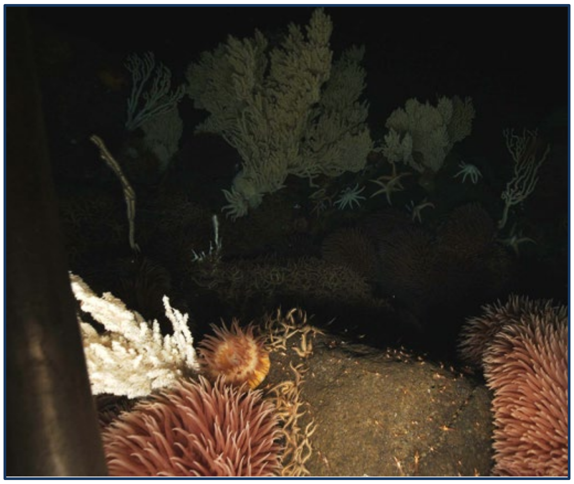
Fisheries and Oceans Canada / Pêches et Océans Canada

Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/038

IDENTIFICATION OF VULNERABLE MARINE ECOSYSTEMS ON SEAMOUNTS IN THE NORTH PACIFIC FISHERIES COMMISSION CONVENTION AREA USING VISUAL SURVEYS AND DISTRIBUTION MODELS



NPFC VME indicator taxa and associated epifauna during a survey of five seamounts in the Cobb-Eickelberg seamount chain (Photo courtesy of DFO and NOAA).

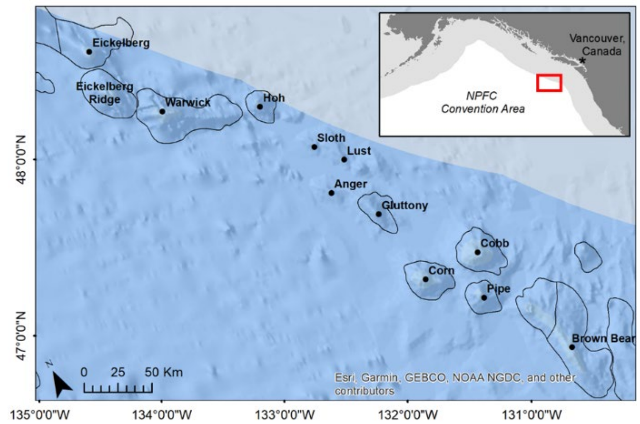


Figure 1. The Cobb-Eickelberg seamount chain in the NPFC Convention Area, adjacent to the Canadian EEZ (light grey). Black dots with outlines indicate named seamounts identified from geomorphic features in Harris et al. (2014).

Context:

Contracting Parties to the North Pacific Fisheries Commission (NPFC), including Canada, are mandated by the Convention on Conservation and Management of High Seas Fisheries Resources in the North Pacific Ocean to protect biodiversity in the marine environment. The NPFC's Scientific Committee identified vulnerable marine ecosystems (VMEs) in the northeast part of the NPFC Convention Area in December 2023, but areas likely to be VMEs have not been identified.

Fisheries and Oceans Canada's (DFO) International Fisheries Policy requested that Science Branch identify VMEs and likely VMEs in the northeast part of the NPFC Convention Area where Canada fishes for Sablefish along the Cobb-Eickelberg seamount chain. The assessment and advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) will be used to inform the NPFC of where VMEs and likely VMEs occur in the Cobb-Eickelberg seamount chain.

