined scenario) would be the most precautionary because it would include C-squares with all VMEs and VME elements supported by data in the VME Database and EMODnet, along with some low, and all medium to high VME Index cells, but excludes areas where VMEs are likely to have been degraded by fishing (> 0.43 SAR).

In addition, ICES considers paragraph 48 of the FAO guidelines to inform its advice on areas that have already been closed for the purpose of VME protection. In areas where fishing has not been permitted in order to protect VMEs, the reopening of such VME closures to bottom contact gear of any type will not be advised by ICES unless it can be shown that VMEs are not present.

4.4.1 Sensitivity testing of Scenario 2 results to changes in the SAR impact thresholds

The effect on fisheries

Understanding how sensitive the VME polygon results are to changes in the SAR threshold value applied to the Scenario 2 options is important. In addition, it is useful to evaluate how the fishing effort is distributed spatially (to understand how much of the fished area is fished and at what level of effort) in order to determine how significant any given area of fishing is in the context of the overall fishing effort in the assessed area. In the present assessment a SAR value of 0.43 has been applied under Scenario 2 as the level of fishing effort above which SAI on VME is known to occur. C-square SAR values for comparison with the 0.43 threshold MBCG is the average of the annual SAR value for the most recent years that quality assured VMS data is available; for the ICES data call this is since 2009. A description of the rationale and method used to determine the 0.43 threshold SAR value is given in Annex 6.

Figure 4.1 shows the relationship between the cumulative fished area against different percentiles of total C-square SAR values (ranked from high to zero fishing effort in the 400-800m fishing footprint). It reveals that C-squares with the highest level of fishing effort (e.g. SAR >8 – red line) account for about 5% of the total fished area (black line) which represents 12% of the total fishing effort in the assessed area. By contrast C-squares associated with the lowest levels of fishing effort (e.g. SAR < 1) account for more than 50% of the total fished area whilst only accounting for about 7% of the total fishing effort. This implies that total fishing activity (or effort) is unlikely to be impacted by applying SAR values to exclude C-squares in the range of 0.1 – 1.

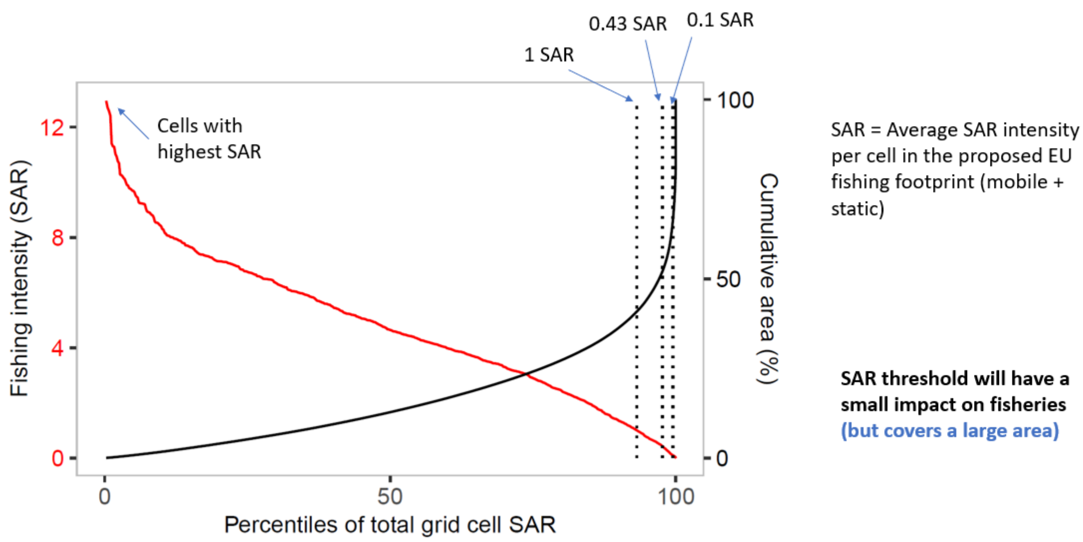

Figure 4.1. Relationship between cumulative fished area, fishing intensity and percentiles of total c-square SAR

The effect on VME polygons

The outcome of Scenario 2 (Option 1) VME analysis depends on how many Low Index VME C-squares are categorised as having fishing effort less than a given SAR threshold value. Clearly the higher the SAR threshold value the more Low VME Index C-squares will be included in the analysis, which in turn will tend to increase the overall number of C-squares, and therefore the area of the defined VME polygons. Figure 4.2 shows how many Low VME Index C-squares (out of a total of about 350 Low VME Index cells present in the Celtic Sea and Bay of Biscay ecoregions between depths of 400 and 800 metres) have a SAR value of 1 or less.

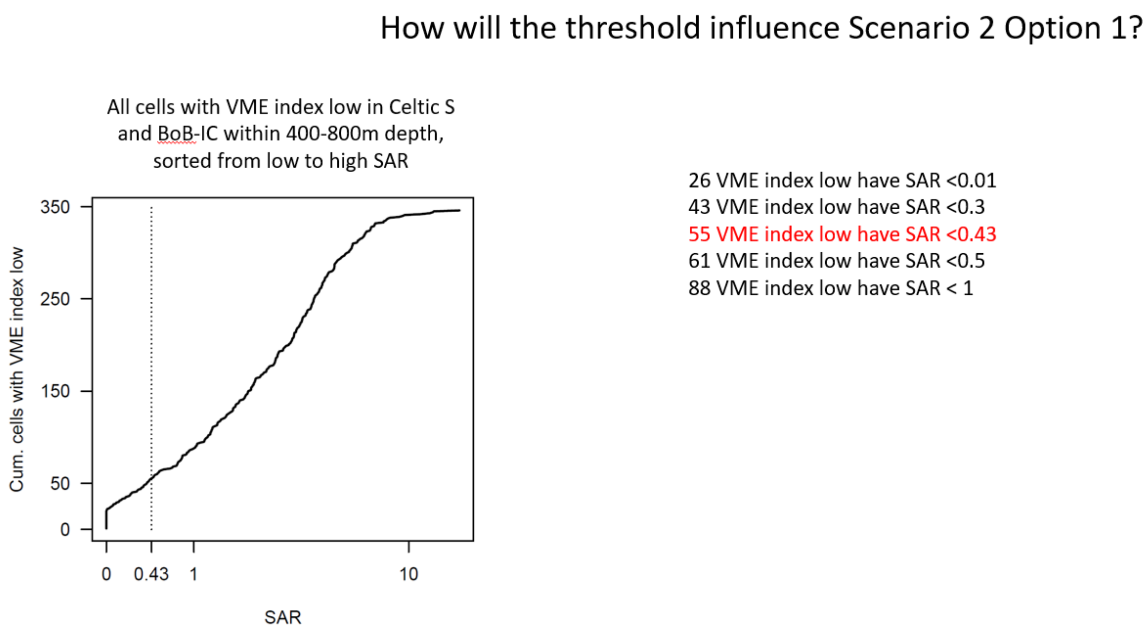

Figure 4.2. The cumulative number of Low VME Index C-squares against C-square SAR values under Scenario 2, Option 1. The applied SAR threshold values of 0.43 is highlighted as a dashed line.

Although, Figure 4.2 shows there are many more Low VME Index C-squares with SAR values >1, it would be highly unlikely for deep-sea species to exhibit a SAR SAI threshold value >1. For example, the deep-sea VME indicator type investigated in the NAFO Regulatory Area with the lowest SAR SAI threshold value were the sea pens at SAR = 0.43 (see Annex 6), with erect bryozoans having a SAR SAI threshold of 0.76 (NAFO, 2021). Accordingly, SAR SAI threshold values for a wide range of VME indicator species may be expected to be <1. Of course, this analysis assumes that each C-square is fished evenly for a given level of SAR, which is unlikely to be the case given the nature of deep-sea fishing is known not to be randomly distributed at small spatial scales, but rather patterns of trawling often follow well defined tracks usually along lines of bathymetry or well-defined seabed features (NAFO, 2021). However, in the absence of a more detailed (higher resolution) analysis of individual trawl tracks it is not possible in the present study to determine the distribution of MBCG trawling within any C-square including, in this instance, Low VME Index C-squares that are only partially trawled.

Given the relatively small number of Low VME Index C-squares at SAR values of <1 (e.g. about 50) the sensitivity of Scenario 2 (Option 1) results are likely to be small based on realistic possible variations in the applied SAR SAI threshold values.

By contrast, the outcome of Scenario 2 (Option 2) depends on excluding all C-squares with any evidence of VME (e.g. all VME low index, VME high and medium index, and VME habitat C-squares) above a given SAR threshold value from the analysis. Essentially this defines a fishing area where the level of fishing effort has been, or continues to be, sufficiently high as to result in a low likelihood of containing VME. Figure 4.3 shows that High and Medium VME Index, and VME habitat C-squares are potentially sensitive to possible changes in the applied SAR threshold value. For example, about 70% of the High and Medium VME Index C-squares coincide with SAR values of <1, so a relatively small change in the SAR threshold value (within realistic limits) could potentially result in a large proportion of High and Medium VME Index C-squares being excluded from the analysis. The sensitivity is increased further when considering VME habitat, in this case more than 90% of VME habitat C-squares coincide with SAR values <1, so any small variation in the SAR threshold value applied (within realistic limits) could result in a relatively large proportion of VME habitat C-squares being excluded from the analysis under this option.

In conclusion, the outcome of Scenario 2 (Option 1) would appear to be less sensitive to changes in the applied SAR threshold value when compared to Scenario 2 (Option 2). The workshop therefore recommends that Scenario 2 (Option 1) be used in preference to Scenario 2 (Option 2) when considering the VME polygon results from the Scenario 2 analysis as it is the least sensitive to changes in the applied SAR threshold value.

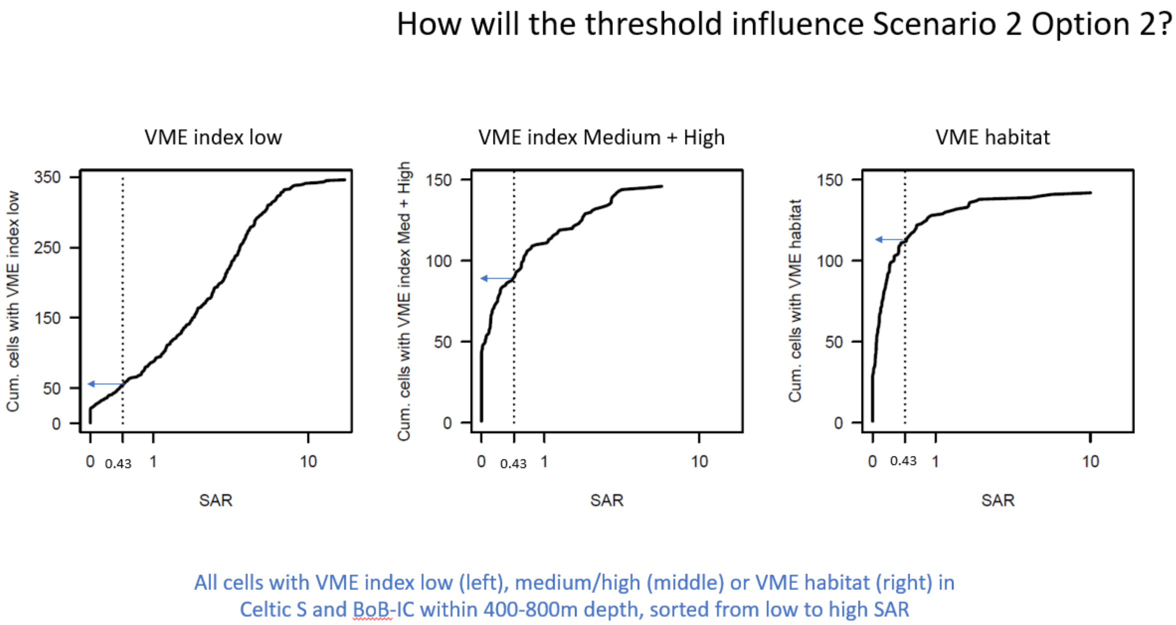

Figure 4.3. The cumulative number of Low VME Index C-squares, Medium and High VME index, and VME habitat against C-square SAR values under Scenario 2, Option 2. Note, VME low index result panel shows the same relationship as described under Scenario 2, Option 1. The applied SAR threshold values of 0.43 is highlighted as a dashed line in each case.

4.5 Assessment production procedure

The 2022 benchmarked assessment procedure (Annex 6), will serve as the technical guidelines for formulating advice on the occurrence and protection of vulnerable marine ecosystems (Figure 4.4). Annually, ICES expert groups produce an assessment at a regional scale using the ICES ecoregions (ICES, 2020a). Both ecoregion-specific assessments and requester-specific advice on the occurrence and protection of VMEs use an agreed template (Annex 6). In accordance with ICES transparent assessment framework (TAF), annual quality assured data is linked to assessment scripts to produce standard outputs and scenario analyses. Outputs are supplemented by expert interpretation of results (Figure 4.4, step 2). The assessment outputs are summarised in "assessment templates" for both ecoregion-specific assessments (Annex 7) and requester-specific advice (Annex 8). These outputs are provided in self-contained HTML files including written text, tables, and maps that allow the user to view the whole assessment area or zoom into areas of interest and to toggle the various layers of information. In addition to the primary self-contained HTML assessment and advice, a PDF containing text, tables, and an example map of what is available in HTML files, will also accompany the assessments.

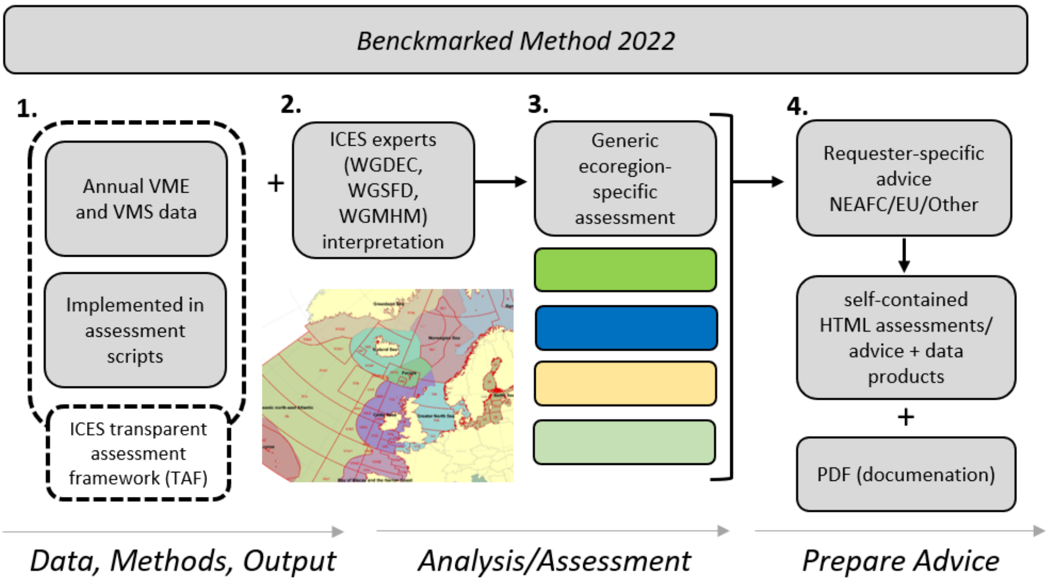

Figure 4.4. Flow chart of data, methods, output, analysis and assessment that feed into the formulation of VME advice defined during the 2022 Benchmarking process.

The assessment utilises R-scripts, which take the annually updated VMS, VME and VME physical element data layers as input and produce the VME polygons for each Scenario and Option, as well as the assessment summaries and statistics for expert interpretation (Figure 4.5; Section 6.6, Annex 6). A further R-Script produces the standardised template HTML file with the full assessment. The R-scripts are available on the open-source VME-Advice GitHub platform (https://github.com/ices-taf/VME-Advice). The HTML assessment files are accompanied by separate data products described in Section 4 of Annex 6.

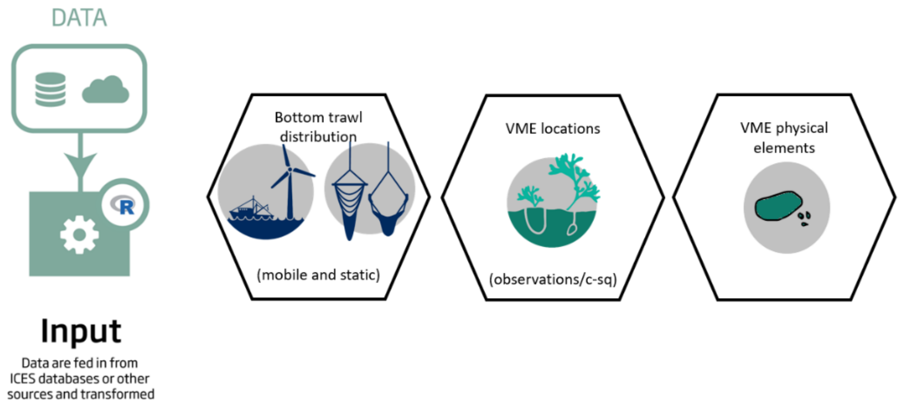

Figure 4.5 Annually updated data input files for the assessment scripts to produce the VME polygons for all scenarios and all options.

The HTML assessment files are accompanied by:

1. PDF maps representing the VME polygons for all scenarios and all options; the maps include the VME polygon ID number and the area defined as fishable domain;

2. .csv, .xlsx and .shp files for all scenarios and all options; these files include the descriptions “VME_Csquare”, “VME_Habitat”, “VME_Indicator” and “VME_Elements” (see further information in Table 6.1 Annex 6).

Data coverage (VME, elements, and fishing activity) varies across the ICES areas, requiring ecoregion-specific considerations (Figure 4.4, step 3). Ecoregion-specific assessment outputs will inform ICES advice on ecosystems and fisheries overviews. In turn, the overviews provide complimentary ecoregion-specific context information for the assessments of VMEs in relation to bottom fishing activity. Requester-specific advice is prepared annually (Figure 4.4, step 4). The spatial coverage of this advice is that of the management area of the requester, often covering several ICES ecoregions. EU layers will be included in the EU-specific advice, and NEAFC layers will be include in the NEAFC-specific advice. Data and knowledge constraints differ between these management areas and determine the feasibility of providing advice based on the different assessment scenarios (i.e. the available VMS information for NEAFC precludes the assignment of fishing activity to bottom contacting gear with confidence, thereby making Scenario 2 and the provision of any metrics for bottom-contact fishing currently unreliable. As a result, NEAFC-specific advice will only reference fishing activity in its totality and Scenario 2 will not be considered (Figure 4.4, step 4).

4.6 Future work

4.6.1 Prioritizing scenario options based on confidence and degree of precaution

The formulation of robust advice for VMEs requires an approach for contrasting the different management options based on their relative likelihood or probability of achieving the VMEs protection objective. This approach should consider temporal and spatial differences in data availability and quality (which determine the level of certainty/uncertainty in scenario outcomes) and differences in input data and assessment configuration and assumptions among scenario options (which determine the level of precaution in scenario outcomes).

Until the available evidence and assessment method can support a full quantitative assessment of the risk of SAI to VMEs from fishing activities, scoring scenario options for precaution and confidence in the underlying data can serve to approximate the relative risk (i.e. the likelihood or probability) of failing to achieve the VMEs protection objective. Such objectives-based risk approach can facilitate communication and handling of the certainty/uncertainty associated with the different options presented in the advice, and is amenable to incremental improvements in data and assessment methods. As the knowledge base for the assessment will be augmented (for example using species distribution models SDMs to inform the VME occurrence layer considering habitat suitability information, and/or spatial population models SPMs to enable consideration of recovery processes), confidence in scenario outcomes will increase and the risk of failing to achieve VMEs protection will be reduced. Eventually it will be possible to quantify and propagate assessment uncertainty and the corresponding risk of SAI to VMEs.

Until then, WKVMEBM recommends that ICES develops criteria for scoring scenario options for confidence in the information base available for the assessment and level of precaution. A brief description of these components is provided below for the purpose of guiding future work. In recurring advice, the combination of a confidence score and precaution score (both updated annually) can provide a relative measure of the risk of failing to achieve VMEs protection among scenario options and assessment regions.

Precaution level

The level of precaution is a measure of risk aversion: more or less precautionary scenarios correspond to a lower and higher risk of SAI to VMEs, respectively. Under the current assessment methodology, the level of precaution associated with each scenario option varies with the evidence base considered (e.g. whether or not data on VME elements are included), key assumptions (e.g. SAR threshold value used in Scenario 2), and the proportion of the available evidence for VME occurrence that is ultimately included in the VME polygons (spatial outcomes). Scoring scenario options for their relative level of precaution can be done considering all of the above or only the spatial outcomes/metrics (current approach). In this context, relevant spatial outcomes include the proportion of the fishable domain that intersects with VME polygons and/or proportion of the available evidence for VME occurrence that is included in VME polygons. Alternatively, the development and application of an ecological risk assessment approach may be used to prioritise scenarios based on precautionary considerations, e.g. Ecological Risk Assessment Framework (ERAF) for Coldwater Corals and Sponge Dominated Communities (DFO. 2019).

Assessing confidence in the available evidence

The data layers used to inform the assessment of VMEs differ in accuracy and completeness in both space and time. Accuracy of the VME occurrence data will vary depending on data collection/sampling protocols (e.g. dedicated vs opportunistic surveys) and other factors described above. The accuracy of the fisheries data will vary among métiers, fishing jurisdictions and assessment regions. More or less complete datasets may be submitted by different ICES member countries in different years and for different areas. The use of data quality criteria for including data in the assessment can also affect the completeness of datasets (e.g. inclusion of VME elements information only where high-resolution bathymetric data is available, which favours accuracy but at the expense of information loss).

The more complete and accurate the available data, the greater the confidence in the assessment, and the lower the risk of failing to achieve VMEs protection. Scoring individual data layers for accuracy and completeness and combining these scores into an overall confidence score for each scenario option can provide a measure of the certainty/uncertainty in the available evidence and assessment outcomes.

4.6.2 Future Work to Improve VME data

VME Index

The VME Index incorporates subjective ranking in its two elements, the vulnerability score and the abundance score, which has a large influence on whether a grid cell is designated as High, Medium or Low. For the first, characteristics of the VME indicator groups are used to assign a value to different VME indicators in the index, scoring how 'well' the indicator meets the five FAO criteria for identification of VMEs and then taking the average of those scores to create the vulnerability score which is then amplified by multiplying by 0.9. However, the FAO guidelines do not rank the importance of VMEs based on their component species, nor do they require a VME to meet more than one criterion. 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.

For the abundance score, a weight of 5 is given if the biomass record is greater or equal to the encounter thresholds that trigger "move-on" rules for commercial vessels, a weight of 3 if it is lies within intermediate thresholds, and a weight of 1 if there is no associated weight information. As most of the biomass data comes from government research vessel trawl surveys typically an order of magnitude shorter than commercial trawls, WKVMEBM considered that application of the upper weight thresholds is inappropriate. It greatly undervalues the use of survey trawl catch data in identifying VMEs, and as it only comprises 10% of the score for the VME Index, it undervalues data from trawls generally. The upper thresholds used for the Index are 200 kg for sponges and 30 kg for all other VME indicators and the intermediate thresholds are 60 kg for sponges and 1 kg for all other VME indicators. For comparison, thresholds for identifying VMEs in the NAFO area from scientific survey trawls of approximately 1 km length using Campelen and Lofoten gear range from 0.2 – 1.3 kg for all of the smaller/lighter indicator species and 100 kg for geodid sponges (Kenchington et al., 2019).

Future work with this index should focus on addressing the original need which was to provide a means to assess the likelihood of a VME being present. For that purpose trawl survey catch data may be very useful as it should document both presence and absence, permitting a straightforward probability of occurrence calculation. However, VME “absence” may be a result of not detecting the VME with the sampling methods, rather than a true absence. To account for this, unbiased parameter estimates drawn from repeated surveys in an area should be obtained (e.g., Mackenzie, 2005). Where only presence data are available the number of records might suffice as an indicator of VME presence. Ultimately the benchmark methodology relies on having High, Medium and Low VME Index cells for summarizing data in cells where there are no VME habitats or VME elements. Creating those categories to better reflect likelihood of VME presence should be a focus for improving the index. As with any change to methodology, the impact on the advice needs to be fully demonstrated and evaluated.

Changing Concepts of VMEs within and across Depths

WKVMEBM notes that one of the challenges of identifying the presence of a VME is in the quantification of the density or biomass associated with ecosystem properties or functions. The relationship between density and biomass is a function of food availability and temperature, and with some exceptions for chemosynthetic ecosystems, productivity of epibenthic megafauna declines with depth. This means that the thresholds used to identify VME should reflect depth related differences. For example, VME indicator taxa were identified down to 4000 m on North Atlantic seamounts (Waller et al., 2021; Lapointe et al., 2020) in low density. Further, there can be spatial variation in growth and reproduction at similar depths within regions (Fountain et al. 2019), with greater size and reproduction potential in settings with steeper slopes and topographically enhanced flows. Efforts to protect VMEs need to recognize that the ecological properties and functions are no less important in low density habitats at depth than in more productive shallower water habitat counterparts. Therefore, it is critical that each VME be evaluated within its ecological setting as outlined in the FAO guidelines.

4.6.3 Future Work to Improve VME Elements

VME elements are important proxies for VMEs and may be the predominant data type in deep-sea areas. Applying the benchmark process to the deep-sea will require expanded data sets of VME elements. In particular canyons, ridges and steep slopes should be incorporated into the data repository even if the spatial resolution is coarse at present. VME polygons identified from data with poor spatial resolution can be highlighted in the associated advice.

4.6.4 Future work and on recovery of VMEs

Ecological restoration practices are receiving worldwide attention as they offer the opportunity to recover damaged ecosystems. While marine restoration practices are increasingly common in shallow environments (e.g., coral reefs, seagrass meadows, kelp forests), restoration initiatives focusing on degraded deep-sea benthic ecosystems are still particularly rare. Recovery is incorporated in the assessment of significant adverse impacts in the FAO guidelines in that “the ability of an ecosystem to recover from harm, and the rate of such recovery” should be considered. It is unlikely that an ecosystem can return to pristine conditions after being damaged, however they may return to a “parallel” functional condition, providing important ecosystem goods and services, which requires habitat recovery. PHM or PSD are also important tools to be used together with the information on larval traits, circulation patterns and population genetics to identify areas that, despite being heavily fished (SAR >0.43) could be identified as candidate areas to allow natural recovery or recovery promoted by assisted restoration (González-Irusta et al., 2018; Downie et al., 2021).

WKVMEBM recommends that ICES investigate expected restoration times and their dependence on the ecological setting, the life-history of foundational taxa, and other features of the area that can affect associated rates of food supply by surface carbon flux (e.g., bathymetry, circulation), connectivity and trade-offs between growth and reproduction.

4.6.5 Future work to improve VMS data

There are differences between the ICES VMS/Logbook data and the NEAFC data in terms of resolution and completeness which impacts the advice that can be given based on each data set.

The fishing ping aggregation by C-square method adopted in the ICES VMS/Logbook data call limits the data to C-square 0.05 degree resolution. Meanwhile for the NEAFC VMS data the ping interval rate is shorter than for the ICES data set (1 hour instead of 2) which would allow ping aggregation at a C-square 0.01 resolution or to construct the vessel tracks themselves.

Whilst the spatial resolution of the NEAFC data provided to ICES is higher than that of the ICES VMS/Logbook data call the completeness of the fishing trip information (e.g. gear used) is lower and for some parameters categorised in broad bins rather than known values (e.g. length and power).

Based on these differences the future work for each data set differs, with a focus on improving the spatial resolution of the ICES VMS/Logbook data and at some point having access to track data, and for NEAFC data either improving the completeness of data received or finding approaches to fill the blanks with estimates based on reasonable assumptions.

Accuracy of the SAR value

WGSFD is looking at estimating the proportion of C-squares that are fishable and how this scales the SAR values generated in practice. This work has commonalities with future work on VMEs to more accurately represent the proportion of C-squares covered by VME. In future when both the fishable area of C-squares is calculated and its spatial extent know then the benchmark process will be able to assess whether the fishing and VME coverage do in fact overlap within a C-square and if part of the C-square can remain open to fishing.

NEAFC VMS track data

The ICES WGSFD has a ToR specifically relating to the provision of NEAFC VMS data products. Progress has been limited in the past due to caveats with the data including the anonymity and randomisation, patchy provision of gear type, and speed data quality. NEAFC and the ICES secretariat have been working to resolve these issues.

To date, suggestions to NEAFC from WGSFD for data quality improvements have been to 1) incorporate gear code into the daily catch (CAT) reports, 2) encourage contracting parties to supply gear information, and 3) to request a comparison of NEAFC VMS data with products of the ICES VMS data call for activity having taken place in the same spatial region.

To resolve the existing NEAFC data caveats there are several options to fill the gaps:

1. A precautionary approach could be taken by assuming that all gear is a demersal trawl and using a conservative estimate of gear width the track data could be used to estimate a swept-area.
2. The ICES VMS/Logbook data could be used to estimate average gear parameters for vessel length/power ranges of the NEAFC VMS data.
3. Bathymetry data could be used to identify a depth threshold below which an assumption would be made that bottom trawling couldn't occur and fishing activity is either static or mid-water trawl.
4. In lieu of gear information attempts could be made to estimate the gear (bottom or midwater) using the catch composition data provided in daily catch reports (CAT) or catch on exit (COX) messages. However, the gear groupings would be broad and potentially subjective. Using catch compositional data would not necessarily identify what was being targeted (i.e. fish, shellfish or mixtures) only what was caught.

ICES VMS data layers could be used as an alternative data source of fishing activity in the NEAFC region however these have other limitations in terms of comprehensiveness as some key countries involved in the fisheries do not submit data to the ICES VMS/Logbook data call such as Russia, Iceland and Norway.

One means to approach the current data limitations of the NEAFC data that prevent the production of intensity measures with sufficient certainty could be for experts from WGSFD and/or the ICES secretariat staff to work with the NEAFC secretariat to enable calculation of swept area ratios before the data is submitted to ICES.

There is also potential to use alternative sources of data such as the automatic identification system, or AIS, which is accepted as a report option of fishing activity in absence of VMS/iVMS. However, the use of AIS for identification of fishing activity also has its own caveats and processes for its estimation are less widely adopted than for VMS.

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6 Recommendations

1. The method described at ANNEX 6, including the self-contained HTML file containing scalable maps and selectable layers, be used when ICES provides advice on the location and protection of VMEs. Because the benchmark identified several avenues for improvement in data layers (e.g., VME distribution, fishing activity), a review of the benchmark should be carried out when changes to the advice could be expected as a result of improvements in the analytical approaches used to produce critical data layers.
2. The workshop recommends that Scenario 2 (Option 1) be used in preference to Scenario 2 (Option 2) when considering the VME polygon results from the Scenario 2 analysis as it is the least sensitive to changes and is likely to afford more protection for VMEs in the applied SAR threshold value.
3. The Workshop recommends that, when data are available, the combined S1O2+S2O1 is the preferred approach as it affords the highest likelihood of protecting VMEs while also facilitating fishing with MBCG in areas where deep-sea fisheries are well established.
4. ToRs be developed for the relevant working groups to address the issues identified in the Future Work section of the WK report, in particular a Workshop to look at improvements to the VME Index and to evaluate changes in fishing activities, and establish robust approaches to the use of predictive habitat models (PHMs) in the management of VMEs.
5. That risk assessment be undertaken by ICES in appropriate working groups (WGECO previously evaluated the Hobday et al. 2011 approach) to initiate an assessment of SAI.

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Annex 2: Terms of Reference WKVMEBM 2022

The Benchmark Workshop on the occurrence and protection of VMEs (WKVMEBM) chaired by Eugene Nixon (ICES Chair, Ireland) and chaired and reviewed by Pierre Pepin (External, Canada) will be established and meet at ICES HQ (Copenhagen + Hybrid) on 7-10 March 2022 to:

a) Review existing methods used by ICES for the provision of vulnerable marine ecosystems (VMEs) advice

b) Based on this review (TOR a) develop and document an operational evidence-based procedure for the production of recurrent ICES advice on VMEs.

Prior to involving reviewers, working documents describing the operational procedure will be prepared by WKVMEBM and provided for external review (15-25 February). The working documents and reviewer's reports will form the basis for a hybrid workshop 7-10 March 2022. WKVMEBM will report by 28 March 2022 for the attention of ACOM and SCICOM.

Supporting information

Priority Certain habitats and species of deep-sea bottom living organisms are defined as VMEs, including seamounts, hydrothermal vents, cold-water coral reefs and aggregations of deep-sea sponges. VMEs can be extremely long lived and are particularly vulnerable to bottom-fishing activity as they are easily disturbed and slow to recover. VMEs are thus protected from bottom fishing under several international treaties that stem from United Nations General Assembly Resolution 61/105 (UNGA, 2006). In this context, ICES provides recurring annual advice on the occurrence and protection of VMEs to NEAFC and the EU. In 2022, ICES will be required to review the appropriateness of all NEAFC VME closures and will start to provide recurring advice to the EC under EU Regulation 2016/2336 on the protection of VMEs below depths of 400m. This benchmark is both timely and a priority.

Scientific justification

Term of Reference a)

This TOR will review existing methods used by ICES for the provision of VME advice, and will include: 1) ICES Technical Guideline on the current basis of ICES VME advice (link); 2) ICES Technical Guidelines on Spatial distribution of fishing effort and physical disturbance of benthic habitats by mobile bottom trawl fishing gear using VMS (link); 2) Methods described in the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC), in particular Section 5 and 6 of WGDEC 2017 Report (link) and Section 5, 6 and 7 and of the WGDEC 2020 Report (link) and methods used in similar advisory processes e.g. NAFO: 3) ICES advice (link) to the EU on the deep-sea access regulation and the report of the workshop on EU regulatory area options for VME protection (WKEUVME, link) 3) Recent ICES advice to NEAFC; 4) ICES Data flow schematics for VME, VMS and logbook data (link); 5) Experience gained through the application of the WKEUVME method in other areas e.g. NAFO.

Term of Reference b)

Based on the review (TOR a) this TOR b will develop and document an operational evidence-based procedure for the production of recurrent ICES advice on VMEs. This procedure should: 1) Be aligned with the ICES Advisory Principles (link) and consistent with the FAO 2009 Guidelines (link); 2) be consistent with requestors' VME policies and advice requests; 3) ensure all relevant information available on significant adverse impacts and on the consequences, e.g. biological, ecological, social and economic consequences of the VME management options using the different regulatory scenarios is presented in the advisory product; 4) apply best practices for data and assessment, i.e. the ICES transparent assessment framework (TAF) principles and ICES data management guidelines (including the FAIR principles); 5) establish a format for the advice, including how the data is presented in text, tabular and map format and update the ICES Technical Guideline on the current basis of ICES VME advice (link). Upon completion of WKVMEBM (TOR a and b) the report will describe the evidence-based procedure that ICES will use for the provision of recurrent advice on the occurrence of VMEs and fishing activity in the vicinity of VMEs as well as advising management options, including closures.

Resource requirements ICES Secretariat and data centre.

Participants Participation WKVMEBM will be limited to a total of 35.

Secretariat facilities Meeting room + hybrid meeting equipment and support.

Financial No financial implications.

Linkages to advisory committees ACOM

Linkages to other committees or groups The workshop WKVMEBM will build on the work done by WGDEC and WGSFD to prepare advice in previous years, and is also linked to the work being done in WGMHM and WGFBIT, as well as the recent workshop WKPHM.

Linkages to other organizations The work of this group is closely aligned with similar work in FAO, and management organizations such as NEAFC, EU (DGMARE and DGENV) and OSPAR.

Annex 3: Review of ICES VME Methods ToR (a)

ICES provides recurrent advice on the identification and protection of VMEs consistent with the FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO, 2009) developed to assist in the implementation of United Nations General Assembly (UNGA) Resolution 61/105. In particular, the guidelines provide a framework to manage fisheries exploiting deep-sea fish stocks with the potential to have significant adverse impacts on vulnerable marine ecosystems (VMEs).

The ICES advisory process utilises, to the fullest extent possible, all available data to advise on a range of management measures that are consistent with the UNGA Resolutions and the FAO Deep-sea Fisheries Guidelines. When VME are known to occur, the management measure advised by ICES is to close the area to fishing with mobile bottom contacting gear (MBCG), the most impacting gear on VMEs. When, based on the presence of a VME indicator species, an area is identified as possibly containing VMEs, ICES uses the information submitted with the indicator record to estimate through expert judgement, the likelihood of that area actually containing VMEs and the confidence the experts have in this assessment. In these circumstances, ICES proposes a range closures to MBCG that allows managers select how precautionary they wish to be when implementing management measures.

The FAO Guidelines (FAO, 2009) require that assessments to establish if deep-sea fishing activities are likely to produce significant adverse impacts should take into account, as appropriate, differing conditions prevailing in areas where deep-sea fisheries are well established and in areas where deep-sea fisheries have not taken place or only occur occasionally. The implication is that VMEs in areas that have been more intensely fished may already be damaged and further fishing would not cause further significant adverse impacts. To account for this ICES uses a fixed threshold for past mobile bottom contacting gear fishing activity and intensity to identify areas where VMEs, if present, would not have been damaged. When fisheries data is not available, or not of sufficient quality to estimate past MBCG activity, it is assumed that if VME are present they have not been damaged by previous fishing activity.

Data collected and collated by ICES on foot of annual data calls are used to identify where VMEs occur or are likely to occur. These data cover the entire ICES area but is generally restricted to 'deep water areas' of 200 meters and greater to be classified by ICES as an area containing VMEs.

To establish the spatial dynamics of fishing activities, ICES couples VMS (vessel monitoring systems) data with logbook data supplied by ICES member countries in response to annual data calls since 2012. For the NEAFC area, VMS and logbook data is submitted to ICES annually from the NEAFC Secretariat.

These two data flows (VME and VMS) are combined by ICES as describe below to assess the interaction between fishing and the location of where VMEs occur or are likely to occur and the potential for significant adverse impacts on VMEs from fishing.

The WK core group summarized the procedures to identify C-squares likely to contain VMEs based on VME indicator data from the VME database and to Identify fishing activities with the potential to have significant adverse impacts on VMEs that had been used in the provision of advice previously. These elements served to identify areas for potential closures to prevent significant adverse impacts on VME. Together, these elements served as the foundation for discussion by workshop participants. The revised procedures are outlined in Annex 6.

Annex 4: External review of draft WKVMEBM framework.

Review WKVMEBM

Dr Emanuela Fanelli, Dr Laura Kaikkonen, Dr Pierre Pepin

25 February, 2022

Summary of work presented in WKEUVME draft framework

WKVMEMB developed a framework aimed at providing the scientific basis for the response of ICES on requests for advice from the EU (DGMARE) and NEAFC on a list of areas where VMEs are known to occur or are likely to occur and on the existing deep-sea fishing areas that can be applied to propose a set of regulatory area options for VME protection.

WKVMEBM based its framework using information on the observed occurrence and likely occurrence of VMEs and fishing activities in the waters of the EU and NEAFC jurisdictions, aimed at quantifying the spatial overlap and estimated the proportion of fishing effort occurring in areas with VME. A structured workflow of procedures was developed including criteria for area selection based on available ICES data with the aim of providing clients on the potential risk to VMEs and options for conservation management measures.

The occurrence of VME habitat was based on quality-controlled observations stored in the ICES VME data base. The likely occurrence of VMEs was based on the observations on VME indicator species in the same ICES VME data base. A VME vulnerability score was provided based on an expert judgement following five FAO habitat criteria (uniqueness/rarity, functional, fragility, life history, structural complexity) on vulnerability and information on the biomass and occurrence of VME indicator species. The VME index (high, medium, low) was then calculated as a weighted sum of the vulnerability score and the abundance index. The analysis was to be done at a spatial resolution of the C-square (0.05 x 0.05 degrees) and the VME index was overruled if a VME habitat was recorded. The confidence in the VME assignment was assessed to be high, medium, or low based on the type of survey method used, the number of surveys within each C-Square, the time span over which surveys were undertaken and the time since the last survey. Throughout the process, a number of data sources that were not in the ICES VME Database were identified.

WKVMEBM further considered that VME habitat may likely occur in certain VME features, according to certain topographical, hydro-physical or geological characteristics. The EMODnet data base was used to locate the C-squares where VME elements occur but their inclusion as VME habitat relied on a confirmed occurrence of VME indicators with a VME element.

Since 2012, ICES has requested VMS and logbook data via an annual data call. The analysis of the fishing footprint considered all C-squares between 400-800m depth. Four scenarios were distinguished to estimate the occurrence of VMEs and the fishing footprint of mobile bottom contacting gear (MBCG) in the depth range of 400-800m and the potential management implications for VME protection.

WKEVMEBM explored a procedure to set potential VME closed areas considering two scenarios each with two options (text table below).

Scenario	Option	Description	Management Implication
Scenario 1	Option 1	C-squares with VME habitats as well as C-squares with high and medium VME indices, regardless of fishing activity. C-squares with a low VME index only included if adjacent to C-squares with medium to high VME indices.	Prioritizes protection of VMEs where they “are known to occur”, and where they “are likely to occur”, regardless of fishing activity.
Scenario 1	Option 2	Scenario 1–Option 1 + C-squares that contain selected VME physical elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME indicator species records.	Prioritizes protection of VMEs where they “are known to occur” and “are likely to occur”, as well as elements that are known to frequently contain VMEs, regardless of fishing activity.
Scenario 2	Option 1	As Scenario 1–Option 1 but includes low VME index C-squares if MBCG fishing pressure is also low (SAR < 0.43).	Prioritizes protection of VMEs where they “are known to occur” or “ are likely to occur”, and includes C squares with low VME index where cumulative fishing activity is also low and significant adverse impacts (SAIs) by past fishing are less likely, this therefore offers VME protection at low cost to the fishery and highest protection of VMEs in the fishing footprint.
Scenario 2	Option 2	C-squares including all VME habitats, high, medium and low VME Index C-squares but excluding C-squares with high cumulative MBCG fishing pressure (SAR > 0.43).	Prioritizes protection of VMEs where they are known or likely to occur, but excludes areas that have been intensely fished and where VMEs are therefore potentially damaged by past trawl fishing. By leaving heavily fished areas open, there is reduced impact on fishing activities.

Scenario 1 is the more precautionary because proposed closures are independent of fishing activities but excludes areas with low VME indices which may limit protection for certain taxa. Scenario 2 includes a broader range of VME indices, but their inclusion as potential closures is dependent on the level of fishing activity with each C-square.

The framework structured the advice to managers to be provided in the form of Assessment Sheets for each of the ecoregions for which advice is being requested. Each Assessment Sheet provides a general overview of the ecoregion, the distribution of VMEs and outlines the datasets, degree of precaution and confidence in VME presence and details of the information for VME habitats, elements, and indicators. Each Assessment Sheet then details the Fishing Footprint and the nature and intensity of the fisheries based on the gridded VMS data as well as the information for the more recent fishing activities. The outcomes of the WK benchmarking are then detailed in terms of Closed Area Scenarios by VME indicator groups, the number of closure and fishery available C-squares, and the consequences, in terms of numbers and percentages, to the extent of protection afforded to VMEs by each scenario and option. This is followed by an analysis of the trade-offs among the different management options in terms of both VME protection and impact on fishing activities.

Strengths and Weaknesses

The Review Group (RG) agrees that the proposed VME Assessment Framework Benchmark is appropriate to address the request for Advice in ToR b. The overall structure reflects careful development of data quality control algorithms, data processing and integration that provides reliable and repeatable estimation of metrics from the framework, thereby providing a high degree of robustness to the processes defined in the framework.

The RG was asked to evaluate whether the framework benchmark would be appropriate for requests for advice from both the EU and NEAFC. The framework is appropriate for evaluation of the risk of significant adverse impact (SAI), but the critical differences across requesting agencies pertains to the quality and resolution of the fishing effort/activity data and the ability to derive comparable metrics of fishing activity for the two agencies. Improvements in data calls should be carried out irrespective of the decision-making policies of different agencies to ensure a high degree of consistency in data quality and the inferences (i.e., metrics) that can be derived from the submissions from each agency. Although privacy concerns may arise in instances where fishing activities are restricted to a small number of enterprises, requesting agencies should undertake a dialogue to identify a path forward to ensure consistent and robust estimations of the risk of SAI to VMEs to assist in the implementation of United Nations General Assembly (UNGA) Resolution 61/105. If privacy is cause for concern that cannot be resolved among agencies, ICES could consider development of an alternative third scenario within the framework, with options for the inclusion of VMEs under different levels of risk, in which advice are determined based on qualitative criteria either about the occurrence of VMEs or the intensity of fishing activities. This would likely result in differences in the reliability of advice if data of differing qualities must be considered.

Strengths:

The structure and elements of the framework provides a logical flow of information that explains steps associated with delineation of VMEs, determination of potential risk associated to fishing with MBCG, and a clear presentation of how advice is to be structured. The workflow is designed to [1] identify where VMEs are known or likely to occur and the confidence in the data to establish the VME Index is undertaken by WGDEC and is described in Appendix 1; [2] establish if prevailing MBCG fishing activity is above or below the fixed threshold for establishing SAI, is undertaken by WGSFD and is described in Appendix 2; and [3] combine the VME Index and confidence with prevailing MBCG fishing activity to establish if the areas should remain open or be closed to MBCG fishing according to different management options.

The frequency or periodicity needed to review the framework, its elements, and the role of expert knowledge in determining vulnerability scores and abundance thresholds required to identify areas with in which VMEs are likely to occur should be explicitly defined as part of the framework.

ICES presents its advice on VMEs in the form of written text, tables and figures as a pdf file. In addition, an associated 'Data Product' file accompanies the written advice and contains, where appropriate:

1. Fishing footprint coordinates. Maps in a pdf-file and coordinates in a csv-file of three fishing footprints; 1) combined, 2) static gears and 3) mobile bottom-contacting gears.
2. VME closure coordinates. Maps in a pdf-file and coordinates in a csv-file of the closure scenarios/options. Each csv-file also indicates the VME habitat, VME indicator and VME physical element data present in each closed area scenario/option, as well as the VME habitat and index C-squares.
3. Leaflet maps. Simple leaflet maps which allow the user zoom in and out and to turn on and off the layers produced from the application of the different scenarios and options set out.

The pdf maps contain numbers for each separate footprint or closure polygon which correspond to the polygon numbers in the csv-files. This Data Product represents an important tool that allows interested parties to contrast the outcome of the different scenarios and options in a very intuitive and effective manner.

The current framework provides a basic foundation for the delineation of areas in which VMEs are likely to occur and which are likely to need protection from the impact of bottom contact human activities. The overall structure of the framework is suitable for enhancements that would allow improvements in the nature and methods used in the provision of advice.

Weaknesses:

The VME Index currently represents an integrated metric of VMEs within each C-square, which focusses on the most sensitive VME taxa within a C-square. As a result, current advice structure of the overall risk of SAI and potential protection from closures for single taxon (i.e., including less sensitive taxa, such as seapens) is not being detailed for consideration by decision-makers. This has potential implications for the degree of protection being afforded to different VME taxa. Consideration of individual taxa would alter the nature of the advice, which would require a comparative assessment of prior and updated advice. This is raised in section 6 “Caveats and Limitations of the VME Index” and represents an important point of discussion in determining what is the required level of protection for different VME types, and therefore what Advice should be provided to managers and stakeholders. The benchmarking should address the consequences of this concern.

Threshold concentrations to quantify the biomass of VMEs does not reflect differences in form and aggregation for the broad range of taxa being considered in the analyses. Defining areas of high concentration of individual taxa should reflect differences in form, coverage, and distribution (more homogeneous in sea pens vs. patchy in hard corals/sponges). Differences in threshold could potentially affect the overall advice if individual taxa are represented more appropriately. The benchmarking should address the consequences of this concern.

The threshold for swept area ratio (SAR) is based on results for work conducted by NAFO (2016) in determining SAI for sea pens (section 7.5) which was converted to an appropriate metric for the C-squares used by ICES. The document currently indicates that the “threshold is therefore conservative for the more sensitive VME indicator species” (Figure 7.1) and that “This threshold is therefore precautionary in terms of maximising the area where VME may occur outside of the defined high fishing intensity areas”. This is an important consideration in light that no analyses that contrast the occurrence or biomass of VMEs in relation to fishing activities have been carried out in the ICES area. The use of C-squares has highlighted that medium and high values of the VME Index may be found in association with values of SAR above the threshold of 0.43. This likely reflects separation of fishing activities and VMEs within the scale of C-Squares, and the reasons for this relationship should be investigated using higher resolution data of fishing activities within each square relative to the location of VME observations. To avoid potential harm to VMEs, the consequences of increasing the SAR threshold to avoid excluding locations from closures where medium or high VME concentrations are known to occur should be evaluated as part of the benchmark until higher resolution analyses are available. This comparison is particularly relevant as to defining whether a lower SAR threshold is warranted for C-squares with a higher concentration of potential VMEs. The comparison of Scenarios 1 and 2 as part of the EUVME assessment provides some sense of the contrast in levels of protection afforded if fishing is or is not considered but the inclusion of low values of the VME-index in scenario 2 option 1 is a confounding factor.

It is unclear how the VME confidence index is being combined with the final VME index to demonstrate the reliability of the estimates of areas with VME occurrence. Steps 2a and 2b of section 5 detail the definition of the confidence index and its mapping but details of how that information is applied in determining where VMEs occur or are likely to occur (step 3, section 5) are missing. With reference to the confidence, the report may consider clarifying the elements of the VME index in terms of the sensitivity score and the likelihood of an area containing a VME. The description given in section 5 is inconsistent with the definition of the VME index as the likelihood of VMEs, as the index is being calculated from the abundance data and the sensitivity score in deterministic terms and does not consider reliability of the data sources or other type of likelihood. This may affect the perceived uncertainty in the advice.

Another source of uncertainty in the assessment framework stems from how the risk from fishing activities associated with different scenarios based on likelihood of the VME occurrence is treated in the advice. As all possible scenarios only consider areas with confirmed VMEs, the process partly overlooks areas where VMEs are likely to occur as opposed to where they are known to occur. The need for confirmation of VME occurrence for inclusion of VME elements may be the result of sampling bias and may affect the overall advice. This uncertainty could at least partly be addressed and made transparent in clarifying how the VME confidence index is used in the final advice to illustrate what is the level of precaution applied in cases of more or less certain VME occurrence.

The rationale for the buffer zones may have been stated in other ICES reports but the current description is far too limited. Application of buffers around C-squares in which VMEs are likely to occur is well described in the report. However, a clear explanation for the reasons why a single approach is appropriate for most circumstances would be beneficial. For example, strong topographic gradients may require wider buffers to deal with possible consequences of sediment resuspension/flow, particularly in areas with steep topographic features, where an extension of the buffer zone downslope (where sediment accumulation after resuspension may occur) should be expected.

The overall strategy for VME protection may integrate results from species distribution models (SDMs) and habitat suitability models (HSMs) when they provide complimentary information with respect to VME elements, areas of potential occurrence and the likelihood or opportunities for recolonization. WGDEC, WKHPM and WGMHM have considered the challenges and requirements for the application of SDMs and HSMs in the provision of advice, and proposed set of Term of Reference have been drafted for a second WKPHM workshop have been identified. The outcome of the second workshop (new criteria and an agreed model specification) would require an ICES data call to be circulated for submission of peer-reviewed, published VME/VME indictor models, followed by a benchmarking exercise to complete the review. The RG notes there remains considerable discussion among members of the WGs/WK concerning criteria for model assessment and error reporting (accuracy and uncertainty) and that decisions about model suitability may be difficult to achieve based on the use of existing peer-review/published models what differ in VME type, spatial coverage, etc.. Given that the current approach for advice focusses on the most sensitive VME within a C-square, the RG believes that ICES may have to consider SDMs and HSMs as qualitative identification of potential areas where multiple or less sensitive VMEs are likely to occur when data are limited in the vicinity of areas that have identified potential closures based on a strong observational foundation.