This Science Advisory Report is from the January 23–25, 2024 regional peer review on the Identification of Vulnerable Marine Ecosystems on Seamounts in the North Pacific Fisheries Commission Convention Area using Visual Surveys and Distribution Models. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

Canada

SUMMARY

- The North Pacific Fisheries Commission's (NPFC) Scientific Committee is required to develop a process to identify Vulnerable Marine Ecosystems (VMEs) and areas where VMEs are likely to occur. NPFC recently adopted i) a methodology to identify VMEs based on visual data; and ii) a framework that identifies predictive models as one means to identify likely VMEs (i.e., areas where VMEs are likely to occur above an identified threshold).
- To identify observed VMEs on Cobb Seamount between 400 m and 1,200 m deep, a threshold methodology was employed based on the United Nations Food and Agriculture Organization's (the FAO) criterion of structural complexity. A VME indicator density threshold was estimated based on visual data from Cobb Seamount. This resulted in Canada identifying five VME areas on Cobb Seamount with a combined area of 508 m2 (representing 5% of the area surveyed).
- The locations of likely VMEs in the broader Cobb-Eickelberg seamount chain, in the depth range from 400 m to 1,200 m, were predicted using spatial modelling of VME indicator density with selected environmental parameters. Likely VMEs were predicted to be present on seven seamounts and one ridge in the Cobb-Eickelberg seamount chain. A total of 99 km2 (representing 10% of the modelled area) was identified as likely VMEs, with Cobb Seamount having the largest total area (27.5 km2).
- Multiple sources of uncertainty were identified including: limited available data; the representativeness of Cobb Seamount and extrapolation to nearby seamounts that may have different environmental characteristics; areas outside the depth range remain that were unassessed; the impact of pre-existing fishery damage on the modeling and results; the exclusion of potential VME indicator taxa; limiting the assessment to only one of five FAO VME criteria; and the selection and resolution of modelled environmental variables.
- An important implication of these sources of uncertainty is that the identified VMEs and likely VME areas are expected to be a subset of the full VME extent in this seamount range, considering VMEs and likely VMEs outside the 400 to 1,200 m depth range have yet to be evaluated.
- Future research to advance Canada's identification of VMEs in the NPFC Convention Area could include: additional visual surveys designed for VME identification; further analysis of the VME indicator density threshold and methodology; investigation of other approaches to identify VMEs and likely VMEs based on the other four FAO VME criteria; and ground-truthing of predictive models of the location of likely VMEs throughout the Cobb-Eickelberg seamount chain.

INTRODUCTION

Contracting Parties to the North Pacific Fisheries Commission (NPFC), including Canada, are mandated by the Convention on Conservation and Management of High Seas Fisheries Resources in the North Pacific Ocean to protect biodiversity in the marine environment, including by preventing significant adverse impacts on vulnerable marine ecosystems (VMEs). In the eastern part of the NPFC's Convention Area (NPFC CA), the NPFC's Scientific Committee is undertaking a two-step process to first identify observed VMEs using visual observations, and second to predict areas that are likely to be VMEs (i.e., likely VMEs) in the NPFC Convention Area (CA) using the best scientific information available.

The NPFC endorsed the first step, a method to identify observed VMEs (NPFC-COM 2023) proposed by Canada in December 2022 (Warawa et al. 2022). This approach is adapted from

Rowden et al.'s (2020) methodology and was applied in the eastern NPFC CA using visual data collected from Cobb Seamount (Curtis et al. 2015) as described in Warawa et al. (2021, 2022, 2023a). Canada's application of this method was reviewed by NPFC members and observers during meetings of the Small Scientific Committee on Bottom Fish and Marine Ecosystems (NPFC-SSC BFME 2021, 2022), endorsed by the NPFC's Scientific Committee (NPFC-SC 2022a), and then adopted by the Commission in March 2023 (NPFC-COM 2023). In support of the second step, the NPFC's Small Scientific Committee on Bottom Fish and Marine Ecosystems and Scientific Committee recognized that Canada's methodology to predict the distribution of likely VMEs throughout the Cobb-Eickelberg seamount chain (Warawa et al. 2023b) fits into the NPFC's existing VME identification framework and encouraged Canada to proceed with their research (NPFC-SSC BFME 2023) in December 2023.

The purpose of this peer-reviewed science process is to identify observed VMEs using the NPFC-endorsed methodology, review the proposed methodology for identification of likely VMEs, advise on the identification of VMEs and likely VMEs in the Cobb-Eickelberg seamount chain, and identify uncertainties in the work.