Although MBCG represent the greatest risk for SAI to VMEs, the absence of assessments for other bottom contact gear (e.g., longlines, midwater trawls, other metiers) represents a gap. For example, intensity and recurrence of longlining activities could represent an important risk for highly sensitive (i.e., fragile) VMEs. Development of methods to estimate risk associated with gears other than MBCG should be considered in the future.

Careful attention needs to be directed to ensuring consistent use of terminology throughout the document because differences in perception may result in uncertainty in the advice being provided (e.g., biomass versus abundance, vulnerability versus sensitivity, likelihood versus confidence).

Completeness of the advice

The report provides a sound basis for the requested framework benchmark that can serve to provide advice to managers for both the EU and NEAFC. Reviewers did not detect missing elements that would limit the value of the benchmarking exercise.

Important points missing

The workflow and approach are comprehensive and no elements appear to be missing from the analysis and management scenarios and options.

Conclusions (are these sound and consistent with the available information)

The Review Group (RG) agrees that the proposed VME Assessment Framework Benchmark is appropriate to address the request for Advice in Tor b. The overall structure reflects careful development of data quality control algorithms and processing in order to provide reliable and repeatable estimation of metrics to be applied in the framework.

The delineation of VME closures under the different scenarios for each ecoregion are sound and comprehensive. Addition of the potential effect of missing data and the benefits of use of SDMs could serve to condition application of the outcome of the different scenarios and options in development of the Advice.

References

NAFO. 2016. Report of the Scientific Council Meeting. 03–16 June 2016, Halifax, Nova Scotia, Canada. NAFO SCS Doc. 16–14 Rev., Serial No. N6587. https://www.nafo.int/Portals/0/PDFs/sc/2016/scs16-14.pdf.

Annex 5: Agenda WKVMEBM 2022

Benchmark Workshop on the occurrence and protection of VMEs (WKVMEBM) SharePoint
5-8th April 2022 - Hybrid / ICES HQ
Agenda

Link to join the meeting: Click here to join the meeting

Tuesday 5th April	1000 - 1800 (CPH)
	Note: This preparatory session is open to all registered participants.
1000 – 1015	Welcome, introductions, Code of Conduct. (Eugene)
1015 – 1100	Update - preparatory VME subgroup (David)
1100 – 1145	Update - preparatory SAR/VMS subgroup (Helen/Roi)
1145 – 1200	Comfort break
1200 – 1300	Issues arising (Eugene)
Lunch	*1300 – 1400 (CPH)*
	Plenary
1400 – 1430	Welcome, introductions, Code of Conduct and agree Agenda (Eugene)
1430 – 1500	Introduction to ICES VME advice, the ICES benchmark process and document "*VME process for Benchmark"* (Eugene)
1500 – 1530	Introduction to the reviewers and review process (Pierre)
1530 – 1545	Comfort break
1545 – 1615	Introduction to VME process (David)
1615 – 1645	Introduction to SAR/VMS process (Helen/Roi)
1645 – 1715	Introduction to advice production and advice template example (Daniel)
1715 – 1745	Scope of the VME Benchmark – priorities to address and operational responsibilities of WGs and ADGs. (Eugene)
1745 – 1800	Planning for following day's work.
Wednesday 6th April	1000 – 1800 (CPH)
1000 – 1300	Subgroups work
Lunch	*1300 – 1400 (CPH)*
	Plenary
1400 – 1500	Feedback from mornings subgroup work and matters arising.
1500 – 1600	Review and agreement on Scenarios and Options (Table 7.1)
1600 – 1615	Comfort break
1615 – 1730	Advice template for NEAFC and EU and issues arising.
1730 – 1800	Planning for following day's work.
Thursday 7th April	1000 – 1800 (CPH)
1000 – 1300	Subgroups work
Lunch	*1300 – 1400 (CPH)*
	Plenary
1400 – 1500	Feedback from mornings subgroup work and matters arising.
1500 – 1600	Advice template for NEAFC and EU and issues arising.
1600 – 1615	Comfort break
1615 – 1730	Finalise and document scope, content, structure and responsibilities for the ICES VME advisory process.
Friday 8th April	1000 – 1800 (CPH)
1000 – 1300	Subgroups work
Lunch	*1300 – 1400 (CPH)*
	Plenary
1400 – 1500	Feedback from mornings subgroup work and matters arising.
1500 – 1600	Finalise and agree advice template.
1600 – 1615	Comfort break

1615 – 1730	Finalise and agree documented scope, content, structure and responsibilities for the ICES VME advisory process.
1730 – 1800	Benchmark recommendations
1800	Close of benchmark.

Annex 6: ICES VME Method Benchmarked April 2022

1. Introduction

ICES provides advice on the identification and protection of VMEs that is consistent with the FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO, 2009), developed to assist in the implementation of United Nations General Assembly (UNGA) Resolution 61/105. They provide a framework to manage fisheries exploiting deep-sea fish stocks with the potential to have significant adverse impacts on vulnerable marine ecosystems (VMEs).

Records submitted to ICES of areas where VME habitats occur are quality checked and the area entered to the VME database as an area where VMEs are known to occur. Records submitted to ICES of the presence of VME indicator species are quality checked and the area entered to the VME database as an area where VMEs are likely to occur. For these areas ICES assess this likelihood using information submitted with the record to establish vulnerability and abundance; this assessment results in a likelihood score known as the VME Index. ICES considers the likelihood as measured by the VME Index when advising on the identification and protection of VMEs.

The FAO guidelines (FAO, 2009) require assessments be undertaken to establish if deep-sea fishing activities could produce significant adverse impacts (SAI) on VMEs. These assessments should take into account, as appropriate, differing conditions prevailing in areas where deep-sea fisheries are well established and in areas where deep-sea fisheries have not taken place or only occur occasionally. The implication is that VMEs in areas that have been more intensely fished may already be damaged and further fishing would not cause further SAI, given their extremely slow recovery rates.

Trawling with mobile bottom contacting gear (MBGC), which includes bottom otter trawls, bottom seines, dredges, and beam trawls, has the potential for far greater impact on VMEs than static gear and it is currently the only gear type for which ICES has information on the spatial intensity of fishing activity. ICES therefore focuses its advice on protecting VMEs from impacts caused by fishing with MBCG.

When considering the effect fishing with MBCG has had on VMEs, ICES uses a fixed threshold for MBCG fishing intensity below which VMEs, should they be present, would not have been significantly adversely impacted and ICES advises that these areas should be closed to MBCG fishing. Above this threshold, ICES considers that MBCG fishing intensity would have already damaged any VMEs that would have been present and that further fishing would not cause further SAI and ICES advises that the area has a low likelihood of hosting VMEs and remains open to MBCG.

When fishing data is not available (or not of sufficient quality) to quantify MBCG fishing intensity, it is assumed that if there is high or medium likelihood of VMEs being present they have not been damaged by previous fishing activity and ICES advice is that these areas have a high likelihood of hosting VMEs and should be closed to MBCG fishing; areas with a low likelihood of VMEs being present remain open to MBCG.

The ICES advisory process utilises, to the fullest extent possible, all available quality-assured/controlled data submitted to ICES by its member countries or by fisheries management authorities. Developments have been identified by managers that will improve the quantity, quality and resolution of VMS data reported to ICES and this in turn will greatly enhance the ability to assess the risk to VMEs from fishing activities. Such improvements will result in better spatially resolved management advice while maintain the level of protection afforded to areas hosting VMEs.

Data collected by ICES through annual VME data calls since 2012 are used to provide cumulative evidence of where VMEs occur or are likely to occur. In addition, data obtained from literature records collected and reviewed by WGDEC, and on VME elements from EMODnet are included. These data cover the entire ICES area but are more prevalent in 'deep-water areas' of 200 meters and greater.

To establish the spatial distribution of fishing activities, ICES couples VMS (vessel monitoring systems) data with catch data supplied by ICES member countries in response to annual VMS data calls. For the NEAFC area, VMS and catch data are submitted to ICES annually from the NEAFC Secretariat.

These two data flows (VME and VMS) are combined by ICES to assess the spatial overlap between MBCG fishing and the location of where VMEs occur or are likely to occur, and the potential for significant adverse impacts on VMEs from ongoing fishing activity with MBCG.

This document describes the evidence based, operational procedure used and benchmarked by ICES in 2022 when providing VME advice. It identifies how data are collected, quality checked and analysed using R-scripts prepared by ICES; the data and R-scripts are made available with each piece of ICES advice released.

2. Spatial management measures to prevent significant adverse impacts

Developing spatial management measures to prevent significant adverse impacts on VMEs relies on the quality, quantity and spatial resolution of information available on the location of where VMEs occur or are likely to occur and the intensity of fishing activity and the type of gears used.

The FAO guidelines (FAO, 2009) identify significant adverse impacts (SAI) as those that compromise ecosystem integrity (i.e. ecosystem structure or function) in a manner that i) impairs the ability of affected populations to replace themselves; ii) degrades the long-term natural productivity of habitats; or iii) causes, on more than a temporary basis, significant loss of species richness, habitat or community types. The guidelines also require impacts to be evaluated individually, in combination and cumulatively and, when determining the scale and significance of impacts, it is particularly important to consider intensity or severity of the impact, spatial extent, duration and timing of the fishing pressure as well as the vulnerability, extent of the impact on the ecosystem functions and recovery time of the ecosystem.

ICES has been providing advice on VMEs since 2008 (ICES, 2008) and in recent years have advised that any bottom-contact fishing on VME habitats will result in damage to these habitats and poses a risk of significant adverse impacts (ICES, 2020a; ICES, 2021a). ICES has also advised that MBCG gears have a far greater impact on VMEs when compared to other gears (ICES, 2021b). For this reason, and also due to the lack of data on spatial intensity of fishing activity other than MBCG, the current focus of ICES work on VMEs relates to the removal of MBCG from areas that contain or are likely to contain VMEs. Future work and recommendation on improving the science and data to better understand issues such as recovery and ecosystem functioning are outlined in section 4.6 of the WKVMEBM Report (ICES, 2022)

In addition, ICES considers paragraph 48 of the FAO guidelines to inform its advice on areas that have already been closed for the purpose of VME protection. In areas where fishing has not been permitted in order to protect VMEs, the reopening of such VME closures to bottom contacting gear will not be advised by ICES unless it can be shown that VMEs are not present. This is consistent with ICES advice on areas that have been closed for the protection of VMEs (ICES, 2017).

ICES uses ecoregions (ICES, 2020b) and a C-square resolution of 0.05° when providing advice on the location and protection of VMEs. Based on currently available data, ICES considers this to be the best pragmatic compromise between protecting the confidentiality of data with respect to the location of fishing activity of individual fishing vessels and collating and assessing data on the occurrence or likely occurrence VMEs.

2.1 Spatial management scenarios used in ICES advice

Based on the scenarios and options set out in Table 2.1, ICES advice provides a range of VME polygon options that can support the implementation of appropriate management measures required to protect VMEs while also taking account of the quality and quantity of both the VME and VMS data available. This allows fisheries managers to determine measures for the protection of VMEs from MBCG fishing depending on the level of precaution they wish to apply and the degree of uncertainty or confidence in the data they are willing to accept.

The VME polygon options proposed by ICES cover two scenarios which place different emphasis on the dual aspects of the UNGA policy that is, the identification and potential protection of VMEs with and without consideration of MBCG fishing intensity, Table 2.1. These scenarios/options can be applied singly or in combination and can be visualised spatially using maps provided with ICES VME advice.

Table 2.1: Scenarios and options used by ICES to define VME polygon areas and the associated management implications for the protection of VMEs and general consequences on fisheries.

Scenario	Option	Description of C-square closures	Management implication
1	1	C-squares with VME habitats as well as C-squares with high and medium VME indices, regardless of fishing activity. C-squares with a low VME Index only included if adjacent to C-squares with medium to high VME indices.	Prioritizes identification of VME polygons where they "are known to occur", and where they "are likely to occur", regardless of fishing activity.
1	2	Scenario 1–Option 1 + C-squares that contain selected VME physical elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME indicator species records.	Prioritizes identification of VME polygons where they "are known to occur" and "are likely to occur", as well as elements that are known to frequently contain VMEs, regardless of fishing activity.
2	1	As Scenario 1–Option 1 but includes low VME index C-squares if MBCG fishing pressure is also low (SAR < 0.43). This option preferentially includes Low VME Index C-squares where these occur outside the more highly fished areas.	Prioritizes identification of VME polygons where they "are known to occur" or " are likely to occur", and includes C-squares with Low VME Index where cumulative fishing activity is also low and significant adverse impacts (SAIs) by past fishing are less likely, this therefore offers potential VME protection at low cost to the fishery and highest potential protection of VMEs in the fishing footprint.
2	2	C-squares including all VME habitats, High, Medium and Low VME Index C-squares but excluding C-squares with high cumulative MBCG fishing pressure (SAR > 0.43). This option effectively only considers VME Index (of any category) in areas outside of relatively high fishing effort areas.	Prioritizes identification of VME polygons where they are known or likely to occur, but excludes areas that have been intensely fished and where VMEs are therefore potentially damaged by past trawl fishing. By leaving heavily fished areas open, there is reduced impact on fishing activities.
Combined scenarios		Scenario 1 option 2 and Scenario 2 option 1: C-squares with VME habitats as well as C-squares with medium and high VME indices and low VME index if MBGC fishing	Prioritizes identification of VME polygons where they "are known to occur" or " are likely to occur", and includes C-squares with low VME Index where cumulative fishing activity is also low and SAIs by

	pressure is low (SAR < 0.43), + C-squares that contain selected VME physical elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME indicator species records.	past fishing are less likely, this therefore offers potential VME protection at low cost to the fishery and highest potential protection of VMEs in the fishing footprint, as well as elements that are known to frequently contain VMEs, regardless of fishing activity.

Scenario 1 prioritizes the identification of VME polygons, irrespective of the fishing activity that may have previously damaged VMEs and is consistent with paragraph 83c of UNGA Resolution 61/105, (UNGA, 2006) for the identification of VMEs. Scenario 2 prioritizes the identification of VME polygons, but also incorporates a threshold for the level of MBCG fishing intensity permissible that is empirically linked to aspects of significant adverse impacts (NAFO, 2016); Scenario 2 is consistent with Resolution paragraph 83a (UNGA, 2006).

Scenario 1 – Option 2 is the most precautionary of the two options (under scenario 1) as it also includes VME physical elements and some Low VME Index squares as areas where VMEs "are likely to occur" in addition to VME Habitats and High and Medium VME Index squares.

For Scenario 2, fishing is considered, but the assessment of fishing intensity is limited to MBCG only. The reasons for this are: 1) MBCG is currently the only gear type for which ICES has information on the spatial intensity of fishing activity; and 2) in most situations, MBCG has the potential for far greater impact on VMEs when compared to static gear (Pham, *et al*., 2014). Under Scenario 2, the key phrase in the UNGA Resolution is the assessment of whether bottom fishing activities would have "*significant adverse impacts on vulnerable marine ecosystems*". The implication is that VMEs in C-squares that have been more intensely fished may already have been impacted and therefore any further fishing activity would not cause additional significant adverse impacts (assuming each cell is independent in terms of recovery processes and VMEs are uniformly distributed within each cell).

2.2 Significant Adverse Impacts (SAI)

Currently, all analyses of the fisheries impacts and protection benefits of VME polygons, should they be closed, are carried out at the 0.05° C-square resolution. It is important to understand that fishing activity with MBCG and the location of VMEs within the same C-square may not necessarily overlap spatially and that more spatially resolved fishing data could result in more spatially resolved ICES advice on the protection of VMEs from MBCG. Within C-squares, where there are significant overlaps between VMEs and MBCG fishing, there may be limited short to mid-term benefit to be gained from closing these C-squares, whereas, where there is little or no overlap (even if intensively fished), closure to prevent fishing in hitherto unfished parts of the C-square also containing VMEs could result in some benefit to VME protection and hence are included in the defined VME polygon.

It is more likely that the distribution of VMEs and fishing is more homogeneous within a C-square where seabed is flat muddy ground (typically where sea pens occur) but it is unlikely to be true in topographically complex areas, such as canyon heads, where coral species may be found.

To account for SAI caused by past and ongoing MBCG fishing, the two options in Scenario 2 use a threshold above which the level of MBCG fishing intensity is known to cause significant adverse impacts on VMEs. Within a C-square, MBCG fishing intensity is measured as the 'swept area ration' (SAR). SAR is the cumulative swept (fished) area divided by the surface area of the C-square grid cell. Calculating SAR requires information on 1) gear type, 2) gear width or in the absence of gear width vessel length or kW engine power, 3) fishing hours, and 4) fishing speed. For ICES data there is a look up table defining the gear parameters required to calculate SAR for metier level 6 codes and benthic gear groupings (Eigaard et al., 2016).

C-square SAR values for comparison with the 0.43 threshold MBCG is the average of the annual SAR value for the most recent years that quality assured VMS data is available; for the ICES data call this is since 2009. It has been estimated that SAI are likely to have occurred at a MBCG fishing intensity of SAR > 0.43, (or 43% of the C-square fished with MBCG if fishing is uniformly distributed). This threshold has been estimated as the MBCG fishing intensity at which the biomass of the VME indicator species type that was found to be the least sensitive to being caught in bottom trawls based on a standard gear configuration (trawl speed of 3 knots, gear swath is 150 meter, based on the dominant fishery, Greenland Halibut, operating in the area). That is, to define a level of fishing intensity above which the least sensitive VME type (e.g. sea pen VME in the NAFO area) are no longer caught (or caught in very small numbers/biomass) in the standard trawl gear (Figure 2.1). This threshold is therefore precautionary in terms of maximising the area identified where VMEs may still occur even though the C-squares may have been subjected to relatively high fishing effort with MBCG.

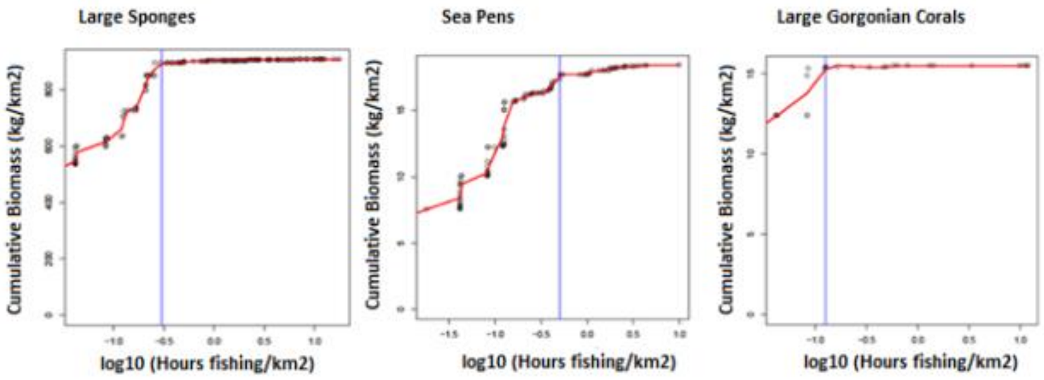

Figure 2.1: Cumulative plots of sponge (left), sea pen (middle), and gorgonian coral biomass against fishing effort per year in the Northwest Atlantic Fisheries Organization (NAFO) area (NAFO, 2016). The inflection cut-off values (blue lines) show the intensity above which the VME indicator species is found in low levels of abundance in bottom trawls. The largest inflexion cut-off value of the VME indicators, sea pens (0.5 hours/km−2 per year, 0.05 < p < 0.1), was used to define a threshold for fishing intensity. This threshold is therefore conservative for the VME indicator species with smaller inflexion cut-off values. To apply the threshold value, it was necessary to convert the 0.5 hours/km^2 fishing effort per year to a SAR value. Using fishing gear dimensions for the halibut trawl fishery in the NAFO area, this became a mean annual value of 0.43 SAR. Figure taken from NAFO (2016, Fig. 4.2.5.3.6).

2.2.1 Sensitivity to changing SAR thresholds

Sensitivity testing of results generated by Scenario 2 to changes in the SAR impact threshold were investigated and documented in the benchmark workshop report (ICES 2022). The conclusion of these investigations was that the outcome of Scenario 2 (Option 1) would appear to be less sensitive to changes in the applied SAR threshold value when compared to Scenario 2 (Option 2). The workshop therefore recommends that Scenario 2 (Option 1) be used in preference to Scenario 2 (Option 2) when considering the VME polygon results from the Scenario 2 analysis as it is the least sensitive to changes in the applied SAR threshold value.

2.3 Buffer Zones

ICES uses a C-square resolution of 0.05° x 0.05° and advises that the buffer around VME C-squares should be a half-C-square in all directions. The application of such a 0.025° buffer results in a buffer of 2,780 m of latitude, 4,451 m of longitude at 37°N. The areal extent of the buffer corresponds to approximately 3 times the average sea-depth, which is deemed sufficient to take into account potential navigational variations in the precise location of fishing gears on the seabed and to mitigate for any potential impacts on VME should VME fishery closures be subsequently established resulting from settling of disturbed sediments.

3. Application of the scenarios

The scenario rules to select VME polygon areas are applied by ICES at an ecoregion level irrespective of the depth and the boundary of the ecoregion. Subsequently, the VME polygons are clipped to fit the relevant areas as defined in the specific requests to ICES as the different scenarios/options generally result in different areal extents and numbers of polygons within the defined area of interest. The consequences of VME polygons on fisheries (should they be subject to fishery closure) are also tabulated. The R-scripts which produced the VME polygon area options and data summaries, including VME polygon shape files, are available on the open-source VME-Advice GitHub platform (https://github.com/ices-taf/VME-Advice).

3.1 Scenario 1: No Consideration of Fishing Pressure

Option 1 - VME Habitat and Medium and High VME Index C-squares

Step 1. Select all VME Habitat, High and Medium VME Index C-squares and create a ½ C-square buffer around them (Figure 3.1). *These cells are known or likely to contain VMEs and the buffer zones account for the offset between vessel positions and the position of their gear, which can be substantial in deep water, and the effects of sediment resuspension, which can have detrimental effects on VMEs, should any part of the VME polygon be subsequently designated as a fishery closure.*

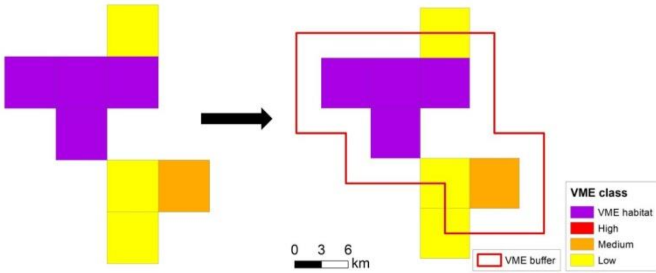

Figure 3.1. Scenario 1 Option 1, Step 1 illustrating the selection of C-squares and creation of a buffer around C-sqrs.

Step 2. Where Low VME Index C-squares are adjacent and joining any C-squares in Step 1, these should be selected and a ½ C-square buffer placed around the C-square (Figure 3.2). *These cells are considered more likely to contain VMEs than other low index cells by their proximity to higher index cells.*

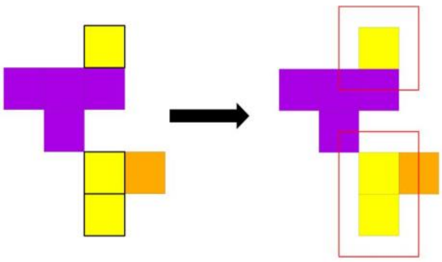

Figure 3.2. Scenario 1 Option 1, Step 2 illustrating inclusion of adjacent VME Index Low C-squares and associated buffers.

Step 3. Where two or more C-squares from Steps 1 and 2 are joined by their buffers or directly joined (in any way) they will be combined into a single VME polygon (Figure 3.3). *This reduces the number of polygons in a data-layer.*

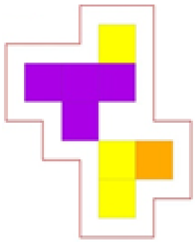

Figure 3.3. Scenario 1 Option 1, Step 3 illustrating the final VME polygon with buffers (red line).

Step 4. All satellite VME C-squares in Step 1 above should be defined as individual VME closures with associated ½ C-square buffer (Figure 3.4). *Many VMEs types can naturally consist of small patches of about one C-square in size or smaller.*

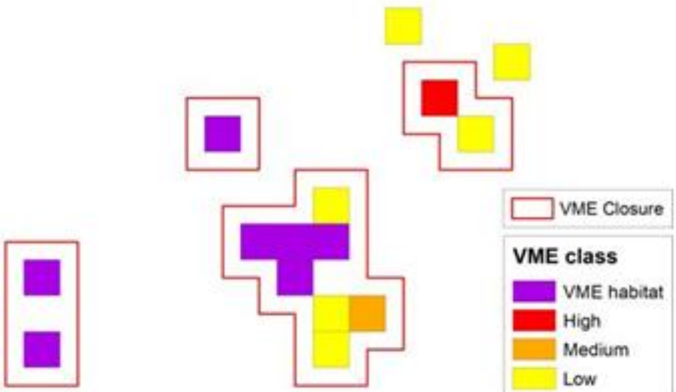

Figure 3.4. Scenario 1 Option 1, Step 4 illustrating the inclusion of isolated C-squares with buffers.

Step 5. Fill all holes with 1 or 2 C-squares inside VME polygons (Figure 3.5). *Fishing vessels are unlikely to be able to fish effectively in very small areas. A trawler that fishes at 3.5 knots will cover 7nm in a typical 2h haul, which is equivalent to about between 2 and 3 C-squares. Open holes of less than 3 C-squares are therefore not considered practical. In addition, the relatively close proximity to areas identified as VME suggests they may be important in maintaining the ecological integrity and functions of the VME polygon as a whole.*

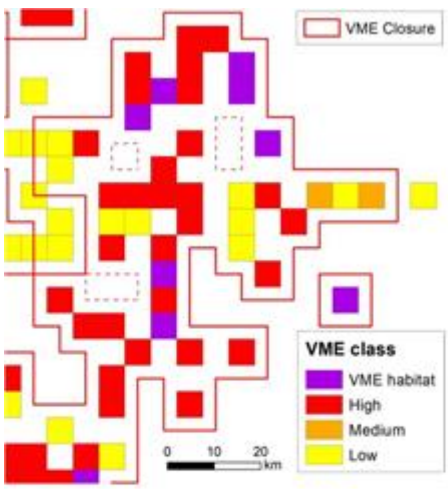

Figure 3.5. Scenario 1 Option 1, Step 5 illustrating the filling of holes (dashed lines) within the VME polygons

(dark red lines) produced from Steps 1-4.

Option 2 - VME Habitat, VME Index C-squares and VME Elements

Step 1. Select the VME elements (bank, coral mound, mud volcano, seamount, cold seeps and hydrothermal vents) with an occurrence of a VME Habitat or VME Indicator (High, Medium and Low). VME elements are selected with the VME points (using middle point position) rather than the C-squares to avoid selecting elements that intersect with the buffer of a C-square but not with a VME record per se (Figure 3.6). *These four VME elements are known to be important drivers of VME presence, and when this is confirmed by the presence of VME indicators. The VME elements used for Scenario 1 option 2 were limited to topographic highs (seamounts, banks) as well as small elements spatially well constrained (coral mounds, mud volcanoes, cold seeps, hydrothermal vents) in EMODnet. Other VME elements that were large and spatially not well constrained, such as steep slopes or canyon systems, were excluded because their spatial footprint was considered too large relative to the evidence of VME occurrences. Using the point data for the VMEs ensures that the VME element is definitely associated with the VME record. Steep slopes/flanks (>6.4 degree) and peaks, mid-ocean ridges, knolls and guyots, may be considered depending on the availability and accuracy of data available to ICES.*

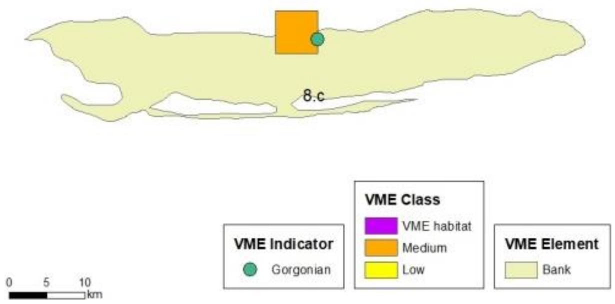

Figure 3.6. Scenario 1 Option 2, Step 1 illustrating the selection of VME elements (bank) with an occurrence of a VME Indicator (Medium).

Step 2. Clip the VME selected in Step 1 to the area and/or depth relevant to the request in hand.

Step 3. Select the C-squares overlapping with the VME elements selected in step 2 (Figure 3.7).

These three technical steps bring the VME elements which are most likely to contain VMEs into the closures. At the same time, VME elements for which there are no supporting evidence of VMEs are not included.

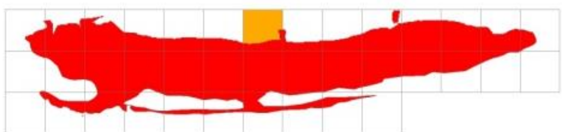

Figure 3.7. Scenario 1 Option 2, Step 3 illustrating the selection of the C-squares overlapping with the VME elements selected in step 2.

Step 4. Remove the C-square buffer from **Scenario 1 Option 1** that intersects with VME elements but does not overlap with the C-squares selected in Step 3 above, and include all C-squares that overlap with the VME element (Figure 3.8). *The VME elements were not buffered.*

This is because the areas with VME elements are generally large and only C-squares along the periphery of the VME elements would potentially be subject to direct or indirect effects of bottom contact fishing should the area be subsequently closed to bottom fishing. Retaining a buffer such as the hatched area in Figure 3.8 would create buffers only where the VME data happen to overlap with the VME element.

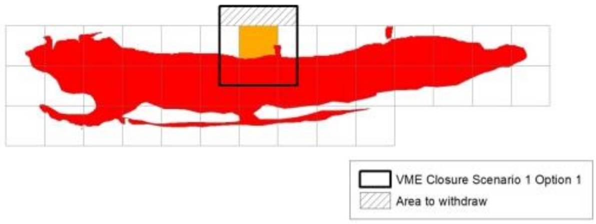

Figure 3.8. Scenario 1 Option 2, Step 4 illustrating the C-squares and its buffer from Scenario 1 Option 1 that intersect with the VME element (orange C-square with black surrounding buffer). In Step 4 the buffer (hatched area above the C-square) is removed.

Step 5. Merge Step 4 above with Scenario 1 Option 1. *This captures areas where VMEs are known or likely to occur (Figure 3.9). There may still be an under-representation of sea pen VMEs in this option.*

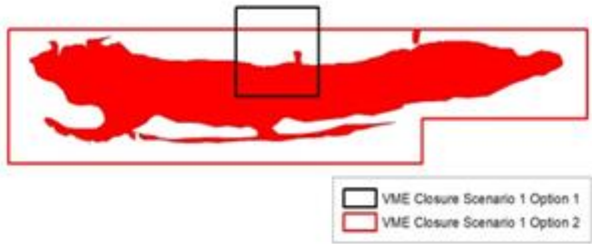

Figure 3.9. Scenario 1 Option 2, illustrating the difference between Scenario 1 Option 1 that does not include the VME element (black line) and Scenario 1 Option 2 that includes the VME element (red line).

Scenario 1 and United Nations General Assembly Policy

The two options presented for Scenario 1 define VME polygons, irrespective of the fishing activity (Table 2.1). These are consistent with the United Nations General Assembly (UNGA) resolutions, specifically UNGA 61/105, paragraph 83:

> (*c*) In respect of areas where vulnerable marine ecosystems, including seamounts, hydrothermal vents and cold water corals, are known to occur or are likely to occur based on the best available scientific information, *to close such areas to bottom fishing* and ensure that such activities do not proceed unless conservation and management measures have been established to prevent significant adverse impacts on vulnerable marine ecosystems (UNGA, 2006).

3.2 Scenario 2: Consideration of Fishing Pressure

Option 1 - VME Habitat, Medium and High VME Index C-squares (irrespective of fishing effort) and only Low VME Index C-squares which coincide with Low Fishing Effort

Step 1. Select all VME Habitat, High and Medium VME Index C-squares and create a ½ C-square buffer around them (Figure 3.1). *These cells are known or likely to contain VMEs and the buffer zones account for the offset between vessel positions and the* *position of their gear, which can be substantial in deep water, and the effects of sediment resuspension, which can have detrimental effects on VMEs. This selection is the same as step 1 in Scenario 1 option 1.*

Step 2. Select all Low VME Index C-squares which have a SAR < 0.43 (as determined by NAFO methodology, see Annex 2) and add a ½ C-square buffer to them (Figure 3.10). *Because they are fished at intensities that allow persistence of VME, and because they are less important for fishing, it can be worthwhile closing these C-squares even if the presence of VMEs is uncertain. Due to the bias in the VME Index against certain VME indicator species (e.g. sea pens in particular, Annex 1) this will ensure that more of such VME types are included in the defined VME polygons.*

Step 3. Where Low VME Index C-squares are adjacent and joining any C-squares in Steps 1 and 2, these should be selected and a ½ C-square buffer placed around the C-square (Figure 3.10). *These cells are considered more likely to contain VMEs than other Low VME Index cells by their proximity to higher VME Index cells.*

Step 4. Where two or more C-squares from Steps 1, 2 and 3 are joined by their buffers or directly joined (in any way) they will be combined into a single VME polygon (Figure 3.10). *This reduces the number of polygons in a data-layer.*

Step 5. All satellite VME C-squares in Steps 1 and 2 above should be defined as individual VME closures with associated ½ C-square buffer. *Many VME habitats naturally occur at the size of a C-square or smaller. These single C-squares can still offer meaningful VME habitat.*

Step 6. Fill all holes with 1 or 2 C-squares inside VME closures. *Fishing vessels are unlikely to be able to fish effectively in very small areas. A trawler that fishes at 3.5 knots will cover 7nm in a typical 2h haul, which is equivalent to about between 2 and 3 C-squares. Open holes of less than 3 C-squares are therefore not considered practical. In addition, the relatively close proximity to areas identified as VME suggests they may be important in maintaining the ecological integrity and functions of the VME polygon as a whole.*

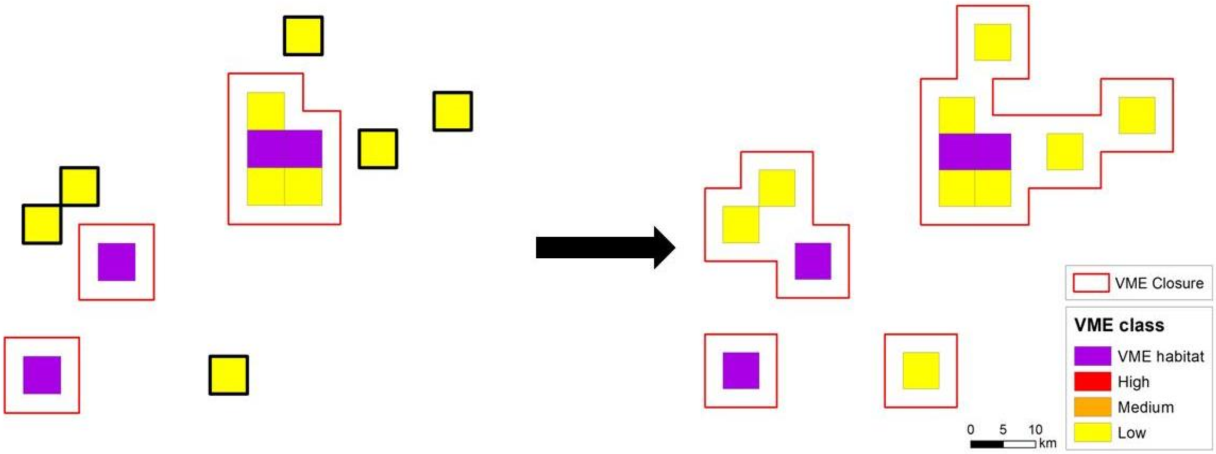

Figure 3.10. Scenario 2 Option 1, Steps 2 to 4 illustrating the inclusion of Low VME Index C-squares with fishing effort less than 0.43 SAR (yellow outlined in black on left panel).

Option 2 - Protection for all VME Habitat, and Low, Medium and High VME Index C-squares but only in Areas of Low Fishing Effort.

Step 1. Determine the area of fishing activity which is at or above the SAR VME significant adverse impact level (> 0.43 SAR) as determined for the least sensitive deep sea VME indicators species (e.g. sea pens) following NAFO methodology (NAFO, 2016). *This area corresponds to a sufficiently high level of fishing activity where effectively the risk of future or new VME impact is low because persistence of VMEs is unlikely due to their vulnerability and sensitivity to bottom fishing activities. The defined area essentially represents an area of 'low risk of further VME fishing impact' at the present time.*

Step 2. Select all VME C-squares (Habitat, and High, Medium and Low VME Index) which do not overlap with the 'low risk of further VME fishing impact' or fishing area as defined in Step 1 above, and create a ½ C-square buffer around them (Figure 3.11). *These are the VME C-squares which are more likely to have VME present on account of being subject to only low or no fishing pressure.*

Step 3. Where two or more C-squares from Step 2 above are joined by their buffers or directly joined (in any way) they will be combined into a single VME polygon. *This is because they are likely to form the same VME type.*

Step 4. All satellite VME C-squares in Step 2 above should be defined as individual VME polygons with associated ½ C-square buffer. *Many VME habitats naturally occur at the size of a C-square or smaller. These single C-squares can still offer meaningful VME habitat.*

Step 5. Fill all holes with 1 or 2 C-squares inside VME polygons. *Fishing vessels are unlikely to be able to fish effectively in very small areas. A trawler that fishes at 3.5 knots will cover 7nm in a typical 2h haul, which is equivalent to about between 2 and 3 C-squares. Open holes of less than 3 C-squares are therefore not considered practical. In addition, the relative close proximity to areas identified as VME suggests they may be important in maintaining the ecological integrity and functions of the VME polygon as a whole.*

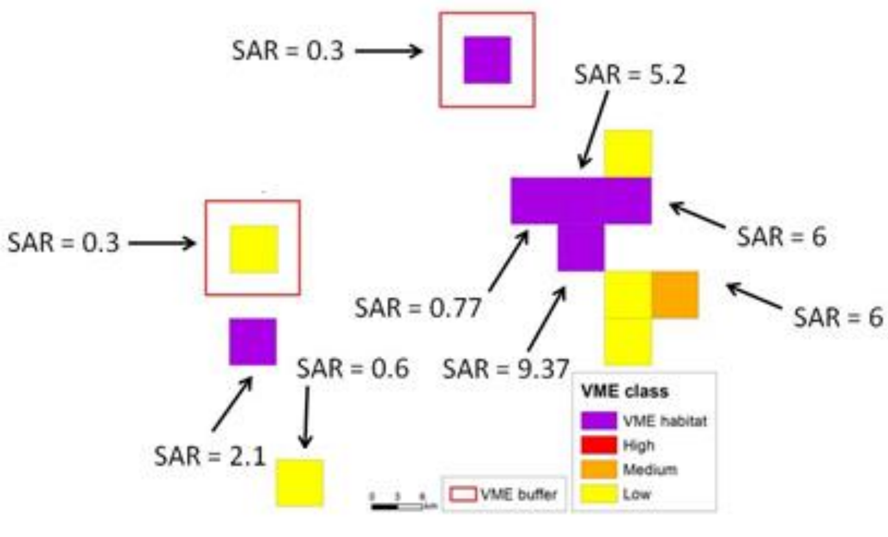

Figure 3.11. Scenario 2 Option 2, Step 2 illustrating the exclusion of C-squares with VME Habitats and VME Index (Low, Medium or High) when fishing effort is greater than 0.43 SAR, and the application of the buffer (red lines). In this example only two C-squares have fishing effort < 0.43 SAR, one with VME habitat and one with a Low VME Index.

4.4. Scenario 2 and United Nations General Assembly Policy

The two options presented for Scenario 2 define VME polygons, but incorporate a threshold for the level of fishing intensity that is linked to significant adverse impacts (Table 2.1). These are consistent with the United Nations General Assembly resolutions, specifically UNGA 61/105, paragraph 83:

> (a) To assess, on the basis of the best available scientific information, whether individual bottom fishing activities would have significant adverse impacts on vulnerable marine ecosystems, and to ensure that if it is assessed that these activities would have significant adverse impacts, they are managed to prevent such impacts, or not authorized to proceed (UNGA, 2006).

4. Assessment procedure and outputs

The assessment is prepared by WGDEC, supported by WGSFD and WGMHM, and is presented each year to the VME advice drafting group (ADG) using the assessment templates described below. The assessment utilises R-scripts, which take the annually updated VMS, VME and VME physical element data layers as input files and produce the VME polygons for each Scenario and Option, as well as the assessment summaries and statistics for expert interpretation. A further R-Script produces the standardised template HTML file with the full assessment. The R-scripts are available on the open-source VME-Advice GitHub platform (https://github.com/ices-taf/VME-Advice).

The assessment outputs are provided in self-contained HTML files including written text, tables, and maps that allow the user to view the whole assessment area, to zoom into areas of interest and to toggle the various layers described below. In addition to the primary self-contained HTML assessment, ICES advice on VMEs are accompanied by:

- PDF maps representing the VME polygons for all scenarios and all options; the maps include the VME polygon ID number and the area defined as fishable domain
- .csv, .xlsx and .shp files for all scenarios and all options; these files include the descriptions “VME_Csquare”, “VME_Habitat”, “VME_Indicator” and “VME_Elements” (see further information in Table 6.1)

The quality and spatial resolution of data differs between different management areas and this determine ICES’ ability to provide advice based on the different assessment scenarios. Where VMS information and data are available, ICES will provide its advice based on Scenario 2. Where such VMS/fisheries information is limited or not available ICES will provide its advice based on Scenario 1.

The outputs from the assessments are the direct inputs to the ADG established each year to prepare the annual advice on the occurrence and protection of VMEs. The main assessment output is a self-contained HTML file containing two scalable maps with selectable layers and a number of tables containing summary information produced by the assessment. The outputs will be prepared by the ICES working groups according to the following specifications.

4.1 Assessment output Figure 1 - Map of VMEs.

The first of the two scalable maps contains 16 selectable layers as shown in Figure 1 and a detailed description of the selectable layers is provided in Table 1.

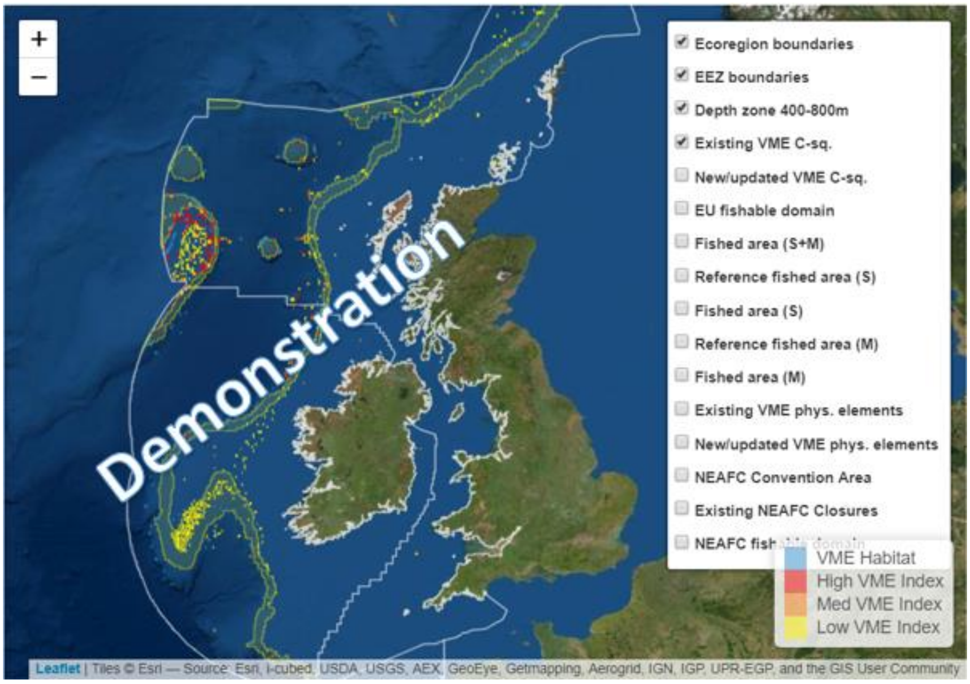

Figure 1: Scalable Map of VMEs included in the assessment output allowing user to toggle various layers to view existing VME closures and new and cumulative evidence of VME occurrences, fishing activity and VME physical elements

Table 1: Key/Description of selectable layers displayed in the scalable VME Map.

Selectable layer	Description
Ecoregion boundaries	ICES spatial unit that synthesise the evidence for the ecosystem approach.
EEZ boundaries	Exclusive Economic Zone. Area beyond and adjacent to the territorial sea, extending to a distance of no more than 200 nautical miles from the baselines from which the breadth of the territorial sea is measured. EEZs shapefiles used by ICES are sourced from the Flanders Marine Institute (2020).
Depth zone 400-800 m	Seafloor at 400 – 800 m depth.
Existing VME C-squares	Existing VME class of each c-square displayed as VME habitat (*bona fide* VME that represent unequivocal evidence for a VME occurrence), and High, Medium and Low VME Index scores, indicating the likelihood of encountering a VME in the assessed C-squares.
New/Updated VME C-squares	VME class in each C-square added or with an updated class based on latest VME data call, displayed as VME habitat (*bona fide* VME that represent unequivocal evidence for a VME occurrence), and High, Medium and Low VME Index scores, indicating the likelihood of encountering a VME in the assessed C-squares.
EU fishable domain	Area with presence of bottom gears within 400-800m depth between 2009-2011 (EU waters only).
Fished area (S+M)	Area with presence of bottom fishing in the latest 5 years by static and mobile gears (all depths > 200m).
Reference fished area (S)	Area with presence of static bottom fishing in 2009-2011 (all depths > 200m).
Fished area (S)	Area with presence of static bottom fishing in the latest 5 years (all depths > 200m).

Selectable layer	Description
Reference fished area (M)	Area with presence of mobile bottom fishing in 2009-2011 (all depths > 200m).
Fished area (M)	Area with presence of mobile bottom fishing in the latest 5 years (all depths > 200m).
Existing VME Physical Elements	Existing seabed topographic features (e.g. banks, coral mounds, seamounts).
New/Updated VME Physical Elements	Additional seabed topographic features (e.g., banks, coral mounds, seamounts) from new data sources or updated delineations of existing features.
NEAFC Convention Area	Area(s) within parts of the Atlantic and Arctic Oceans and their dependent seas covered by the NEAFC Convention.
Existing NEAFC Closures	Existing management areas restricting the use of bottom contact gears in areas with VME.
NEAFC fishable domain	NEAFC existing bottom fishing areas.

4.2 Assessment output Table 1 - summary table of new and cumulative VME evidence and fishing activity.

The first table in the assessment output contains a summary information table (Table 2) of the existing number of C-squares containing or likely to contain VMEs habitats at the time of the assessment (in this case 2018-2020) and the new and updated number C-squares resulting from the current assessment (in this case 2021). The overlap of the new/updated C-squares with the derived VME polygons is also shown.

Table 2: Example of Table 1 of the assessment output showing of the cumulative VME evidence for the period 2018 to 2020 and the overlap of new and updated VME polygons (2021 assessment) with the derived VME polygons. Note that VME physical elements can include seamounts, banks, coral mounds, mud volcanoes, cold seeps, hydrothermal vents steep slopes/flanks (>6.4 degree) and peaks, mid-ocean ridges, knolls and guyots, depending on the availability and accuracy of data.

	Number of VME/VME element c-squares									
	Total existing				New/updated in 2021					
	Assessed area	Areas fished between 2018-2020			Assessed area	In defined VME polygons				
	All	Mobile gears	Static gears	M + S gears	All	S1O1	S1O2	S2O1	S2O2	S1O2+S2O1
VME habitat										
200-400m	27	22	16	22	0	0	0	0	0	0
400-800m	77	78	69	84	24	0	0	3	2	3
>800m	87	14	16	23	17	0	0	0	0	0
VME index Medium and High										
200-400m	87	73	60	76	3	2	2	2	2	2
400-800m	74	58	60	63	[illegible]	0	0	0	0	0
>800m	73	20	10	22	5	0	0	0	0	0
VME index Low										
200-400m	113	113	108	[illegible]	7	0	0	0	0	0
400-800m	249	251	237	[illegible]	17	0	0	0	0	0
>800m	79	19	8	21	0	0	0	0	0	0
VME physical elements										
Seamounts	919	37	[illegible]	149	0	0	0	0	0	0
Banks	0	0	0	0	0	0	0	0	0	0
Coral mounds	205	60	45	72	0	0	0	0	0	0
Mud volcanoes	0	0	0	0	0	0	0	0	0	0

Table 3: Key/Description of the information contained in each column of Table 1 of the assessment output.

Row/Column	Description
VME habitat	The number of C-squares with VME habitat records across seafloor in 200 – 400, 400-800, >800m[2]
VME index Medium and High	The number of C-squares with VME index Medium and High records across seafloor in 200 – 400, 400-800, >800m[1]
VME index Low	The number of C-squares with VME index Low records across seafloor in 200 – 400, 400-800, >800m[1]
VME physical elements	Seamounts, Banks, Coral mounds, Mud volcanoes
Total number of C-squares within the assessed area (200 – 400, 400 – 800, >800 m)	This provides an indication of the size of the area, measured in terms of total number of C-squares at a scale of 0.05°
Total number of existing VME/ VME element C-squares. Within the assessed area.	This provides an indication of how much of the assessed area has been identified as supporting, or is likely to support, VME and VME indicator species, in terms of VME elements (seamounts, banks, coral mounds, and mud volcanoes), VME habitat, High, Medium and Low VME Index C-squares.
Number of new and updated VME/ VME element C-squares within the assessed area during the current assessment	This provides an indication of how much new area has been identified as supporting, or is likely to support, VME and VME indicator species, from the previous assessment (year), in terms of VME elements (seamounts, banks, coral mounds, and mud volcanoes), VME habitat, High, Medium and Low VME Index C-squares.
Number of new and updated VME/ VME elements C-squares in defined VME polygons (for each scenario – S1O1, S1O2, S2O1, S2O2) during the current assessment	This provides an indication of how much new area has been identified as supporting, or is likely to support, VME and VME indicator species, from the previous assessment (year), in terms of VME elements (seamounts, banks, coral mounds, and mud volcanoes), VME habitat, High, Medium and Low VME Index C-squares, under the different Scenarios assessed.
Total number of VME/ VME element C-squares. Within static gear fished areas between 2009 and the most recent year of data	This provides an indication of how much of the area identified as supporting, or is likely to support, VME and VME indicator species assessed in terms of VME elements (seamounts, banks, coral mounds, and mud volcanoes), VME habitat, High, Medium and Low VME Index C-squares fall within areas that have been actively fished by static gears (e.g. longline) since 2009
Total number of VME/ VME element C-squares within mobile gear fished areas between 2009 and the most recent year of data	This provides an indication of how much of the area identified as supporting, or is likely to support, VME and VME indicator species assessed in terms of VME elements (seamounts, banks, coral mounds, and mud volcanoes), VME habitat, High, Medium and Low VME Index C-squares fall within areas that have been actively fished by mobile bottom contact gears (e.g. trawls) since 2009.
Total number of VME/ VME element C-squares within static and mobile gear fished areas between 2009 and the most recent year of data	This provides an indication of how much of the area identified as supporting, or is likely to support, VME and VME indicator species assessed in terms of VME elements (seamounts, banks, coral mounds, and mud volcanoes), VME habitat, High, Medium and Low VME Index C-squares fall within areas that have been actively fished by all bottom contact gear types (e.g. trawls and longline) since 2009.