ANALYSIS

Methods Used to Identify VMEs in the Eastern NPFC CA

The NPFC approach and this research follow the FAO's International Guidelines for the Management of Deep-sea Fisheries in the High Seas recommendation for the development of case-specific operational definitions of VMEs (FAO 2009). The FAO's guidelines list five potential criteria for identification of VMEs. This research focuses on the identification of VMEs and likely VMEs based on a single criterion, specifically structural complexity.

Within the NPFC CA, observed VMEs are identified using visual data and, for areas where visual data are not currently available, likely VMEs are identified using predictive modelling or other approaches (see Annex 2.3 of NPFC 2023a and NPFC 2023b). Rowden et al.'s (2020) VME identification method was adapted to the eastern NPFC CA, with minor modifications, to ensure it is ecologically appropriate and follows the NPFC's science standards, Scientific Committee research plan, and conservation and management measures. Figure 2 outlines the steps in Rowden et al.'s (2020) approach and compares it to Canada's adaptation in the eastern NPFC CA to identify both VMEs and likely VMEs.

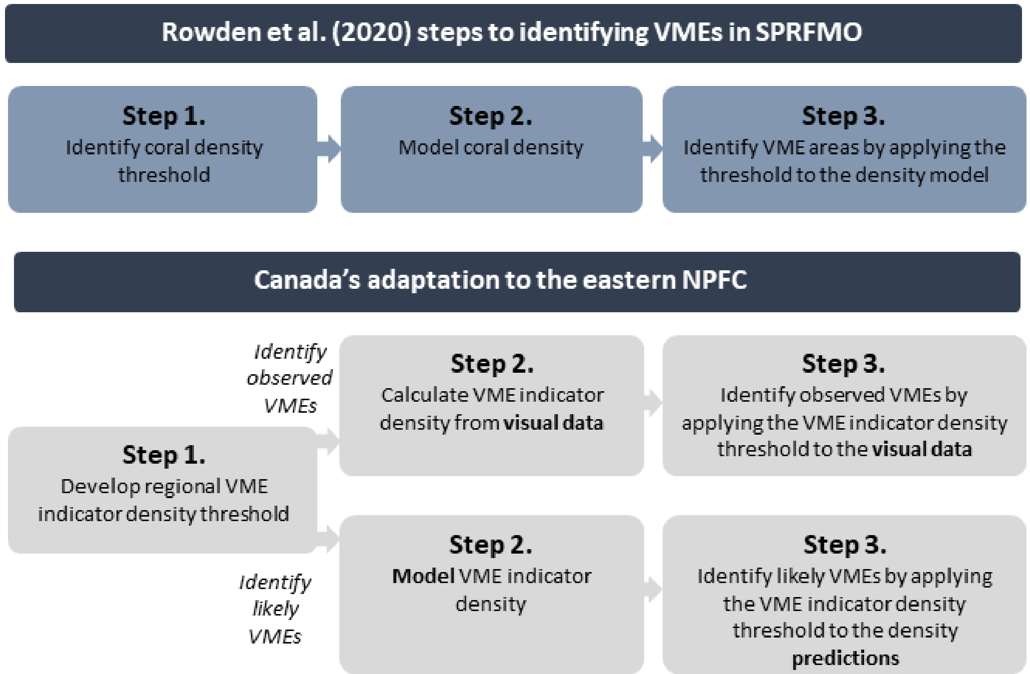


Figure 2. Canada's adaptation of Rowden et al.'s approach to identifying VMEs (Rowden et al. 2020) in the eastern NPFC CA.

Study area

The study area, the Cobb-Eickelberg seamount chain, is in the eastern part of the NPFC CA just outside of Canada's exclusive economic zone (EEZ), approximately 450 km offshore of Vancouver Island (Figure 1). This seamount chain includes 11 named seamounts and one ridge (Eickelberg Ridge), with Cobb Seamount having the shallowest pinnacle depth of 24 m (Parker and Tunnicliffe 1994).