[2] The depths used correspond to known important transitions in the distribution of fishes and VMEs found in the Northeast Atlantic (Mangi et al., 2016), as such they have generic applicability and ecological relevance for the advice in addition to regulatory significance in EU waters.

4.3 Assessment output Figure 2 – Map of VME protection polygons

The second of the two scalable maps also contains 16 selectable layers shown in Figure 2 and a detailed description of the selectable layers is provided in Table 4.

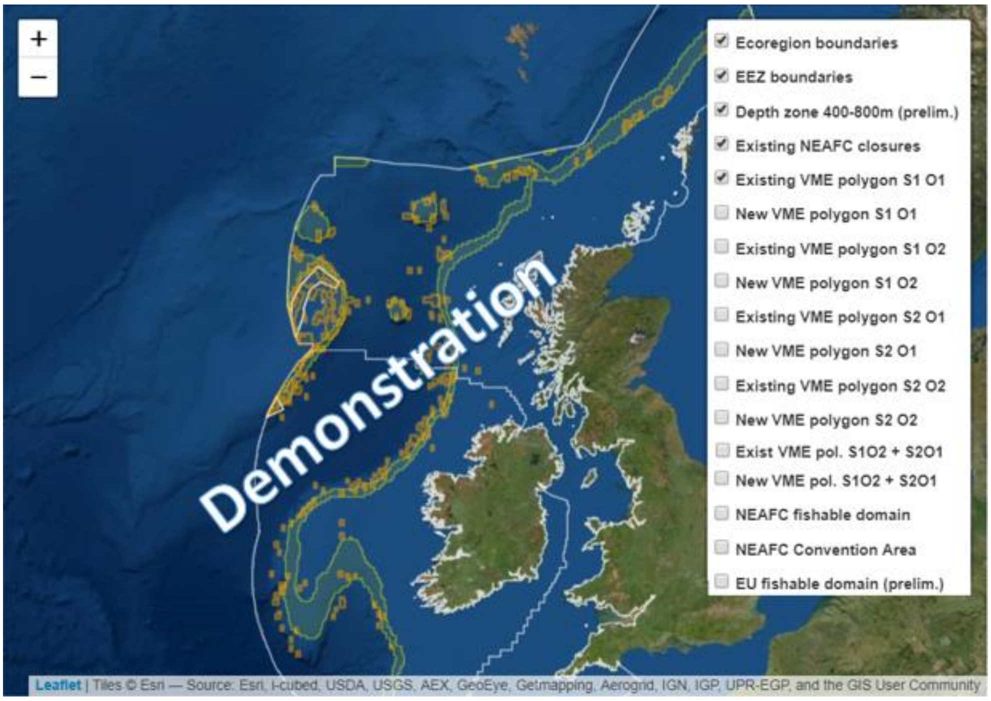

Figure 2: Scalable Map of VME protection polygons included in the assessment output allowing the user toggle various layers to view closures, and proposed closure options following the closure scenarios.

Table 4: Key/Description of selectable layers displayed in the scalable VME protection polygons Map.

Selectable layer	Description
Ecoregion boundaries	ICES spatial unit that synthesise the evidence for the ecosystem approach.
EEZ boundaries	Exclusive Economic Zone. Area beyond and adjacent to the territorial sea, extending to a distance of no more than 200 nautical miles from the baselines from which the breadth of the territorial sea is measured. . EEZs shapefiles used by ICES are sourced from the Flanders Marine Institute (2020).
Depth zone 400-800 m	Seafloor at 400 – 800 m depth.
Existing NEAFC Closures	Existing management areas restricting the use of bottom contact gears in areas with VME.
Existing VME polygons Scenario 1 Option 1	Existing polygons delineating continuous areas of VME (containing C-squares with VME habitats or a High and Medium VME Index).
New VME polygons Scenario 1 Option 1	Updated delineation of continuous areas of VME (containing C-squares with VME habitats or a High/Medium VME Index) based on the most recent VME data call.

Selectable layer	Description
Existing VME polygons Scenario 1 Option 2	Existing polygons delineating continuous areas of VME (Option 1 + selected VME elements associated with any VME records).
New VME polygons Scenario 1 Option 2	Updated delineation of continuous areas of VME (Option 1 + selected VME elements associated with any VME records).
Existing VME polygons Scenario 2 Option 1	Existing polygons delineating continuous areas of VME (containing C-squares with VME habitats or a High/Medium VME Index, or a Low VME Index if adjacent to higher index VMEs - and fishing pressure is low).
New VME polygons Scenario 2 Option 1	Updated delineation of continuous areas of VME (containing C-squares with VME habitats All VME habitats, or a High and/ Medium VME Index, or a. Low VME Index: only if adjacent to higher index VMEs and Low VME Index in C-squares with low and fishing pressure is low).
Existing VME polygons Scenario 2 Option 2	Existing polygons delineating continuous areas of VME (containing C-squares with VME habitats or a High/Medium/VME Index where fishing pressure is low).
New VME polygons Scenario 2 Option 2	Updated delineation of continuous areas of VME (containing C-squares with VME habitats or a High/Medium/VME Index where fishing pressure is low).
Existing VME polygons based on the combination of Scenario 1 Option 2 and Scenario 2 Option 1	Existing polygons delineating continuous areas of VME (containing C-squares with VME habitats as well as C-squares with medium and high VME indices and low VME index where fishing pressure is low, and C-squares that contain selected VME physical elements associated with any VME indicator species records).
New VME polygons based on the combination of Scenario 1 Option 2 and Scenario 2 Option 1	Updated delineation of continuous areas of VME (containing C-squares with VME habitats as well as C-squares with medium and high VME indices and low VME index where fishing pressure is low, and C-squares that contain selected VME physical elements associated with any VME indicator species records).
NEAFC fishable domain	NEAFC existing bottom fishing areas.
NEAFC Convention Area	Area(s) within parts of the Atlantic and Arctic Oceans and their dependent seas covered by the NEAFC Convention.
EU fishable domain	Area with presence of bottom gears between 2009-2011 within 400-800m depth (EU waters only).

The scalable Map of VME protection polygons contained in the assessment outputs will display the information on a VME polygon shown in Table 5 when hovering over the VME polygon.

Table 5: "Figure 2" scalable map feature popup that presents the below metadata when hovering over a VME polygon. The VME Habitats and Indicators reported in the popup feature are shown in Table 6.

Total area	Km^2
Average depth	m
Proportion fished (static)	%
Proportion fished (mobile)	%

ICES VME Habitats	Number of records	Number of c-sqrs with records

ICES VME Indicators	Number of records	Number of c-sqrs with records

Table 6: List of VME habitats and indicators accepted as entries into the ICES VME database (ICES, 2020c)

VME indicator
Anemones
Black coral
Cup coral
Chemosynthetic species (seeps and vents)
Gorgonian
Soft coral
Stalked crinoids (sea lilies)
Sponge
Sea-pen
Stylasterids
Stony coral
Xenophyophores
VME habitat
Anemone aggregations
Bryozoan patches
Cold-water coral reef
Coral garden
Cold seeps

VME indicator
Deep-sea sponge aggregations
Hydrothermal vents/fields
Mud and sand emergent fauna
Stalked crinoid aggregations
Sea-pen fields
Tube-dwelling anemone aggregations
Xenophyophore aggregations

4.4 Assessment output – Supplementary table at Annex A summary of the biology in the assessment area

A supplementary table at Annex A of the assessment output will provide a summary of the biology in the assessment area in terms of species groups (indicators and habitats) new and cumulative number of historic records, also per scenario and option, as shown in Table 7.

Table 7: Supplementary table in the Annex of the assessment output containing summarized information on the biology in the ecoregion/management area in terms of species groups (indicators and habitats) new and cumulative number of historic records, also per Scenario and Option.

VME species groups	Number of records
VME indicator	
Anemones	
Black coral	
Cup coral	
Chemosynthetic species (seeps and vents)	
Gorgonian	
Soft coral	
Stalked crinoids (sea lilies)	
Sponge	Total records in region new and historic. In addition presented per scenario and option (S1 – O1, S1 – O2, S2 – O1, S2 – O2, combined S1 – O2 + S2 – O1)
Sea-pen	
Stylasterids	
Stony coral	
Xenophyophores	
VME habitat	

VME species groups	Number of records
Anemone aggregations	
Bryozoan patches	
Cold-water coral reef	
Coral garden	
Cold seeps	
Deep-sea sponge aggregations	
Hydrothermal vents/fields	
Mud and sand emergent fauna	
Stalked crinoid aggregations	
Sea-pen fields	
Tube-dwelling anemone aggregations	
Xenophyophore aggregations	

4.5 Assessment output Table 2 – summary of scenario outcomes and associated risk to VMEs.

The second table in the assessment output contains a summary of scenario outcomes and associated risk to VMEs ecoregion/management area in assessment year (Table 8).

Table8: Content of Table 2 of the assessment output is a summary of scenario outcomes and associated risk to VMEs ecoregion/management area in (year). Table 9 provides a description of information contained in each column.

	Scenario 1 Option 1	**Scenario 1 Option 2**	**Scenario 2 Option 1**	**Scenario 2 Option 2**	**Scenario 1 Option 2 + Scenario 2 Option 1**
VME polygon description	All VME habitats, High and Medium VME Index. Low VME Index: only if adjacent to medium or high Index VMEs.	Option 1 + selected VME elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME records.	All VME habitats, High and Medium VME Index. Low VME Index: only if adjacent to higher index VMEs and Low VME Index in C-squares with low fishing pressure	All VME habitats, High, Medium and Low VME Index excluding C-squares with high fishing pressure (SAR > 0.43)	Scenario 2, Option 1 + selected VME elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME records.
VME polygon outcomes					
% of fishable domain identified as VME polygon	10.1	10	11.8	7.5	11.7
% of VME polygon protected by existing VME fishery closures	NA	NA	NA	NA	NA
Number of VME polygons and their average areal extent (size)	163 (188.8 km^2)	149 (289.8 km^2)	[illegible] (176.5 km^2)	185 (142.7 km^2)	185 (256 km^2)
Number (and average size) of large VME polygons in upper 25th percentile of the size distribution	2 (4804.7 km^2)	2 (6325.[illegible] km^2)	2 (4970.4 km^2)	10 (673.5 km^2)	2 (6408.7 km^2)
Risk to VME	NA	NA	NA	NA	NA
Fishery consequences					
% of [effort] per year by static gear (>200m depth) overlapping with VME polygons (average annual [effort] between 2018 to 2020)	NA	NA	NA	NA	NA
% of fished area (>200m depth) by static gear overlapping with VME polygons between 2018 to 2020	8.2	8.9	9.3	5.4	10
% of SAR by mobile gear (>200m depth) overlapping with VME polygons (average annual SAR between 2018 to 2020)	3.6	3.6	4.2	1.1	4.2
% of fished area (>200m depth) by mobile gear overlapping with VME polygons between 2018 to 2020	9	9.1	9.9	5.2	10

Table 9: Key/Description of information contained in each column of Table 2 of the assessment output.

VME polygon outcomes	
% of fishable domain identified as VME polygon	This provides an indication of the potential overlap of areas identified as VME polygon with the fishable domain.
% of VME polygon protected by existing VME fishery closures	This provides an indication of regulatory performance in protecting VMEs.
Number of VME polygons and their average areal extent (size)	This provides an indication of how the different Scenarios and Options perform in identifying and mapping VME polygons.
Number (and average size) of large VME polygons in upper 25th percentile of the size distribution	This provides an estimate of the individual size of the number and average size of the larger VME polygons under each Scenario and Option.
Risk to VME	"to be implemented"
Fishery consequences	
% of effort per year by static gear (>200m depth) overlapping with VME polygons (average annual effort for the three most recent years with data)	This provides an indication of the potential importance of areas identified as static gear fishing grounds within areas identified as VME polygon based on the percentage of effort that overlaps.
% of fished area (>200m depth) by static gear overlapping with VME polygons (for the three most recent years with data)	This provides an indication of the potential importance of areas identified as static gear fishing grounds within areas identified as VME polygon based on the percentage of area fished that overlaps.
% of SAR by mobile gear (>200m depth) overlapping with VME polygons (average annual SAR (for the three most recent years with data)	This provides an indication of the potential economic importance of areas identified as mobile gear fishing grounds within areas identified as VME polygon based on the percentage of effort that overlaps.
% of fished area (>200m depth) by mobile gear overlapping with VME polygons (for the three most recent years with data)	This provides an indication of the potential importance of areas identified as mobile gear fishing grounds within areas identified as VME polygon, based on the percentage of area fished that overlaps.

4.6 Description of data products released with VME advice

The self-contained HTML assessment files containing the outputs for both the assessment and are accompanied by data products containing:

- PDF maps representing the VME polygons for all scenarios and all options; the maps include the VME polygon ID number and the area defined as fishable domain;
- .csv, .xlsx and .shp files for all scenarios and all options; these files include the descriptions “VME_Csquare”, “VME_Habitat”, “VME_Indicator” and “VME_Elements” (see further information in Table 10).

Updates to the area defined as fishable domain (e.g. in EU waters new information might become available on the spatial distribution of static and mobile bottom gears between 2009-2011 within the 400-800m depth range), will be deliver as the coordinates of the combined static and mobile bottom fishing gear footprint, the static gear only footprint, and the mobile only footprint in .csv, .xlsx and .shp files and also as maps in PDF.

Table 10a: Key/Description of data product describing VME polygon .csv, .xlsx and .shp file column headers released with ICES advice.

Column header	Description
Poly_No	The unique polygon ID number that corresponds to the VME polygon in the pdf map
Coord_order	The unique coordinate number for each polygon number which can be used to connect the individual coordinates in each polygon.
Longitude	Longitude in decimal form according to the WGS84 coordinate system, the coordinates are rounded at 4 decimal places (note that the trailing zeros are removed in the csv file)
Latitude	Latitude in decimal form according to the WGS84 coordinate system, the coordinates are rounded at 4 decimal places (note that the trailing zeros are removed in the csv file)
Hole	TRUE/FALSE, if TRUE there is an inner hole in the VME polygon
Group	The unique grouping number for each VME polygon number. The number X_1 groups all coordinates that form the outer border of VME polygon X. Subsequent numbers (e.g. X_2) group coordinates that describe inner holes (if Hole is TRUE).
VME_C-square	Shows whether there is a VME habitat, High, Medium or Low VME Index C-square in the VME polygon. For example, VME_Low means that there is at least one VME habitat (written as VME) and one Low index C-square in the VME polygon.
VME_Habitat	Describes which unique VME habitats are in the VME polygon.
VME_Indicator	Describes which unique VME Indicator species are in the VME polygon.
VME_Elements	Describes which unique VME physical elements are in the VME polygon.

Table 10b: Key/Description of data product describing the fishable domain (fishing footprint) .csv, .xlsx and .shp file column headers released with ICES advice.

Column header	Description
Poly_No	The unique polygon number that corresponds to the footprint polygon in the pdf map
Coord_order	The unique coordinate number for each polygon number which can be used to connect the individual coordinates
Longitude	Longitude in decimal form according to the WGS84 coordinate system, the coordinates are rounded at 4 decimal places (note that the trailing zeros are removed in the csv file)
Latitude	Latitude in decimal form according to the WGS84 coordinate system, the coordinates are rounded at 4 decimal places (note that the trailing zeros are removed in the csv file)
Hole	TRUE/FALSE, if TRUE there is an inner hole in the polygon
Group	The unique grouping number for each polygon number. The number X_1 groups all coordinates that form the outer border of polygon X. Subsequent numbers group coordinates that describe the inner holes (if Hole is TRUE).

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Appendix 1 - Identifying VME Polygons that contain or are likely to contain VMEs.

Introduction

Paragraph 42 of the FAO Guidelines list five internationally agreed upon criteria for identifying VMEs. These are uniqueness, function, fragility, life-history traits and structural complexity and are used by ICES when identifying areas where VMEs are known or likely to occur.

Various depth limits have been used to define what constitutes deep-sea fisheries and ICES uses a depth of 200 m and deeper when issuing data calls for new data information on VMEs (ICES, 2021). ICES data calls for VMEs describe the scope, rational and legal framework for the call as well as the VME Database.

ICES uses a 0.05° C-square grid resolution for VME advice as the best pragmatic compromise between protecting the confidentiality of data with respect to the location of fishing activity of individual fishing vessels and collating and assessing data on the occurrence or likely occurrence VMEs.

ICES VME Data call.

Each year, a data call is sent to ICES member states requesting any new data on VMEs to be submitted to the ICES VME Database. The data call is issued to member countries through a single point of contact for each country; for EU countries these are the DCF contacts and for non-EU countries, the ICES ACOM members. The data submitter must have usage rights on the data that they submit to ICES.

As an international science organisation, ICES do not prescribe how national level data are managed. It is the responsibility of each point of contact that receives the data call to coordinate data submission at a national level, and ensure data are submitted to ICES correctly and by the deadline. To support data submission, good communication and collaboration is encouraged between VME experts who collect and hold data, and the national point of contact (DCF and/or ACOM member). Experts that collect and hold data are also encouraged to be members of the Joint ICES/NAFO Working Group on Deep-water Ecology (WGDEC) so that their close knowledge and understanding of the data is utilised.

When submitting data that have been collected during multinational research projects, the national data submitter is asked to confirm that there is a data agreement between the countries involved in the research project.

The data call provides a list of habitats and associated representative taxa "indicators", that are currently recognised as VME by ICES based on the five criteria defined by the FAO (2009):

1. Uniqueness or rarity
2. Functional significance of the habitat
3. Fragility
4. Life history traits of the component species that make recovery difficult
5. Structural complexity

VME data submissions to ICES can take three forms:

1. VMEs – records for which there is unequivocal evidence for a VME, e.g., ROV observations of a coral reef;
2. VME indicators - records that suggest the presence of a VME with varying degrees of uncertainty, e.g., bycatch of gorgonians (sea fans) from a fishing vessel;
3. Absence data – samples where neither a VME nor a VME indicator has been identified.

Specific considerations apply for the inclusion of absence data, as detailed in ICES (2017). Any questions or requests for support on data submissions can be sent to the ICES Data Centre (data.call@ices.dk).

VME Database Quality Control

All data submitted to the ICES VME Database are subject to quality control (QC) standards via the ICES Data Centre and WGDEC. A data flow illustrating the quality control process for VME data submission is shown in Figure 6.1.

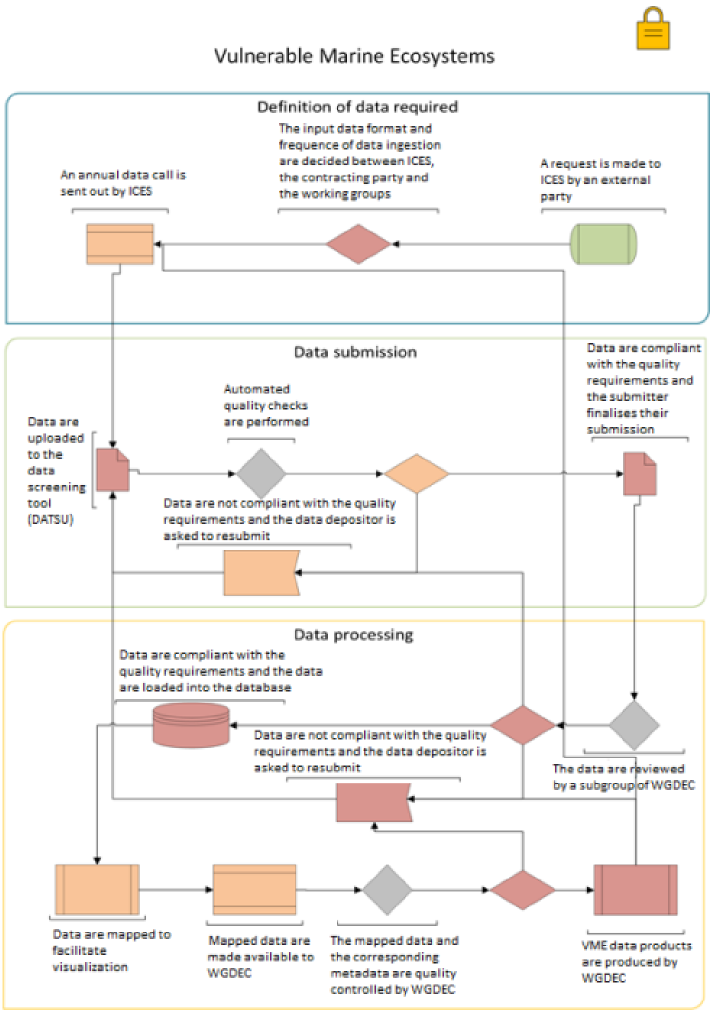

Figure 6.1 ICES VME data flow schematic. Please note that the above ICES VME

Following the VME data call, data are uploaded to the Data Screening Utility (DATSU) developed by the ICES Data Centre. This tool runs a series of automated QC checks which flag initial problems to the data provider that need addressing before the data can be formally accepted to the database, for example, warnings of coordinates being located on land, or species linked to incorrect VME indicator types. Support is available via the ICES Data Centre for any queries over these errors.

Once the data are compliant with these initial QC checks, the data are then reviewed by a subgroup of WGDEC. If any issues are noted during this stage, these are addressed with the data supplier, and if not, the data are uploaded into the VME database. Data are then put into draft maps to be reviewed during the WGDEC meeting for sign off. Again, any issues noted during this stage are addressed with the data supplier and a request made for data re-submission if needed.

The VME Index

The method currently in use for deriving the VME Index is described below, but the reader's attention is directed to known issues and the future work planned to improve the index, see sections 3.1, 4.1 and 4.6 of the WKVMEBM Report (ICES, 2022).

Records of the occurrence of actual VMEs submitted to ICES are, following the quality checks described above, automatically assigned to a 'VME habitat' category and uploaded to the ICES VME database.

Records of VME indicators suggesting the likelihood of the occurrence of a VME habitat are, following the quality checks described above, processed by WGDEC through the ICES multi-criteria assessment system so as to make best use of these valuable data, whilst acknowledging their limitations. This assessment follows a series of transparent steps to establish a VME likelihood score and a confidence score to indicate the likelihood of a C-square containing a VME. The index combines two sources of information:

1. A ranked VME indicator 'vulnerability score', based on expert knowledge of each indicator species considered against the five FAO criteria for VMEs (FAO, 2009);
2. Available data on the abundance (weight) of VME indicator species records, where provided in the database.

The VME Index combines these two parameters and scores overall VME likelihood as either high, medium or low. The index was created on a 0.05° C-square grid resolution. Cumulative information on VME occurrence within each cell is used to rank and iteratively update the likelihood of VME occurrence.

Once a VME indicator record has been process by WGDEC, the record is assigned a VME Index score and uploaded to the ICES VME database. Maps of the VME Index are provided in the WGDEC reports for all areas where new VME data has been submitted through the annual ICES VME data call.

Method for calculating the 'VME Index' for VME indicator records reported to ICES

The VME weighting algorithm produces an index that can be interpreted as the likelihood of an area containing an actual VME. C-square cells are scored as 'high', 'medium' or 'low' likelihood.

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

Step 1a-Applying a VME vulnerability score

Using the expert judgement of the WGDEC 2015 attendees (ICES 2016), the records uploaded to the VME database are ranked according to vulnerability, as detailed within the FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO, 2009)

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

5. Structural complexity: if the indicator is a) frame-building and creates structural habitat; b) has commensal or closely associated species.

Each VME indicator is assigned a score from 1 (low) to 5 (high) against these five criteria. These scores are then averaged across the five criteria to produce a final VME vulnerability score (Table 6.1).

Table 6.1: Ranking of each of the VME indicators according to the FAO criteria for VMEs (FAO, 2009).

	FAO habitat criteria					
VME indicator	Uniqueness/ Rarity	Functional	Fragility	Life History	Structural complexity	VME Indicator score
Stony coral	3	4	5	5	5	4.47
Black coral	5	2	4	5	2.5	3.91
Large Sponge	2	5	4	4	3	3.74
Chemosynthetic spp. (seeps and vents)	5	5	1	4	3	3.90
Gorgonian	4	3	3	5	2.5	3.61
Xenophy-ophores	2	3	5	2	2	3.03
Stylasterids	4	1	4	2.5	2	2.94
Sponge	2	3	3	3	2	2.65
Seapen	2	3	3	2	2	2.45
Stalked crinoids	4	1	2	4	1	2.76
Cup coral	2	1	2	4	1	2.28
Soft coral	1	1	2	2	2	1.67
Anemones	1	1	2	2	1	1.48

To distinguish between the fact that sponges could be comprised of large, aggregation forming sponges such as *Asconema*, *Geodia* and *Pheronema*, or could be made up of smaller encrusting species such as *Alpsylla sulphuria*, which would likely have different vulnerability scores, two categories of sponge are included in the scoring process, 'Large sponge' and 'Sponge' respectively. These VME indicator scores are automatically assigned to the VME indicator records within the VME database when the weighting algorithm is run.

Step 1b-VME abundance score.

For each record in the database, the abundance (weight), where recorded, is evaluated against the VME commercial fishing encounter thresholds for corals (30 kg) and half the encounter thresholds for sponges (200 kg), which are used as upper threshold values. Intermediate encounter thresholds, 1 kg (for coral) and 60 kg (for sponges) are also used (Morato et al. 2018). As there are no agreed thresholds for VME indicators such as gorgonians, black corals or sea pens, the same value for corals (30 kg) is used. The upper threshold values are almost certainly too high a threshold for such VME indicators, but without agreed thresholds, this was considered the most appropriate option (ICES, 2015).

Scores are assigned to each VME indicator record based on whether the abundance is above the upper threshold (5) above the intermediate threshold, but below the upper threshold (3), or if no data on abundance is available (1) (Table 6.2).

Table 6.2 VME abundance scores

	VME abundance score		
VME Indicator	5	3	1
Stony coral	>= 30 kg	< 1 kg	No data
Sponge	>= 200 kg	< 60 kg	No data
Black coral	>= 30 kg	< 1 kg	No data
Gorgonian	>= 30 kg	< 1 kg	No data
Lace coral	>= 30 kg	< 1 kg	No data
Sea pen	>= 30 kg	< 1 kg	No data
Cup coral	>= 30 kg	< 1 kg	No data
Soft coral	>= 30 kg	< 1 kg	No data
Hydroid	>= 30 kg	< 1 kg	No data

Step 1c-VME index score

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

$$\textit{VME index} = \textit{VME vulnerability score} * 0.9 + \textit{abundance score} * 0.1.$$

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

Step 1d-VME habitats

Records of VME habitat showing presence of actual VME submitted to ICES are added as 'VME habitat' in the VME database and assigned the maximum values when the weighting algorithm is run.

Step 1e-Mapping the VME index and VME habitats

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

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

- Low VME index, for total scores <2.64;
- Medium VME index, for total scores between 2.64 and 3.74;
- High VME index, for total scores >3.74.

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

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

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

Step 2 Combining information on the location of known VME habitats, the VME Index and expert judgement to identify C-squares where VMEs occur or are likely to occur.

Figure 6.2: outlines the process used by ICES when identifying C-squares that contain VME habitats or are likely to contain VMEs. VME habitats and VME index data are considered together in a Geographic Information System (GIS) alongside other data layers including bathymetry (depth data). Any new information which suggests changes to existing boundaries around known sensitive areas will also be closely studied.

When providing advice on VMEs, records of VME habitat are considered as areas where VME are known to occur, while areas identified with the VME Index are areas where VMEs are likely to occur. Grid cells with VME habitats and those with a VME Index are considered and mapped according to the management measures outlined in Table 6.1.

VME Elements are topographic features referred to in the UNGA resolutions and supporting FAO guidelines, as areas that are likely to contain VMEs based on inference from global data on VME occurrence. When VME elements can be identified from bathymetry data (such as a bank, seamount or knoll), then this will also be considered in ICES advice. Where VME Elements occur without associated data on VME presence the entire element may be considered as an area where VMEs are likely to occur. Such areas may be very large and be un- or poorly-supported by other data, but meet the intent of the UNGA resolutions. ICES has provided the option of including such information in the decision-making process, but has limited inclusion to those VME Elements which could be defined with sufficient resolution to ensure their spatial accuracy and where they are associated with at least one VME record (Table 6.2).

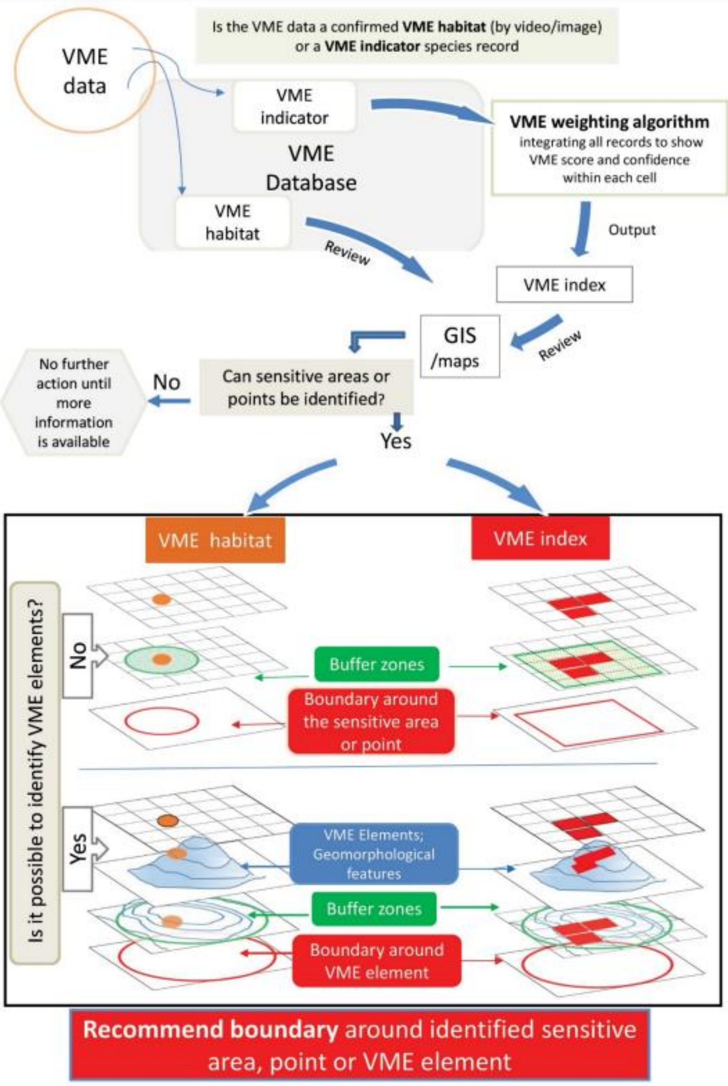

Figure 6.2: Process used by ICES when identifying C-squares that contain VME habitats or are likely to contain VMEs.

Caveats and Limitations of the VME Index

Although the VME Index has been used since 2018 in ICES advice, it is recognised that there are a number of improvements that could be made to support its use for ICES moving forward, for example those detailed by WGDEC in 2018 (ICES, 2018, Section 7.3).

Firstly, the VME Index is based on a mix of information on the presence of VME indicator groups, the characteristics of these species, and measures of their abundance, and it is hard to disentangle how each of these contributes to the index when using the final C-square gridded outputs. This means that it is difficult to infer what an index value within a specific location is likely to represent. This is relevant because clarity about the nature of the indicator ('concreteness') is vital for acceptance of outcomes by managers and stakeholders (Rice and Rochet, 2005), and for the appropriate use by scientists.

Secondly, the characteristics of the VME indicator groups are used to assign a value to different VME indicators in the index, scoring how 'well' the indicator meets the VME designation criteria (FAO, 2009). However, the process of deciding what a VME is has been carried out elsewhere and a list of what constitutes a VME already exists, so there may be no need to value different types of VMEs again in this index. 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. Therefore, other methods of detecting whether a VME indicator may represent a VME habitat should be explored.

Thirdly, the way in which abundance feeds into the index down-weights the importance of some VME types, such as sea pens, and gives unduly weight to others, such as stony corals. As it stands, sea pens can never attain the status of 'High VME Index' and even when bycatch totals more than 30 kg of sea pens (which represents 1000-100000s of sea pens), they only reach the threshold to be considered as 'Medium VME Index'. At the other extreme, any amount of stony coral causes a designation as High VME Index. As a result, the index risks becoming an index of perceived vulnerability rather than likelihood of occurrence. This could be improved on by reviewing the VME weight thresholds used for particular VME indicators, as proposed by WGDEC in 2018 (ICES, 2018, section 7.3.2).

Additional methods being considered by ICES for incorporation into ICES VME advice.

VME elements are defined in the FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO, 2009) as topographical, hydrophysical or geological features, including fragile geological structures, that potentially support VMEs. They have been used in the provision of advice on VMEs by ICES. Elements include:

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

Whilst confirmed records of VMEs and VME indicators are readily available from the ICES VME Database, and mapped by ICES, the location of VME elements is less certain. These data are, however, obtainable from existing maps and modelled data using, for example, multibeam bathymetry datasets.

Full details on the method used to map the VME elements are reported in the WGMHM, 2020 report (ICES, 2020). However, they are briefly summarised here.

Existing definitions were reviewed and working definitions for the analysis were applied for five VME elements:

3. Isolated seamounts
4. Steep-slopes and peaks on mid-ocean ridges
5. Knolls
6. Canyons
7. Steep flanks > 6.4°
8. Hydrothermal vents

In addition, WGMHM identified 3 other geomorphological features which could be considered as VME elements, namely:

1. Guyots (isolated or groups of seamounts with a smooth, flat top);
2. Escarpments (elongated, linear, steep slopes separating gently sloping sectors of the seafloor in non-shelf areas); and

3. Glacial troughs (elongated troughs formed by shelf valleys at high latitudes incised by glacial erosion during the Pleistocene).

To map the VME elements, WGMHM mainly used the Grid Arendal Global Geomorphological maps provided by Harris et al. (2014), available as vector files from the Blue Habitats website2. "Flanks" and "Steep slopes on ridges" were generated using the 2019 General Bathymetric Chart of the Oceans (GEBCO) bathymetric dataset. Slope was derived from the bathymetry data and a prescribed threshold of 6.4° was used to extract steep slope areas. For hydrothermal vents, point data was extracted from the InterRidge database for active submarine hydrothermal vent fields. These were buffered with a radius of 500 m. The final data outputs were clipped to the ICES Ecoregions, with a 10 km buffer included to ensure features on the ecoregion boundaries were included.

ICES identified the EMODnet seafloor geology as an additional source of information on VME elements. The EMODnet seafloor geology is publicly available and provides georeferenced geological and biogenic structures such as banks, coral mounds, mud volcanoes and seamounts at a higher spatial resolution than other global sources of information such as those utilized by WGMHM. Given that this dataset addresses many of the concerns raised by WGMHM, EMODnet seafloor geology data are also used to identify VME elements in this report. In particular the VME element 'banks' was an important feature in linking VME data records in the Bay of Biscay and Iberian Coast ecoregion.

ICES recommended that the distribution of elements is regularly updated when elements are more clearly defined, and as better data sources become available. It was found during the analysis that the calculation of slope was highly dependent on the resolution of the bathymetric grid selected, and that the underlying data type (whether modelled/remotely sensed from satellites or observed by single-beam and multibeam echosounders), and hence quality, influenced the calculation of slope. Therefore, the reliance on slope, and thresholds of slope angles, for defining some elements is considered a significant weakness, unless the method for deriving estimates of slope is carefully stated when used.

Species distribution models (SDMs) can also be used to provide an evaluation of whether a VME or VME indicator is `likely to occur', and have been used for such advice in NAFO and in Canada in the North Atlantic (NAFO, 2019; Kenchington et al., 2016). There, the SDMs are used to refine the distribution the VMEs within the larger VME polygons (NAFO, 2019) and to estimate the probability of occurrence of the VME between data points. These models use a range of environmental predictors, including oceanographic and topographic variables, to approximate distribution of particular VME species (e.g., cold-water corals, sponges) based on species' abiotic preferences. These models can be verified with independent ground truthing data where available. A number of SDM models have been published for different VME indicators in the northeast Atlantic. And while ICES has yet to establish how they will be used in the advice (e.g. identifying areas that require further survey effort, or used to make fragmented closures arising from patchy sampling more contiguous) or standards for accepting these models into the advisory stream, the process towards incorporating SDMs into ICES advice is underway (ICES, 2021).

Additional sources of data on VMEs: it is recognised that other sources of data on the occurrence of VME exist for the northeast Atlantic. For example, the *OSPAR list of threatened and/or declining species and habitats* features habitats that qualify as VME or VME elements: *Lophelia pertusa* reefs, seamounts, deep-sea sponge aggregations, coral gardens, oceanic ridges with hydrothermal vents, carbonate mounds, and sea pen and burrowing megafauna. And while some preliminary work on the incorporation of these data in the ICES VME database has been undertaken previously, it was agreed that it would not be possible to complete this work during WKVMEBM 2022. Instead, a consolidation and review of the previous work along with identification of development needs and the mechanisms to achieve this would be best addressed as a specific term of reference in future WGDEC meetings.

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Appendix 2 - Identifying fishing activities with the potential to have significant adverse impacts on VMEs.

Introduction

The spatial distribution of fishing activities is estimated for MBCGs (bottom otter trawls, bottom seines, dredges, and beam trawls) and static bottom-contacting gears (pots and traps, gillnets, and longlines). MBCG has a far greater impact on VMEs when compared to static gear. Based on data currently available, it is possible to determine the presence or absence of fishing activity within a C-square for mid-water trawls and static gears; however, for MBCG, in addition to presence or absence, fishing intensity can be quantified as the area swept per unit area, or "swept-area ratio" (SAR). Swept area is calculated as hours fished × average fishing speed × gear width. The gear width, expressed as surface and subsurface bottom contact, is estimated based on relationships between average gear widths and average vessel length or engine power (kW), as stated in Eigaard et al. (2015) and using ICES expert input. SAR is the proportion of the seabed surface area which is contacted (swept) the MBCG in relation to the total seabed surface area of the C-square. SAR is used by ICES to estimate the intensity of MBCG pressure on VMEs and, when closures are advised, it can also be used to map the consequence of closures on MBCG fishing activity. For mid-water trawls and static gears, a SAR equivalent is not available at the present and therefore the fishing intensity for these gears cannot be assessed.

Until methods to reliably quantify the intensity of static gear and mid-water trawls that have the potential to contact the sea floor during the course of fishing operations, ICES advice on VMEs does not consider these gear types when establishing the potential for VMEs to already have been damaged and where further fishing would not cause further significant adverse impacts (SAI). Fishing depth is not recorded in ICES or NEAFC VMS data therefore whether or not fishing activity was bottom contacting is unknown. Management measures for these gears can be established but for the moment can only be based on presence and absence and not on intensity or the potential for past or future significant adverse impacts.

The FAO guidelines do not address depth when considering the interaction between fishing activities and VMEs. The FAO guidelines characterise deep-sea fisheries as those in which the total catch includes species that can only sustain low exploitation rates and where the gear is likely to contact the sea floor during the course of fishing. It also does not touch on the technical issues that may prevent fishing mobile gears in deep waters, it may be useful to get input from gear specialists on whether practical lower limits of activities can be defined.

Various depth limits have been used to define what constitutes deep-sea fisheries and ICES uses a depth of 200 m and deeper when issuing data calls for new data on VMEs (ICES, 2021a). ICES data calls for VMEs describes the scope, rational and legal framework for the call and how the data will be used by ICES.

Data collection, through ICES data calls, is the preferred option for ICES when preparing advice on VMEs and is used when providing advice to the EU, see section 2.1. When providing advice to NEAFC, ICES received VMS data annually from NEAFC, see section 2.6.

VMS and logbook/catch data.

VMS data is received from two sources the International **ICES VMS/Logbook Data Call** and **NEAFC VMS/Catch**. The Vessel Monitoring System (VMS) is the principal satellite systems used by commercial fishing vessels to provide information on their location, course and speed. While this data is primarily collected for monitoring control and surveillance purposes, they are also a vital source of information for scientific purposes.. VMS data is coupled with the logbook or catch data to gain information on the details of fishing activity e.g. gear type and target species.

New data collection systems that provide reliable vessel positional data will be used by ICES as they become available in the future.

International ICES VMS/Logbook Data Call.

International VMS linked logbook data are received by ICES in response to ICES VMS/logbook data call (ICES, 2021b) as part of the EU Data Collection Framework (DCF) to ICES member countries. National fisheries authorities collect and collate these data following ICES standardized guidelines established by members of the ICES WGSFD (ICES. 2019. Working Group on Spatial Fisheries Data) which are quality controlled before being accepted into the ICES VMS database. The data submitted by each country is afterwards aggregated at the ICES data Centre to produce a unique data product including international fishing activity indicators. This international fishing activity product is quality controlled by members of ICES WGSFD, see Figure 7.2. and the scripts and functions used to calculate SAR from VMS data developed and used by ICES are available at https://github.com/ices-tools-dev/sfdSARThe VMS database is used by ICES to prepare ICES products, in this case SAR, for use in ICES assessments and advice, Fig. 7.1.

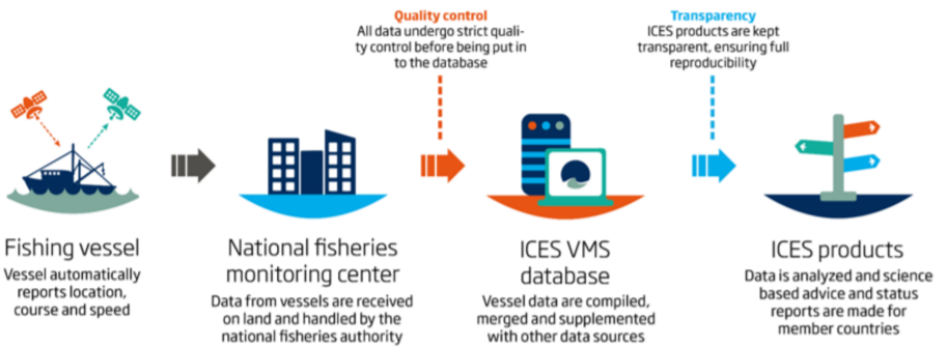


Figure 7.1: How VMS and logbook data is collected, stored and used by ICES to develop SAR values for use in VME advice.

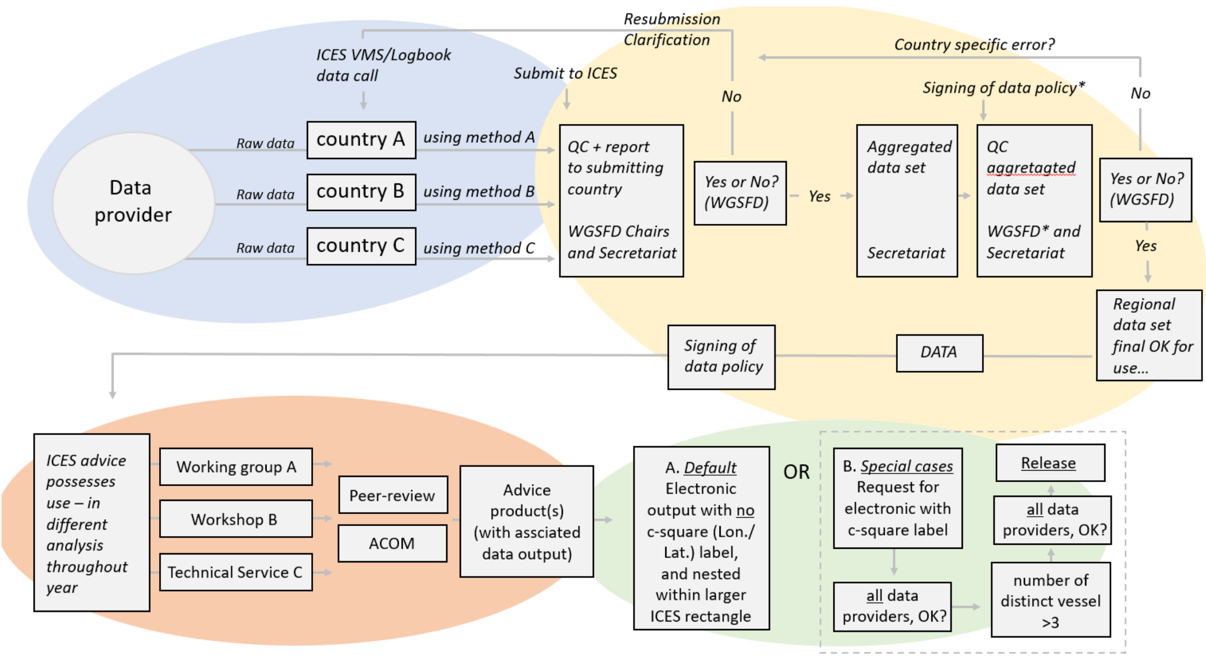


Figure 7.2: Detailed description of the ICES VMS data collection, quality control and product delivery.

Current EU control regulation establish that vessels greater than 12 meters are obliged to send their VMS data, so-called "pings", at least every 2 hours (the ping rate varies for some countries, fisheries, fleets or vessels, and can change over time). VMS pings are linked to electronic logbook data in order to get additional information about the vessel flag country, gear used (equivalent to Data Collection Framework (DCF) metier level 4), fishing metier (DCF level 6), vessel length and engine power, departure and landing ports, and the weight and value of the species captured by fishing trip.

ICES VMS data Methods

ICES VMS data are cleaned to remove errors occurring when receiving or sending data from the VMS GPS units to the database. Common errors including duplicate records, points that can't be possible, pseudo duplicates with short interval rates, points in harbour and points on land are removed.

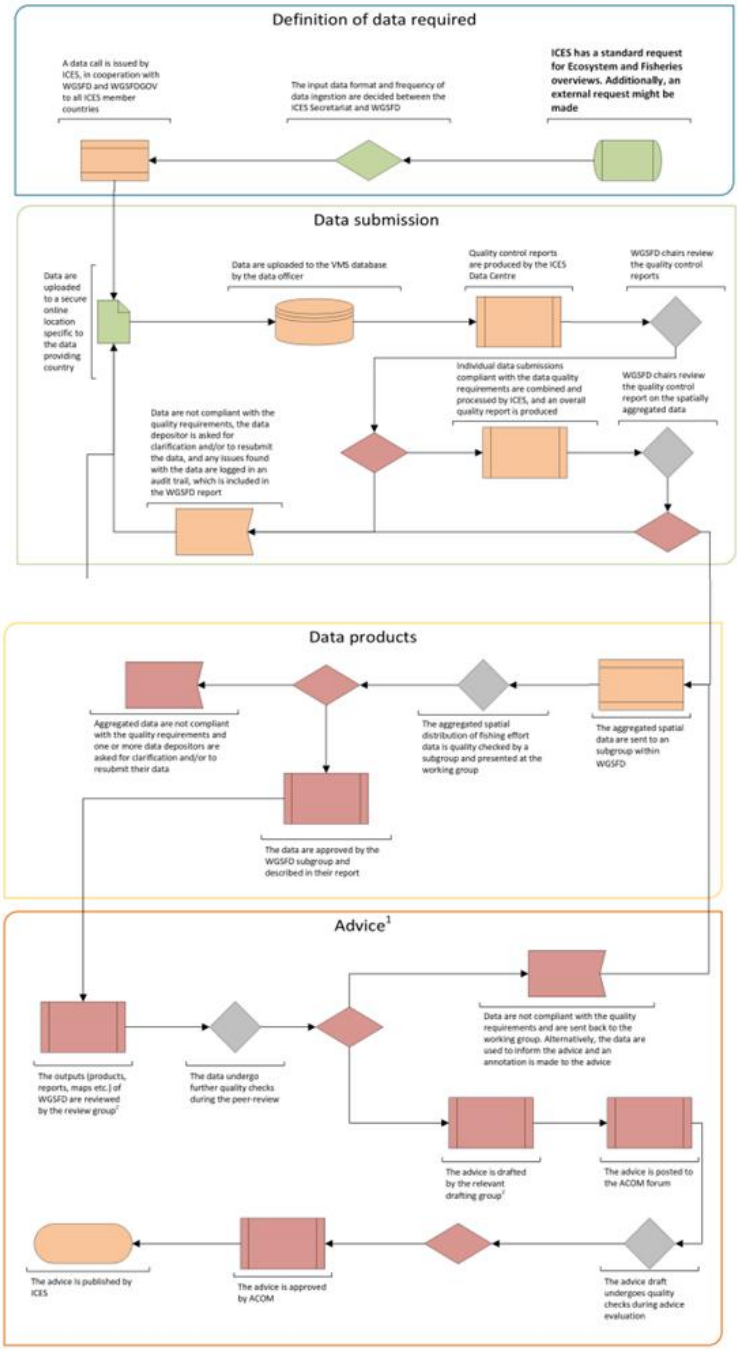
Logbook data are cleaned to warn of or remove outlying catch records, non-unique trip identifiers, impossible time stamps, trips starting in the previous calendar year, trips overlapping and trips with arrival dates prior to departure dates.

VMS and logbook data are merged together using algorithms based on vessel identifier and data and time to relate the landings component to the vessel activity.

Fishing events from the VMS data are inferred from vessel speed profiles for each of the gears, under the assumption that VMS polls recorded at slower speeds represent fishing. Records are assigned to year, month, quarter, and area and c-square a C-square grid cell which is 0.05 x 0.05 degrees grid, about 15 km² (3km x 5km) at 60°N latitude, using the C-square approach (Rees, 2003). Only VMS locations identified as fishing events are aggregated at C-square level. to).

The vessel speed provided with the VMS data is used to differentiate whether the vessel is fishing or steaming based on activity pattern, by gear. This approach is more accurate when used to identify mobile gears fishing events, since the current 2-hour VMS ping resolution is not sufficient to identify the different activities related to static gears (hauling, setting gear, etc.). The static gears indicators given in the data product derived from the VMS data call are not yet reliable and there are ongoing studies aiming to improve these indicators (ICES. 2019. Working Group on Spatial Fisheries Data (WGSFD) - ToR C: Development of spatial effort indicators for static gears, ICES. 2022. Workshop on Geo-Spatial Data for Small-Scale Fisheries).

Figure 7.3 shows how the highly detailed VMS/logbook data on vessel positions, activity, and commercial catches gathered by the fishing industry which is shared with the fisheries control agencies in ICES member countries in the North East Atlantic (ICES, 2021c) flows into the ICES data management and advice systems.