Data

The visual data available in the study area are from a scientific survey completed on Cobb Seamount in 2012 (Curtis et al. 2015). The survey aimed to characterize the epifaunal and fish community structure and used an autonomous underwater vehicle (AUV) to collect still photos along four transects below 400 m on Cobb Seamount (Curtis et al. 2015). Those transects had an average length of 1,805 m and ranged from 435 to 1,154 m in depth (Figure 3). The United States National Oceanic and Atmospheric Administration (NOAA) produced a fully annotated dataset of 2,614 AUV photos.

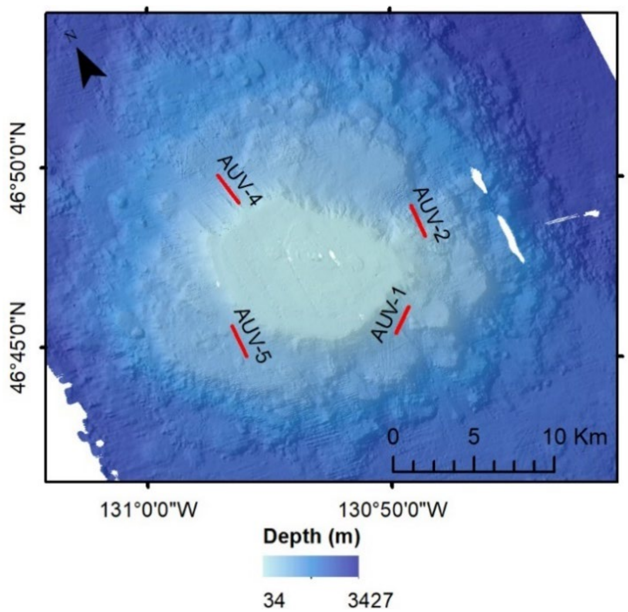


Figure 3. Bathymetry map of Cobb Seamount showing the locations of four autonomous underwater vehicle (AUV) transects (red) from the survey of Cobb Seamount in 2012 (see Curtis et al. 2015).

VME indicator taxa

Canada's adaptation of Rowden et al.'s (2020) approach utilizes the VME indicator taxa currently recognized by the NPFC, which include four higher-level groups of cold-water corals occurring in the northeast Pacific Ocean—Alcyonacea (historically non-gorgonian soft corals), Antipatharia (black corals), Gorgonacea (historically gorgonian corals), and Scleractinia (stony corals)—as well as two classes of sponges: Demospongiae (demosponges) and Hexactinellida (glass sponges) (NPFC-COM 2023). VME indicator taxa included in the analyses were filtered to exclude taxa that do not contribute significantly to the formation of structurally complex areas (see Table 1).

Table 1. NPFC VME indicator taxa represented in the autonomous underwater vehicle (AUV) annotated data from the Cobb Seamount 2012 survey (Curtis et al. 2015). Taxa that form structurally complex habitats are indicated with an asterisk (*) and total count is from all four AUV transects.

VME Group	Scientific Name	Total Count
Black Coral	*Bathypathes**	373
	*Lillipathes**	281
	*Stichopathes**	61
Glass Sponge	*Euretidae**	27
	*Farrea omniclavata**	39
	*Rossellidae**	128
	*Staurocalyptus**	8
Gorgonian	*Callistephanus simplex**	29
	*Keratoisididae**	570
	*Primnoidae**	188
Soft Coral	*Gersemia*	40
Stony Coral	*Desmophyllum dianthus*	8

Identifying VMEs

The three key steps for identifying VMEs are outlined below, following the flow chart in Figure 2.

VME Step 1: Calculate a VME indicator density threshold.

- The density of NPFC VME indicators m^{-2} and number of associated epifaunal taxa and fishes were calculated within each of the 221 area-standardized 50 m^2 segments of the AUV transects.
- A generalized additive model (GAM) that included depth and transect was used to model the relationship between the number of associated epifauna and fishes (dependent variable) and the density of VME indicators (independent variable) as in Rowden et al. (2020).
- The VME indicator density threshold of 0.6 VME indicator taxa m^{-2} was calculated from this GAM by applying the same four thresholding methods described by Rowden et al. (2020) and taking the mean threshold value (Table 2).