Definition of data required
A data call is issued by ICES, in cooperation with WGSFD and WGSFDGOV to all ICES member countries
The input data format and frequency of data ingestion are decided between the ICES Secretariat and WGSFD
ICES has a standard request for Ecosystem and Fisheries overviews. Additionally, an external request might be made
Data submission
Data are uploaded to a secure online location specific to the data providing country
Data are uploaded to the VMS database by the data officer
Quality control reports are produced by the ICES Data Centre
WGSFD chairs review the quality control reports
Individual data submissions compliant with the data quality requirements are combined and processed by ICES, and an overall quality report is produced
WGSFD chairs review the quality control report on the spatially aggregated data
Data are not compliant with the quality requirements, the data depositor is asked for clarification and/or to resubmit the data, and any issues found with the data are logged in an audit trail, which is included in the WGSFD report
Data products
Aggregated data are not compliant with the quality requirements and one or more data depositors are asked for clarification and/or to resubmit their data
The aggregated spatial distribution of fishing effort data is quality checked by a subgroup and presented at the working group
The aggregated spatial data are sent to an subgroup within WGSFD
The data are approved by the WGSFD subgroup and described in their report
Advice1
Data are not compliant with the quality requirements and are sent back to the working group. Alternatively, the data are used to inform the advice and an annotation is made to the advice
The outputs (products, reports, maps etc.) of WGSFD are reviewed by the review group2
The data undergo further quality checks during the peer-review
The advice is drafted by the relevant drafting group2
The advice is posted to the ACOM forum
The advice is published by ICES
The advice is approved by ACOM
The advice draft undergoes quality checks during advice evaluation

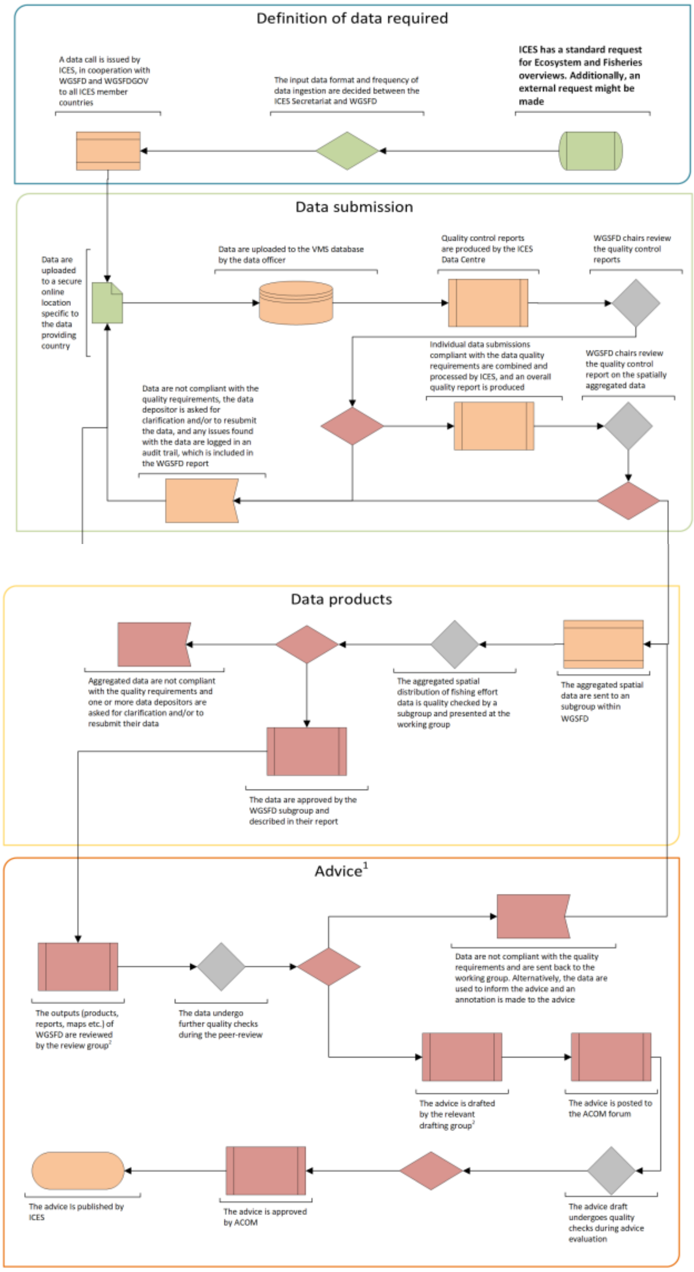


Figure 7.3: Data flow schematic of the ICES data management systems for VMS and logbook data used in ICES VME advice.

NEAFC VMS Data

VMS and catch data from the NEAFC Regulatory Area are also received by ICES from NEAFC, along with authorisation details, and vessel information from the NEAFC fleet registered, under the ICES-NEAFC memorandum of understanding and NEAFC's Recommendations to Provide VMS and Catch Data to ICES for Scientific Purposes. This source of data has been used by WGSFD for the VMS analysis presented over several years in conjunction with WGDEC of fishing activities in and around deep-water VME's (Figure 7.4).

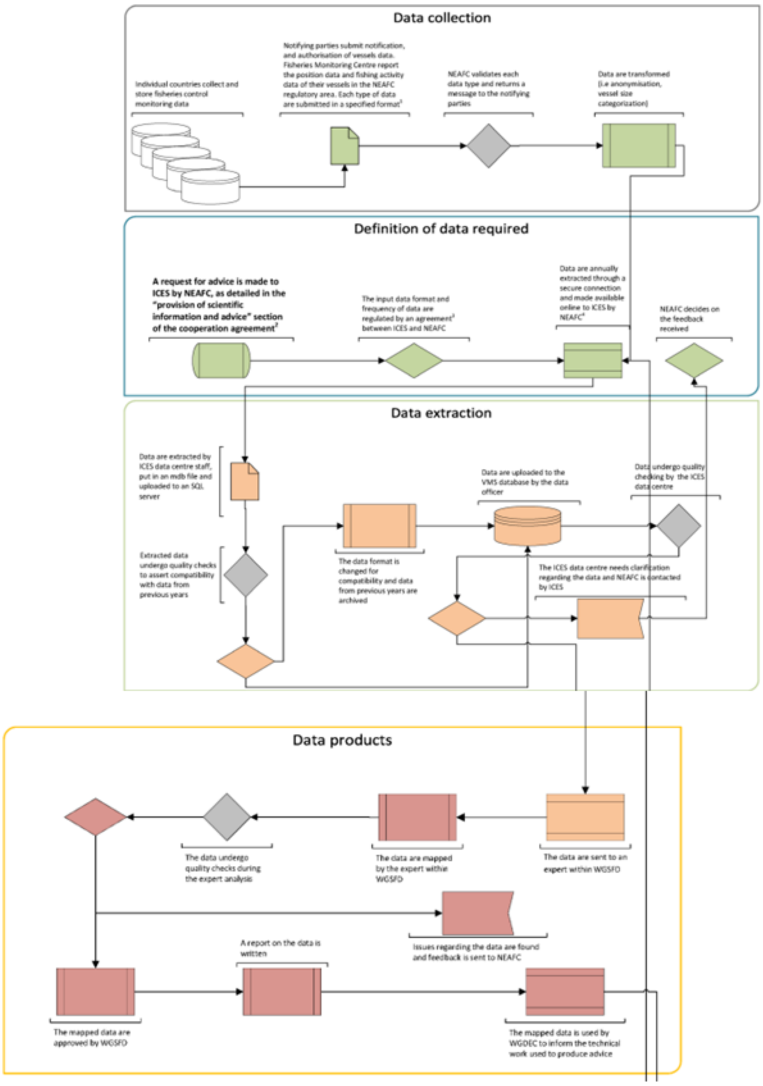


Figure 7.4: Data flow into the ICES data management system and expert group originating from the North East Atlantic Fisheries Commission (NEAFC) control regulation for its contracting parties

NEAFC VMS data Methods

The data provided by NEAFC to ICES consists of four files (Vessels, Catch Data, VMS and Authorisations) linked by a common anonymised vessel identifier field. The VMS data file from NEACF are filtered in R to select the relevant time period for assessment and to exclude all duplicate reports 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 is 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.

Further quality control checks are made on the NEAFC VMS data. For example, examination of the speed field of the VMS data can show issues with the quality of speed data. The "estimated speed" and "vessel speed" columns have previously contained no values, and whilst the "SP" field may contain numeric values, they have previously ranged from zero to 500, suggesting a problem with decimal places, but not in a consistent manner across the dataset. As a means of avoiding this problem, a derived speed was 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. A suitable speed threshold can then be chosen to demarcate fishing from non-fishing pings for all gears, which can be then be visually checked to assess its appropriateness (Figure 7.5).

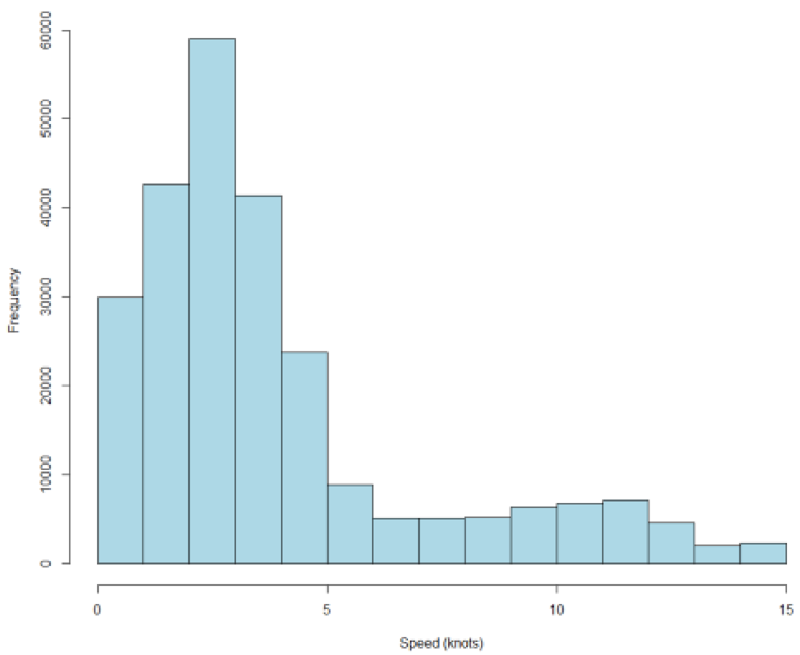


Figure 7.5 Histogram of derived speeds for all gears, based on position and time, conforms to expected distribution. (a speed of 5 knots and lower has been used in this particular example to demarcate fishing from non-fishing activities).

The speed filtered pings (0–5 knots) are presented to WGDEC in the form of a raster grid (of fishing intensity as hours fished) and individual tow tracks, consecutive pings at fishing speeds grouped into putative "tows" and as a set of points data, to give a range of options for display purposes. These were provided for vessels registered as using mobile bottom contact gears (otter trawl – OTB and shrimp trawl - TBS), static gear (gear codes "LL" and "LLS"), and for vessels for which no gear code was available ("NIL"). For example, during 2021 37% of vessels had no gear assignment and 8% of VMS data were from vessels with no registered gear (ref Workshop report ICES, 2022).

Whilst the NEAFC data are quality checked for a number of errors common to VMS data (i.e. removal of duplicate records or high interval values etc.), there are fundamental differences between the quality in terms of data field completeness between the NEAFC data and ICES data call data. This has ramifications for applying the approaches used to estimate SAR for ICES VMS/logbook data to NEAFC VMS data. The current limitations to obtaining a SAR value for NEAFC VMS data are described in detail in the workshop report. NEAFC and the ICES secretariat have been working to resolve these issues. Further work is required to retrieve or estimate the parameters needed to calculate the swept are ratio. The ICES WGSFD has an ongoing term of reference (ToR F) to provide a narrative on how NEAFC VMS data could be improved to facilitate subsequent analysis of fishing activity to provide more detailed analysis by gear types, vessel sizes and operational methods (passive and active). It will also do a comparison of NEAFC VMS with products of the ICES VMS/logbook data call for the same spatial extent.

Whilst the NEAFC VMS and catch data is useful for highlighting the distribution of fishing activity in a relative sense due to the uncertainty resulting from the caveats with the NEAFC data a calculated SAR for this data is not included in this benchmark at this point. However, the existing raster grid data products of hours fished can be used to contextualise the results of the benchmarking scenarios but not for the provision of advice. As described above WGSFD and the NEAFC secretariat will work to progress this for review at a future benchmark or inter-benchmark.

References

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Annex 7: Demonstration: Generic ecoregion-specific assessment (Celtic Sea)

Demonstration of an ecoregion-specific assessment. The demonstration is done for the Celtic Seas Ecoregion. The latest outputs can be downloaded from https://github.com/ices-taf/VME-Advice.

The current outputs are purely for demonstration purposes and should not be used for anything else. Each page shows one tab of the developed HTML for the Celtic Seas

Overview

Vulnerable marine ecosystem assessment

ICES

April 2022

Available evidence on the occurrence of Vulnerable marine ecosystems (VMEs), fishing activity in relation to VMEs, and spatial management options to minimise the risk from fishing activities to VMEs

Celtic Seas | Bay of Biscay and the Iberian Coast | Greater North Sea | Azores | Icelandic Waters

Overview | New VME data | VME polygon options | Interpretation of results | Read me | Sources and references

For the purpose of this assessment, evidence of VME occurrence is aggregated at the scale of individual 0.05 x 0.05 degrees C-square cells (hereafter termed C-square) where VME habitats or indicator taxa are assumed to be homogeneously distributed. Similarly, fishing effort information is aggregated at the scale of C-squares.

The VME polygon methodology is described in the ACOM technical guidelines based on WKVMEBM (ICES 2022).

Bottom fishing (static and mobile) is the single most important human-induced pressure on the seafloor in this area (see ICES ecosystem overviews).

The VME database contains 234 VME habitat and 872 VME indicator c-squares in this area (based on the 2021 VME data call). This information has been collected through various gear types and survey methods.

New VME data

Map of VMEs

Celtic Seas | Bay of Biscay and the Iberian Coast | Greater North Sea | Azores | Icelandic Waters

Overview | New VME data | VME polygon options | Interpretation of results | Read me | Sources and references

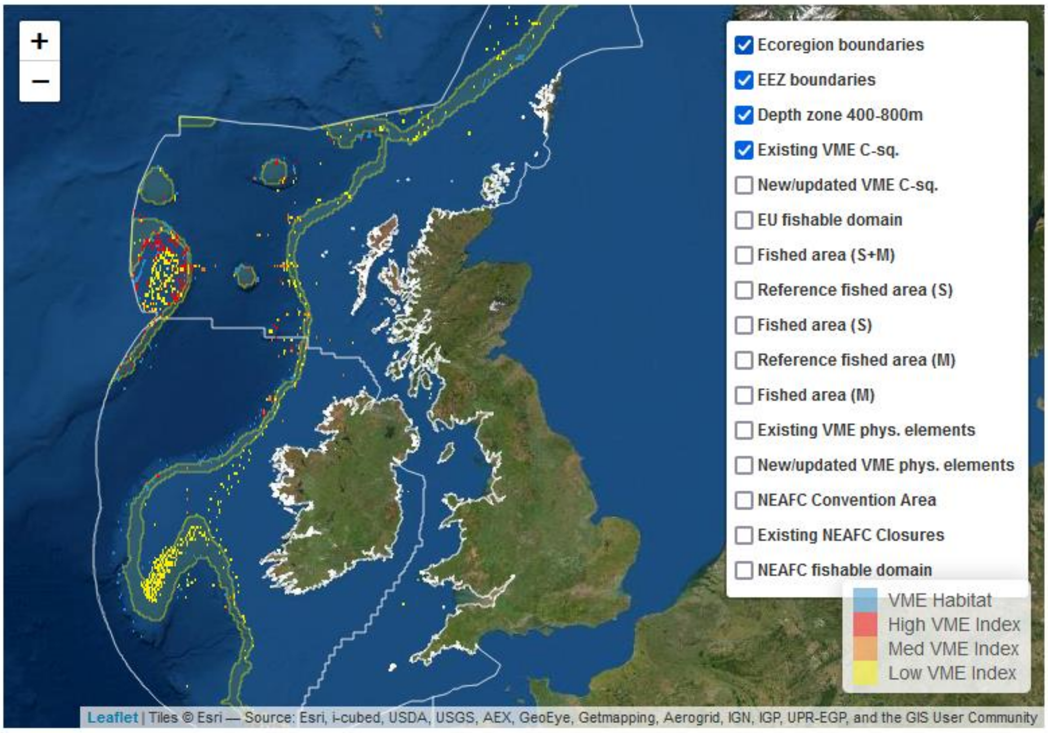
New VME habitat and indicator records were submitted and quality checked. This resulted in 41 new VME Habitat c-squares and 33 new VME Index c-squares; 5 index High, 4 index Medium and 24 index Low.

No new VME physical elements were added to the area.

Most new VME Habitat and Index C-squares are outside previous defined VME polygons.

Map of VMEs | Key to map layers | Overlap VME c-sqs and fishing

Information on VME Habitat and Index C-squares and the spatial distribution of static and mobile bottom-fishing



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New VME data

Key to map layers

Celtic Seas | Bay of Biscay and the Iberian Coast | Greater North Sea | Azores | Icelandic Waters

Overview | New VME data | VME polygon options | Interpretation of results | Read me | Sources and references

New VME habitat and indicator records were submitted and quality checked. This resulted in 41 new VME Habitat c-squares and 33 new VME Index c-squares; 5 index High, 4 index Medium and 24 index Low.

No new VME physical elements were added to the area.

Most new VME Habitat and Index C-squares are outside previous defined VME polygons.

Map of VMEs | Key to map layers | Overlap VME c-sqs and fishing

Layer	Description
Ecoregion boundaries	ICES spatial unit that synthesise the evidence for the ecosystem approach.
EEZ boundaries	Exclusive Economic Zone. Area beyond and adjacent to the territorial sea, extending to a distance of no more than 200 nautical miles from the baselines from which the breadth of the territorial sea is measured.
Depth zone 400-800 m	Seafloor at 400 – 800 m depth.
Existing VME c-sqrs	Existing VME class of each c-square displayed as VME habitat (bona fide VME that represent unequivocal evidence for a VME occurrence), and high, medium and low VME index scores, indicating the likelihood of encountering a VME in the assessed grid cells.
New/Updated VME c-sqrs	VME class in each c-square added or with an updated class based on latest VME data call, displayed as VME habitat (bona fide VME that represent unequivocal evidence for a VME occurrence), and high, medium and low VME index scores, indicating the likelihood of encountering a VME in the assessed grid cells.
EU fishable domain	Area with presence of bottom gears within 400-800m depth between 2009-2011 (EU waters only).
Fished area (S+M)	Area with presence of bottom fishing in the latest 5 years by static and mobile gears (all depths > 200).
Reference fished area (S)	Area with presence of static bottom fishing in 2009-2011 (all depths > 200).
Fished area (S)	Area with presence of static bottom fishing in the latest 5 years (all depths > 200).
Reference fished area (M)	Area with presence of mobile bottom fishing in 2009-2011 (all depths > 200).
Fished area (M)	Area with presence of mobile bottom fishing in the latest 5 years (all depths > 200).
Existing VME Physical Elements	Existing seabed topographic features (e.g. banks, coral mounds, seamounts), extracted from EMODnet .
New/Updated VME Physical Elements	Additional seabed topographic features (e.g. e.g. banks, coral mounds, seamounts) from new data sources or updated delineations of existing features.
NEAFC Convention Area	Area(s) within parts of the Atlantic and Arctic Oceans and their dependent seas covered by the NEAFC Convention.
Existing NEAFC Closures	Existing management areas restricting the use of bottom contact gears in areas with VME.
NEAFC fishable domain	NEAFC existing bottom fishing areas.

New VME data

Overlap VME c-sqs and fishing

Celtic Seas | Bay of Biscay and the Iberian Coast | Greater North Sea | Azores | Icelandic Waters

Overview | New VME data | VME polygon options | Interpretation of results | Read me | Sources and references

New VME habitat and indicator records were submitted and quality checked. This resulted in 41 new VME Habitat c-squares and 33 new VME Index c-squares; 5 index High, 4 index Medium and 24 index Low.

No new VME physical elements were added to the area.

Most new VME Habitat and Index C-squares are outside previous defined VME polygons.

Map of VMEs | Key to map layers | Overlap VME c-sqs and fishing

Summary table of new and cumulative VME evidence and overlap with static gear and/or mobile fishing gears at the scale of C-squares.

	Number of VME/VME element c-squares									
	Total existing				New/updated in 2021					
	Assessed area	Areas fished between 2018-2020			Assessed area	In defined VME polygons				
	All	Mobile gears	Static gears	M + S gears	All	S1O1	S1O2	S2O1	S2O2	S1O2+S2O1
VME habitat										
200-400m	27	22	16	22	0	0	0	0	0	0
400-800m	77	78	69	84	24	0	0	3	2	0
>800m	87	14	16	23	17	0	0	0	0	0
VME index Medium and High										
200-400m	87	73	60	76	3	2	2	2	2	0
400-800m	74	58	60	63	1	0	0	0	0	0
>800m	73	20	10	22	5	0	0	0	0	0
VME index Low										
200-400m	113	113	108	113	7	0	0	0	0	0
400-800m	249	251	237	255	17	0	0	0	0	0
>800m	79	19	8	21	0	0	0	0	0	0
VME physical elements										
Seamounts	919	37	120	149	0	0	0	0	0	0
Banks	0	0	0	0	0	0	0	0	0	0
Coral mounds	205	60	45	72	0	0	0	0	0	0
Mud volcanoes	0	0	0	0	0	0	0	0	0	0

VME polygon options

Map of updated VME polygons

Celtic Seas | Bay of Biscay and the Iberian Coast | Greater North Sea | Azores | Icelandic Waters

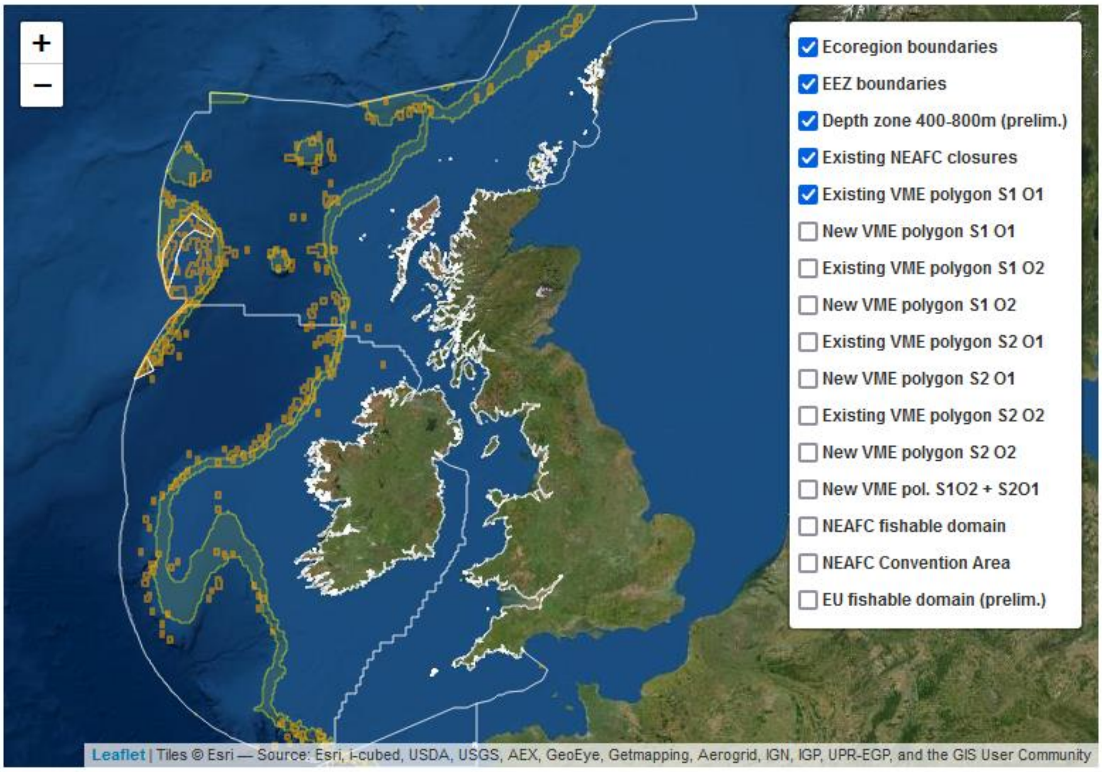
Overview | New VME data | VME polygon options | Interpretation of results | Read me | Sources and references

The new data submissions lead to several new and updated VME polygons in the area.

The VME polygons will reduce the fishable domain between 400-800m depth with 7.5-11.7% (depending on the scenarios/options).

Map of updated VME polygons | Key to map layers | Scenario options | Scenario outcomes and risks

Update of the VME polygons following the scenarios/options.



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VME polygon options

Key to map layers

Celtic Seas | Bay of Biscay and the Iberian Coast | Greater North Sea | Azores | Icelandic Waters

Overview | New VME data | VME polygon options | Interpretation of results | Read me | Sources and references

The new data submissions lead to several new and updated VME polygons in the area.

The VME polygons will reduce the fishable domain between 400-800m depth with 7.5-11.7% (depending on the scenarios/options).

Map of updated VME polygons | Key to map layers | Scenario options | Scenario outcomes and risks

Layer	Description
Ecoregion boundaries	ICES spatial unit that synthesise the evidence for the ecosystem approach.
EEZ boundaries	Exclusive Economic Zone. Area beyond and adjacent to the territorial sea, extending to a distance of no more than 200 nautical miles from the baselines from which the breadth of the territorial sea is measured.
Depth zone 400-800 m	Seafloor at 400 – 800 m depth.
Existing NEAFC Closures	Existing management areas restricting the use of bottom contact gears in areas with VME.
Existing VME polygons scenario 1 option 1	Existing polygons delineating continuous areas of VME (containing c-squares with VME habitats or a High and Medium VME Index, see Scenario options).
New VME polygons scenario 1 option 1	Updated delineation of continuous areas of VME (containing c-squares with VME habitats or a High/Medium VME Index) based on the most recent VME data call.
Existing VME polygons scenario 1 option 2	Existing polygons delineating continuous areas of VME (Option 1 + selected VME elements associated with any VME records, see Scenario options).
New VME polygons scenario 1 option 2	Updated delineation of continuous areas of VME (Option 1 + selected VME elements associated with any VME records).
Existing VME polygons scenario 2 option 1	Existing polygons delineating continuous areas of VME (containing c-squares with VME habitats or a High/Medium VME Index, or a Low VME Index if adjacent to higher index VMEs - and fishing pressure is low see Scenario options).
New VME polygons scenario 2 option 1	Updated delineation of continuous areas of VME (containing c-squares with VME habitats All VME habitats, or a High and/ Medium VME Index, or a. Low VME Index: only if adjacent to higher index VMEs and Low VME Index in C-squares with low and fishing pressure is low).
Existing VME polygons scenario 2 option 2	Existing polygons delineating continuous areas of VME (containing c-squares with VME habitats or a High/Medium/VME Index where fishing pressure is low see Scenario options).
New VME polygons scenario 2 option 2	Updated delineation of continuous areas of VME (containing c-squares with VME habitats or a High/Medium/VME Index where fishing pressure is low).
NEAFC fishable domain	NEAFC existing bottom fishing areas.
NEAFC Convention Area	Area(s) within parts of the Atlantic and Arctic Oceans and their dependent seas covered by the NEAFC Convention.
EU fishable domain	Area with presence of bottom gears between 2009-2011 within 400-800m depth (EU waters only).