VME Step 2: Calculate the density of VME indicators from the visual data.

- The density of VME indicators on the four AUV transects in Curtis et al. (2015) were calculated for each of the 221 area-standardized 50 m^2 segments of the AUV transects.

VME Step 3: Apply the VME indicator density threshold.

- Transect segments were identified as VMEs when the VME indicator density was equal to or greater than the regional VME density threshold (0.6 individuals m^{-2}). Adjacent transect segments that were above this threshold were grouped and considered to form a single VME.

Table 2. Calculations of VME indicator density thresholds for the Cobb Seamount visual surveys using the four methods Rowden et al. (2020) used to estimate a VME indicator density threshold in the South Pacific Regional Fisheries Management Organization (SPRFMO) CA (in number of VME indicators m^{-2}). The mean and standard deviation are also calculated.

Threshold Method	Threshold Value
1. the point of intersection of linear regressions using the initial and final 5% of data	0.53
2. the point of intersection between a linear regression using the initial 5% of data and the maximum cumulative species richness value	0.74
3. the point on the curve that is closest to the top right corner (0,1)	0.61
4. the point on the curve that maximizes the distance between the curve and the line between extreme points (Youden Index)	0.52
Mean	0.60 (SD = 0.1)

Review of Existing Methods to Identify Likely VMEs

Methods for identifying the location of likely VMEs were reviewed spanning four Regional Fisheries Management Organizations (see Kenchington et al. 2014; Morato et al. 2018; Miyamoto and Yonezaki 2019; Rowden et al. 2020). These approaches varied considerably in terms of the data requirements and repeatability of methods.

Three key methods that met identified priorities of quantitative rigour and repeatability were identified that draw on catch data from extractive scientific sampling methods (Kernel density estimation), historical observation data of VME indicator taxa (multi-criteria assessment), and/or visual data from non-extractive scientific surveys of benthic organisms (structural complexity density threshold).

Canada's Sablefish fishery is conducted with long-lined traps or hook and line gear, which typically do not efficiently retain VME indicator taxa. As a result, there are insufficient incidental catch records of NPFC's VME indicator taxa available in this region to support the kernel density estimation approach to VME identification developed and applied by Kenchington et al. (2014) using bottom trawl data.

Conducting a multi-criteria assessment as in Morato et al. (2018) also requires databases with large numbers of observations of VME indicator taxa. Observations are limited in the eastern NPFC CA.

A suitable method to identify likely VMEs in the eastern NPFC CA using existing data is the approach based on structural complexity outlined by Rowden et al. (2020), because it can be adapted for use with the single visual survey dataset in Curtis et al. (2015). These visual data can be used to calculate a regional VME indicator threshold on Cobb Seamount. The same threshold can be applied to predictions of the density of VME indicator taxa and identify locations of likely VMEs on other seamounts in the Cobb-Eickelberg seamount chain.

Identifying likely VMEs

The three key steps for identifying likely VMEs within the modelling depth range are the same three steps used by Rowden et al. (2020) to predict the location of VMEs (see Figure 2), as described below:

Likely VME Step 1: Develop a regional VME indicator density threshold.

- Because visual VME survey data were only available from Cobb Seamount, the same regional VME indicator density threshold of 0.6 VME indicators m^{-2} used to identify VMEs on Cobb Seamount (see VME Step 1 above) is used to identify likely VMEs regionally in the Cobb-Eickelberg seamount chain.

Likely VME Step 2: Develop predictive models of VME indicator density.

- A GAM was used to predict the density of VME indicators in the Cobb-Eickelberg seamount chain using VME indicator density values from the AUV visual survey on Cobb Seamount as the dependent data.
- Independent data for the GAM were environmental variables known or assumed to be correlated with the distribution and density of corals and sponges.
- The final GAM structure included the covariates depth, northness, and slope.
- The density of VME indicators was predicted using a 100 m by 100 m resolution in areas between 400 m and 1,200 m depth to avoid extrapolating beyond the depth range of the dependent data.

Likely VME Step 3: Apply the regional VME indicator density threshold.

- Predictions of the density of VME indicators were converted to binary predictions of likely VME presence and absence using the Cobb Seamount-specific VME indicator density threshold of 0.6 individuals of VME indicator taxa m^{-2} from VME Step 1 and applying it regionally to the Cobb-Eickelberg seamount chain.

Results

Observed VMEs identified

Based on AUV observations, five VMEs were identified on Cobb Seamount with a combined area of 508 m^2 (Table 3). VMEs ranged in size from approximately 50–200 m^2 and in depth from 500 to 1,154 m. VMEs were identified on two out of the four AUV transects on Cobb Seamount (Figure 3). Larger VME areas occurred in the deepest areas of transect AUV 4. VMEs on transect AUV 4 included 290 gorgonian corals, 45 black corals, and 13 individual glass sponges, while the VME on transect AUV 2 included 30 colonies of black corals and only one gorgonian and one glass sponge.

Table 3. Summary of five areas identified as VMEs on Cobb Seamount.

VME ID	Latitude of central points (m)	Longitude of central points (m)	Area (m^2)	Approx width (m)	Approx length (m)	Depth of central points (m)	VME indicator density (individuals/m^2)
VME-A	46.80567	-130.845	201	2.3	87.5	1138	0.9
VME-B	46.80434	-130.844	152	2.3	66	1112	0.71
VME-C	46.79705	-130.842	51	2.3	22.4	802	0.66
VME-D	46.79162	-130.841	52	2.3	22.8	508	0.6
VME-E	46.75812	-130.724	52	2.3	22.7	689	0.64

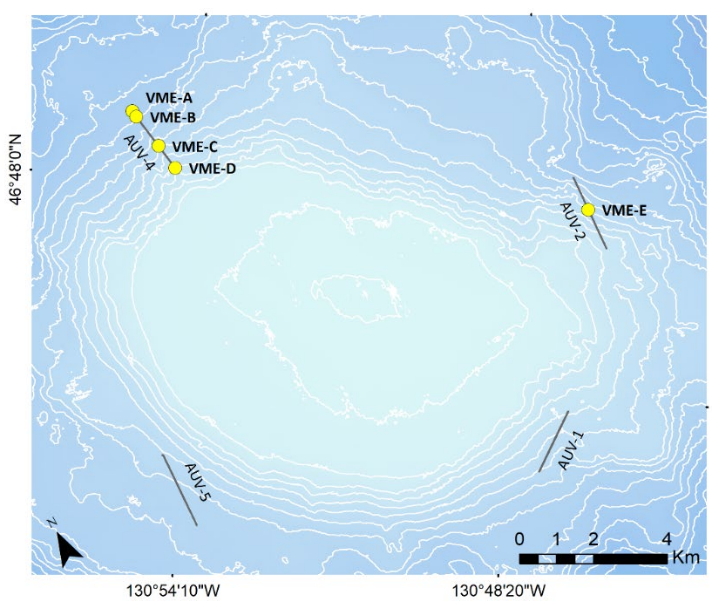


Figure 4. Central points of VMEs identified on Cobb Seamount (yellow circles). White lines are 100 m depth contour lines and grey lines are AUV transect lines (see Curtis et al. 2015).

Likely VMEs identified

Likely VMEs were identified on all seamounts in the study area (see Figure 1 and Figure 5). The total area of likely VMEs identified per seamount ranged from 2.1 km^2 to 27.6 km^2 (Table 4), the largest of which was identified on Cobb Seamount. The total area of likely VMEs identified over the entire seamount chain is 99 km^2, which covers about 10% of the seamount area in the depth range of 400–1,200 m (see Figure 5).

Table 4. Characteristics of areas identified as likely VMEs by seamount in the Cobb-Eickelberg seamount chain.