VME polygon options

Scenario options

Celtic Seas | Bay of Biscay and the Iberian Coast | Greater North Sea | Azores | Icelandic Waters

Overview | New VME data | VME polygon options | Interpretation of results | Read me | Sources and references

The new data submissions lead to several new and updated VME polygons in the area.

The VME polygons will reduce the fishable domain between 400-800m depth with 7.5-11.7% (depending on the scenarios/options).

Map of updated VME polygons | Key to map layers | Scenario options | Scenario outcomes and risks

Scenario	Option	Description of C-square closures	Management implication
1	1	C-squares with VME habitats as well as C-squares with high and medium VME indices, regardless of fishing activity. C-squares with a low VME index only included if adjacent to C-squares with medium to high VME indices.	Prioritizes identification of VME polygons where they "are known to occur", and where they "are likely to occur", regardless of fishing activity.
1	2	Scenario 1–Option 1 + C-squares that contain selected VME physical elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME indicator species records.	Prioritizes identification of VME polygons where they "are known to occur" and "are likely to occur", as well as elements that are known to frequently contain VMEs, regardless of fishing activity.
2	1	As Scenario 1–Option 1 but includes low VME index C-squares if MBCG fishing pressure is also low (SAR < 0.43). This option preferentially includes Low Index c-sqrs. where these occur outside the more highly fished areas.	Prioritizes identification of VME polygons where they "are known to occur" or " are likely to occur", and includes C squares with low VME index where cumulative fishing activity is also low and significant adverse impacts (SAIs) by past fishing are less likely, this therefore offers potential VME protection at low cost to the fishery and highest potential protection of VMEs in the fishing footprint.
2	2	C-squares including all VME habitats, high, medium and low VME Index C-squares but excluding C-squares with high cumulative MBCG fishing pressure (SAR > 0.43). This option effectively only considers VME Index (of any category) in areas outside of relatively high fishing effort areas.	Prioritizes identification of VME polygons where they are known or likely to occur, but excludes areas that have been intensely fished and where VMEs are therefore potentially damaged by past trawl fishing. By leaving heavily fished areas open, there is reduced impact on fishing activities.
Combined	scenario	Scenario 1 option 2 and Scenario 2 option 1: C-squares with VME habitats as well as C-squares with medium and high VME indices and low VME index if MBGC fishing pressure is low (SAR < 0.43), + C-squares that contain selected VME physical elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME indicator species records.	Prioritizes identification of VME polygons where they "are known to occur" or " are likely to occur", and includes C-squares with low VME Index where cumulative fishing activity is also low and SAIs by past fishing are less likely, this therefore offers potential VME protection at low cost to the fishery and highest potential protection of VMEs in the fishing footprint, as well as elements that are known to frequently contain VMEs, regardless of fishing activity.

VME polygon options

Scenario outcomes and risks

Celtic Seas | Bay of Biscay and the Iberian Coast | Greater North Sea | Azores | Icelandic Waters

Overview | New VME data | VME polygon options | Interpretation of results | Read me | Sources and references

The new data submissions lead to several new and updated VME polygons in the area.

The VME polygons will reduce the fishable domain between 400-800m depth with 7.5-11.7% (depending on the scenarios/options).

Map of updated VME polygons | Key to map layers | Scenario options | Scenario outcomes and risks

Summary table of scenario outcomes and associated risk to VMEs.

	Scenario 1 Option 1	Scenario 1 Option 2	Scenario 2 Option 1	Scenario 2 Option 2	Scenario 1 Option 2 + Scenario 2 Option 1
VME polygon description	All VME habitats, High and Medium VME Index. Low VME Index: only if adjacent to medium or high Index VMEs.	Option 1 + selected VME elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME records.	All VME habitats, High and Medium VME Index. Low VME Index: only if adjacent to higher index VMEs and Low VME Index in C-squares with low fishing pressure	All VME habitats, High, Medium and Low VME Index excluding C-squares with high fishing pressure (SAR > 0.43)	Scenario 2, Option 1 + selected VME elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME records.
VME polygon outcomes					
% of fishable domain identified as VME polygon	10.1	10	11.8	7.5	11.7
% of VME polygon protected by existing VME fishery closures	NA	NA	NA	NA	NA
Number of VME polygons and their average areal extent (size)	163 (188.8 km^2)	149 (289.8 km^2)	199 (176.5 km^2)	185 (142.7 km^2)	185 (256 km^2)
Number (and average size) of large VME polygons in upper 25th percentile of the size distribution	2 (4804.7 km^2)	2 (6325.9 km^2)	2 (4970.4 km^2)	10 (673.5 km^2)	2 (6408.7 km^2)
Risk to VME	NA	NA	NA	NA	NA
Fishery consequences					
% of [effort] per year by static gear (>200m depth) overlapping with VME polygons (average annual [effort] between 2018 to 2020)	NA	NA	NA	NA	NA
% of fished area (>200m depth) by static gear overlapping with VME polygons between 2018 to 2020	8.2	8.9	9.3	5.4	10
% of SAR by mobile gear (>200m depth) overlapping with VME polygons (average annual SAR between 2018 to 2020)	3.6	3.6	4.2	1.1	4.2
% of fished area (>200m depth) by mobile gear overlapping with VME polygons between 2018 to 2020	9	9.1	9.9	5.2	10

Interpretation of results

Celtic Seas | Bay of Biscay and the Iberian Coast | Greater North Sea | Azores | Icelandic Waters

Overview | New VME data | VME polygon options | **Interpretation of results** | Read me | Sources and references

Brief interpretation of results (max ½ page) [A verbal reference to factors in ecology (realism), management and/or fishing practices which are important in understanding the indicated results and ranked closure options. Also if there are any noticable trendsm and if these changes are related to the specific locations or not. Special emphasis on certainty of data in terms of the VME index, elements, and other supporting information.

Limitations and caveats relate to issues concerning the provision of vessel data and their interpretation, the scale at which the data are used and considered to be informative, and the information base used in the definition and evaluation of spatial closure scenarios.

Read me

Celtic Seas Bay of Biscay and the Iberian Coast Greater North Sea Azores Icelandic Waters

Overview New VME data VME polygon options Interpretation of results **Read me** Sources and references

This scientific assessment of occurrence of vulnerable marine ecosystems (VMEs), fishing activity in the vicinity of VMEs, as well as spatial management options consists of this assessment and a data product, consisting of spatial data layers (as shapefiles) of the fishable domain and proposed VME polygons based on the different scenarios/options. The spatial data layers are accompanied with a csv-file with the coordinates. Each VME polygon csv-file also indicates the VME habitat, VME indicator and VME physical element data present, as well as the VME habitat and index C-squares.

The data and scripts that produced the assessment are available here: https://github.com/ices-taf/VME-Advice

Sources and references

Annex 8: Demonstration: Requester-specific advice (EU or NEAFC)

Demonstration of an EU VME assessment. The demonstration is done for the entire EU waters in the northeast Atlantic. The latest outputs can be downloaded from https://github.com/ices-taf/VME-Advice.

The current outputs are purely for demonstration purposes and should not be used for anything else. Each page shows one tab of the developed HTML for the EU VME assessment.

Overview

EU vulnerable marine ecosystem assessment

ICES

April 2022

Available evidence on the occurrence of Vulnerable marine ecosystems (VMEs), fishing activity in relation to VMEs, and spatial management options to minimise the risk from fishing activities to VMEs

Overview | New VME data | VME polygon options | Interpretation of results | Read me | Sources and references

For the purpose of this assessment, evidence of VME occurrence is aggregated at the scale of individual 0.05 x 0.05 degrees C-square cells (hereafter termed C-square) where VME habitats or indicator taxa are assumed to be homogeneously distributed. Similarly, fishing effort information is aggregated at the scale of C-squares.

The VME polygon methodology is described in the ACOM technical guidelines based on WKVMEBM (ICES 2022).

Bottom fishing (static and mobile) is the single most important human-induced pressure on the seafloor in this area (see ICES ecosystem overviews).

The VME database contains 212 VME habitat and 932 VME indicator c-squares in this area (based on the 2021 VME data call). This information has been collected through various gear types and survey methods.

New VME data

Map of VMEs

Overview | **New VME data** | VME polygon options | Interpretation of results | Read me | Sources and references

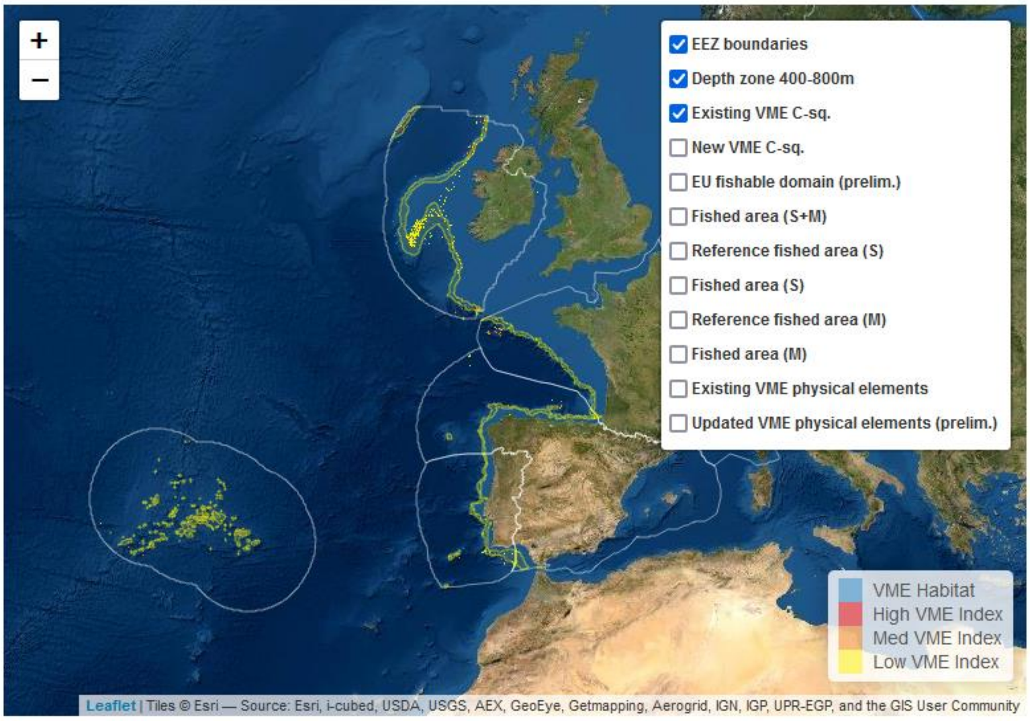
New VME habitat and indicator records were submitted and quality checked. This resulted in 49 new VME Habitat c-squares and 212 new VME Index c-squares; 41 index High, 46 index Medium and 125 index Low.

No new VME physical elements were added to the area.

Most new VME Habitat and Index C-squares are outside previous defined VME polygons.

Map of VMEs | Key to map layers | Overlap VME c-sqs and fishing

Information on VME Habitat and Index C-squares and the spatial distribution of static and mobile bottom-fishing



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New VME data

Key to map layers

Overview | **New VME data** | VME polygon options | Interpretation of results | Read me | Sources and references

New VME habitat and indicator records were submitted and quality checked. This resulted in 49 new VME Habitat c-squares and 212 new VME Index c-squares; 41 index High, 46 index Medium and 125 index Low.

No new VME physical elements were added to the area.

Most new VME Habitat and Index C-squares are outside previous defined VME polygons.

Map of VMEs | **Key to map layers** | Overlap VME c-sqs and fishing

Layer	Description
EEZ boundaries	Exclusive Economic Zone. Area beyond and adjacent to the territorial sea, extending to a distance of no more than 200 nautical miles from the baselines from which the breadth of the territorial sea is measured.
Depth zone 400-800 m	Seafloor at 400 – 800 m depth.
Existing VME c-sqrs	Existing VME class of each c-square displayed as VME habitat (bona fide VME that represent unequivocal evidence for a VME occurrence), and high, medium and low VME index scores, indicating the likelihood of encountering a VME in the assessed grid cells.
New/Updated VME c-sqrs	VME class in each c-square added or with an updated class based on latest VME data call, displayed as VME habitat (bona fide VME that represent unequivocal evidence for a VME occurrence), and high, medium and low VME index scores, indicating the likelihood of encountering a VME in the assessed grid cells.
EU fishable domain	Area with presence of bottom gears within 400-800m depth between 2009-2011 (EU waters only).
Fished area (S+M)	Area with presence of bottom fishing in the latest 5 years by static and mobile gears (all depths > 200).
Reference fished area (S)	Area with presence of static bottom fishing in 2009-2011 (all depths > 200).
Fished area (S)	Area with presence of static bottom fishing in the latest 5 years (all depths > 200).
Reference fished area (M)	Area with presence of mobile bottom fishing in 2009-2011 (all depths > 200).
Fished area (M)	Area with presence of mobile bottom fishing in the latest 5 years (all depths > 200).
Existing VME Physical Elements	Existing seabed topographic features (e.g. banks, coral mounds, seamounts), extracted from EMODnet .
New/Updated VME Physical Elements	Additional seabed topographic features (e.g. e.g. banks, coral mounds, seamounts) from new data sources or updated delineations of existing features.

New VME data

Overlap VME c-sqs and fishing

Overview | **New VME data** | VME polygon options | Interpretation of results | Read me | Sources and references

New VME habitat and indicator records were submitted and quality checked. This resulted in 49 new VME Habitat c-squares and 212 new VME Index c-squares; 41 index High, 46 index Medium and 125 index Low.

No new VME physical elements were added to the area.

Most new VME Habitat and Index C-squares are outside previous defined VME polygons.

Map of VMEs | Key to map layers | **Overlap VME c-sqs and fishing**

Summary table of new and cumulative VME evidence and overlap with static gear and/or mobile fishing gears at the scale of C-squares.

	Number of VME/VME element c-squares									
	Total existing				New/updated in 2021					
	Assessed area	Areas fished between 2018-2020			Assessed area	In defined VME polygons				
	All	Mobile gears	Static gears	M + S gears	All	S1O1	S1O2	S2O1	S2O2	S1O2+S2O1
VME habitat										
200-400m	4	5	4	6	3					
400-800m	64	67	68	76	27	0	5	3	2	0
>800m	78	17	23	28	19					
VME index Medium and High										
200-400m	12	15	15	16	5					
400-800m	81	64	69	73	60	1	13	1	1	0
>800m	110	17	17	23	22					
VME index Low										
200-400m	95	134	133	134	40					
400-800m	211	274	260	278	81	1	1	1	1	0
>800m	59	9	5	10	4					
VME physical elements										
Seamounts	3644	70	25	84	0	0	0	0	0	0
Banks	275	0	6	6	0	0	0	0	0	0
Coral mounds	168	53	44	65	0	0	0	0	0	0
Mud volcanoes	28	11	0	11	0	0	0	0	0	0

VME polygon options

Map of updated VME polygons

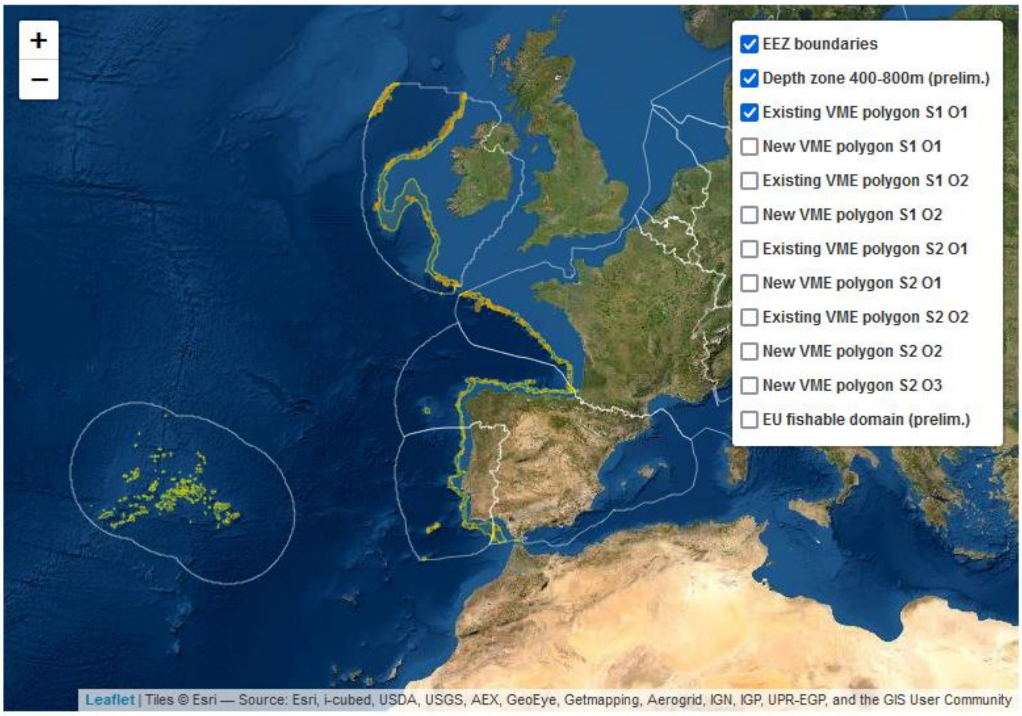
Overview | New VME data | **VME polygon options** | Interpretation of results | Read me | Sources and references

The new data submissions lead to several new and updated VME polygons in the area.

The VME polygons will reduce the fishable domain between 400-800m depth with xx-xx% (depending on the scenarios/options).

Map of updated VME polygons | Key to map layers | Scenario options | Scenario outcomes and risks

Update of the VME polygons following the scenarios/options.



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VME polygon options

Key to map layers

Overview | New VME data | VME polygon options | Interpretation of results | Read me | Sources and references

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The VME polygons will reduce the fishable domain between 400-800m depth with xx-xx% (depending on the scenarios/options).

Map of updated VME polygons | Key to map layers | Scenario options | Scenario outcomes and risks

Layer	Description
EEZ boundaries	Exclusive Economic Zone. Area beyond and adjacent to the territorial sea, extending to a distance of no more than 200 nautical miles from the baselines from which the breadth of the territorial sea is measured.
Depth zone 400-800 m	Seafloor at 400 – 800 m depth.
Existing VME polygons scenario 1 option 1	Existing polygons delineating continuous areas of VME (containing c-squares with VME habitats or a High and Medium VME Index, see Scenario options).
New VME polygons scenario 1 option 1	Updated delineation of continuous areas of VME (containing c-squares with VME habitats or a High/Medium VME Index) based on the most recent VME data call.
Existing VME polygons scenario 1 option 2	Existing polygons delineating continuous areas of VME (Option 1 + selected VME elements associated with any VME records, see Scenario options).
New VME polygons scenario 1 option 2	Updated delineation of continuous areas of VME (Option 1 + selected VME elements associated with any VME records).
Existing VME polygons scenario 2 option 1	Existing polygons delineating continuous areas of VME (containing c-squares with VME habitats or a High/Medium VME Index, or a Low VME Index if adjacent to higher index VMEs - and fishing pressure is low see Scenario options).
New VME polygons scenario 2 option 1	Updated delineation of continuous areas of VME (containing c-squares with VME habitats All VME habitats, or a High and/ Medium VME Index, or a. Low VME Index: only if adjacent to higher index VMEs and Low VME Index in C-squares with low and fishing pressure is low).
Existing VME polygons scenario 2 option 2	Existing polygons delineating continuous areas of VME (containing c-squares with VME habitats or a High/Medium/VME Index where fishing pressure is low see Scenario options).
New VME polygons scenario 2 option 2	Updated delineation of continuous areas of VME (containing c-squares with VME habitats or a High/Medium/VME Index where fishing pressure is low).
EU fishable domain	Area with presence of bottom gears between 2009-2011 within 400-800m depth (EU waters only).

VME polygon options

Scenario options

Overview | New VME data | **VME polygon options** | Interpretation of results | Read me | Sources and references

The new data submissions lead to several new and updated VME polygons in the area.

The VME polygons will reduce the fishable domain between 400-800m depth with xx-xx% (depending on the scenarios/options).

Map of updated VME polygons | Key to map layers | **Scenario options** | Scenario outcomes and risks

Scenario	Option	Description of C-square closures	Management implication
1	1	C-squares with VME habitats as well as C-squares with high and medium VME indices, regardless of fishing activity. C-squares with a low VME index only included if adjacent to C-squares with medium to high VME indices.	Prioritizes identification of VME polygons where they "are known to occur", and where they "are likely to occur", regardless of fishing activity.
1	2	Scenario 1–Option 1 + C-squares that contain selected VME physical elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME indicator species records.	Prioritizes identification of VME polygons where they "are known to occur" and "are likely to occur", as well as elements that are known to frequently contain VMEs, regardless of fishing activity.
2	1	As Scenario 1–Option 1 but includes low VME index C-squares if MBCG fishing pressure is also low (SAR < 0.43). This option preferentially includes Low Index c-sqrs. where these occur outside the more highly fished areas.	Prioritizes identification of VME polygons where they "are known to occur" or " are likely to occur", and includes C squares with low VME index where cumulative fishing activity is also low and significant adverse impacts (SAIs) by past fishing are less likely, this therefore offers potential VME protection at low cost to the fishery and highest potential protection of VMEs in the fishing footprint.
2	2	C-squares including all VME habitats, high, medium and low VME Index C-squares but excluding C-squares with high cumulative MBCG fishing pressure (SAR > 0.43). This option effectively only considers VME Index (of any category) in areas outside of relatively high fishing effort areas.	Prioritizes identification of VME polygons where they are known or likely to occur, but excludes areas that have been intensely fished and where VMEs are therefore potentially damaged by past trawl fishing. By leaving heavily fished areas open, there is reduced impact on fishing activities.
Combined	scenario	Scenario 1 option 2 and Scenario 2 option 1: C-squares with VME habitats as well as C-squares with medium and high VME indices and low VME index if MBGC fishing pressure is low (SAR < 0.43), + C-squares that contain selected VME physical elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME indicator species records.	Prioritizes identification of VME polygons where they "are known to occur" or " are likely to occur", and includes C-squares with low VME Index where cumulative fishing activity is also low and SAIs by past fishing are less likely, this therefore offers potential VME protection at low cost to the fishery and highest potential protection of VMEs in the fishing footprint, as well as elements that are known to frequently contain VMEs, regardless of fishing activity.

VME polygon options

Scenario outcomes and risks

Overview New VME data **VME polygon options** Interpretation of results Read me Sources and references

The new data submissions lead to several new and updated VME polygons in the area.

The VME polygons will reduce the fishable domain between 400-800m depth with xx-xx% (depending on the scenarios/options).

Map of updated VME polygons Key to map layers Scenario options **Scenario outcomes and risks**

Summary table of scenario outcomes and associated risk to VMEs.

	Scenario 1 Option 1	Scenario 1 Option 2	Scenario 2 Option 1	Scenario 2 Option 2	Scenario 1 Option 2 + Scenario 2 Option 1
VME polygon description	All VME habitats, High and Medium VME Index. Low VME Index: only if adjacent to medium or high Index VMEs.	Option 1 + selected VME elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME records.	All VME habitats, High and Medium VME Index. Low VME Index: only if adjacent to higher index VMEs and Low VME Index in C-squares with low fishing pressure	All VME habitats, High, Medium and Low VME Index excluding C-squares with high fishing pressure (SAR > 0.43)	Scenario 2, Option 1 + selected VME elements (banks, seamounts, coral mounds, mud volcanoes) associated with any VME records.
VME polygon outcomes					
% of fishable domain identified as VME polygon	13.1	13.9	15.3	9.8	16.1
% of VME polygon protected by existing VME fishery closures	NA	NA	NA	NA	NA
Number of VME polygons and their average areal extent (size)	139 (208.7 km^2)	139 (416 km^2)	161 (206.5 km^2)	144 (173.9 km^2)	161 (385 km^2)
Number (and average size) of large VME polygons in upper 25th percentile of the size distribution	7 (1081 km^2)	1 (27344.5 km^2)	9 (988.9 km^2)	10 (657.6 km^2)	1 (27344.5 km^2)
Risk to VME	NA	NA	NA	NA	NA
Fishery consequences					
% of effort per year by static gear (400-800m depth) overlapping with VME polygons (average annual effort between 2018 to 2020)	NA	NA	NA	NA	NA
% of fished area (400-800m depth) by static gear overlapping with VME polygons between 2018 to 2020	9.8	9.8	11.1	6.2	11.1
% of SAR by mobile gear (400-800m depth) overlapping with VME polygons (average annual SAR between 2018 to 2020)	6.1	6.1	7.6	2.1	7.6
% of fished area (400-800m depth) by mobile gear overlapping with VME polygons between 2018 to 2020	7.8	7.8	9.3	4.8	9.3

Interpretation of results

Overview | New VME data | VME polygon options | **Interpretation of results** | Read me | Sources and references

Brief interpretation of results (max ½ page) [A verbal reference to factors in ecology (realism), management and/or fishing practices which are important in understanding the indicated results and ranked closure options. Also if there are any noticable trendsm and if these changes are related to the specific locations or not. Special emphasis on certainty of data in terms of the VME index, elements, and other supporting information.

Limitations and caveats relate to issues concerning the provision of vessel data and their interpretation, the scale at which the data are used and considered to be informative, and the information base used in the definition and evaluation of spatial closure scenarios.

Read me

Overview | New VME data | VME polygon options | Interpretation of results | **Read me** | Sources and references

This scientific assessment of occurrence of vulnerable marine ecosystems (VMEs), fishing activity in the vicinity of VMEs, as well as spatial management options consists of this assessment and a **data product**, consisting of spatial data layers (as shapefiles) of the fishable domain and proposed VME polygons based on the different scenarios/options. The spatial data layers are accompanied with a csv-file with the coordinates. Each VME polygon csv-file also indicates the VME habitat, VME indicator and VME physical element data present, as well as the VME habitat and index C-squares.

The data and scripts that produced the assessment are available here: **https://github.com/ices-taf/VME-Advice**

Sources and references

Overview | New VME data | VME polygon options | Interpretation of results | Read me | **Sources and references**

ICES 2022 WKVMEBM
ICES 2021 VME datacall
ICES 2021 VMS datacall