Seamount	Peak depth (m)	Total likely VME area (km^2)	Seamount area within the 400–1,200 m depth range (km^2)	Percent of seamount area within 400–1,200 m depth range identified as likely VME
Brown Bear North	655	20.4	102.6	19.8%
Brown Bear South	575	13.7	312.3	4.4%
Cobb	24	27.6	179.0	15.4%
Corn	380	6.9	121.2	5.7%
Eickelberg	786	2.1	30.6	6.9%
Eickelberg Ridge	739	11.0	48.2	22.7%
Hoh	1199	2.1	7.2	29.5%
Pipe	893	2.1	16.3	13.0%
Warwick	510	13.	134.8	9.9%
Total	–	99.2	953.0	10.4%

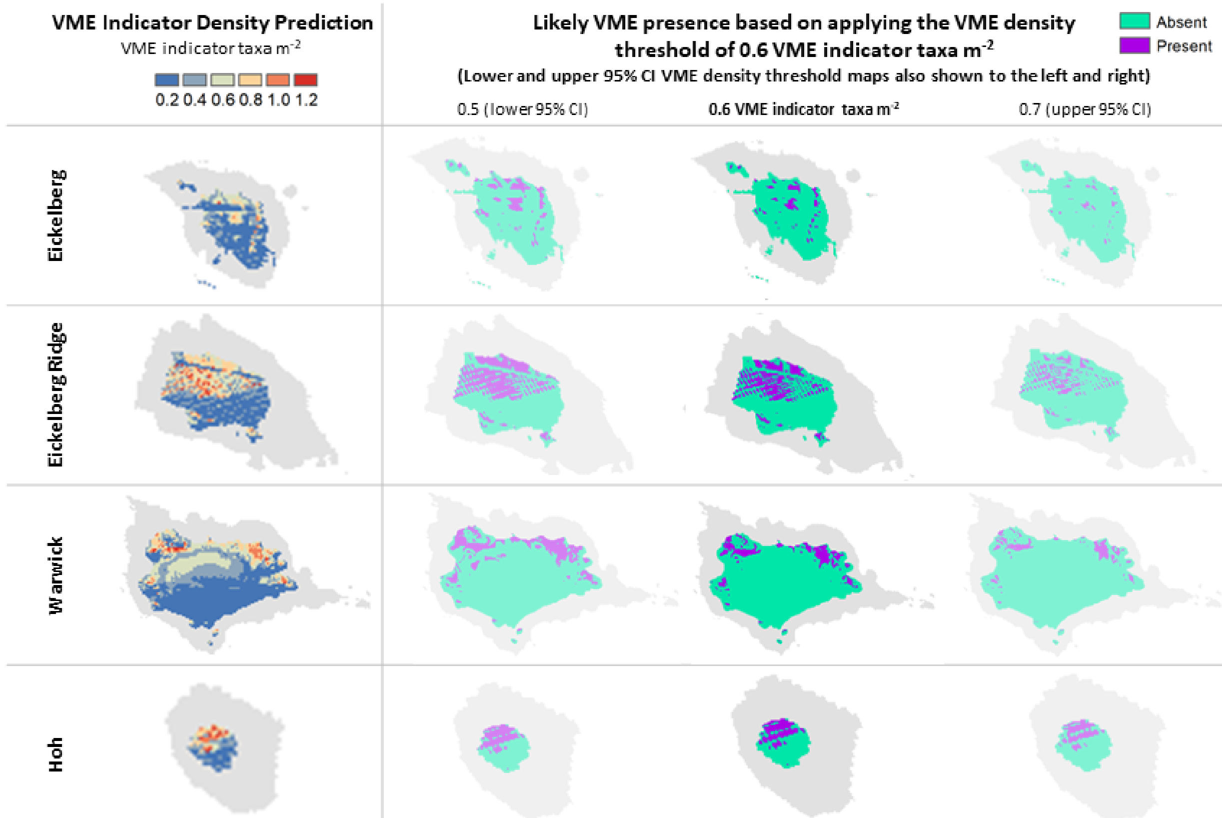


Figure 5a. VME indicator density model prediction maps and likely VME presence by seamount (not to scale). Likely VME presence maps using the lower and upper 95% confidence interval of the VME density threshold (0.5 and 0.7, respectfully) is shown for comparison. The grey shaded areas represent depths outside of the prediction area, which was limited to 400–1,200 m.

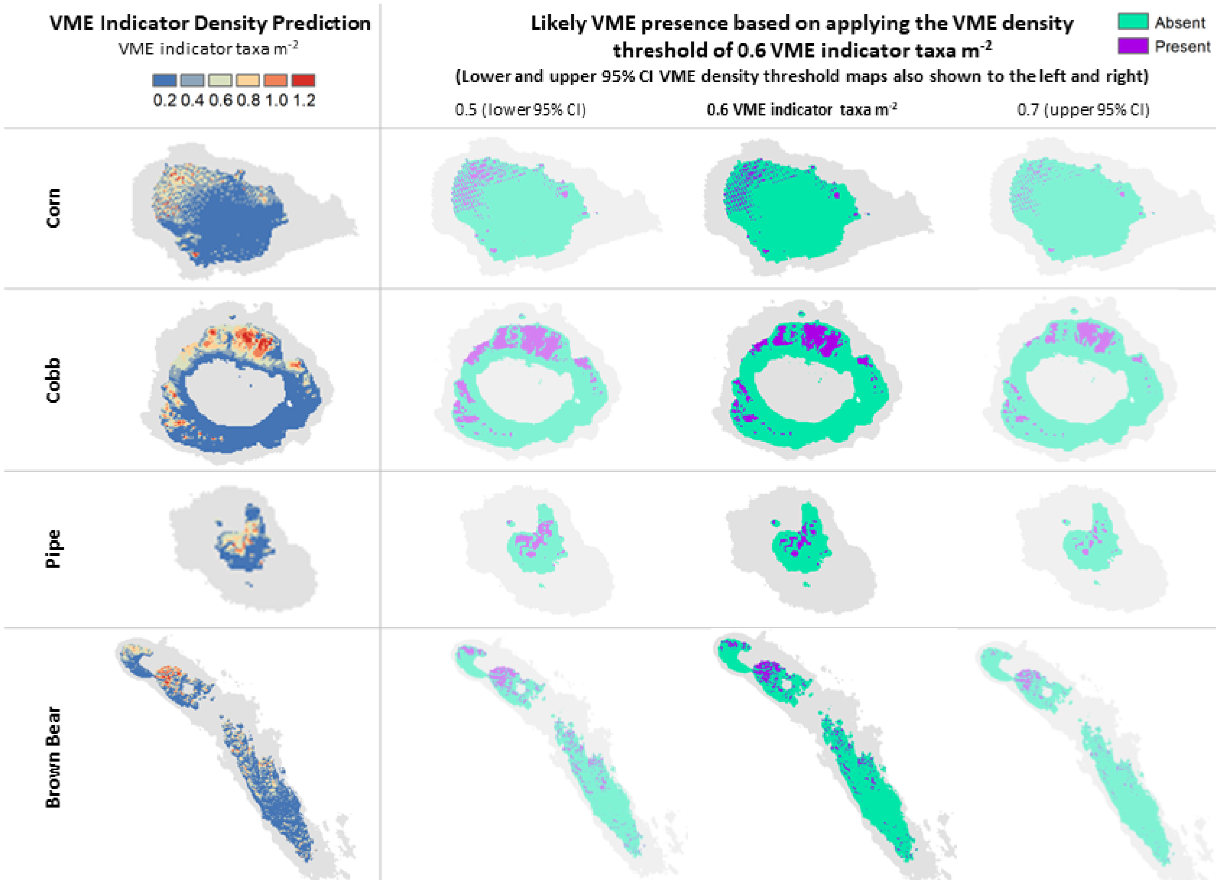


Figure 5b. Continuation of Figure 5a.

Sources of Uncertainty

Limited available data:

The key source of uncertainty for identifying VMEs and likely VMEs is the limited amount of annotated visual data available in the eastern part of the NPFC CA. This data limitation means there is uncertainty associated with the threshold calculated with the methodology adapted from Rowden et al. (2020). Use of the mean Cobb Seamount-specific VME indicator density threshold (0.6 indicator taxa m^{-2}) results in identification of five VMEs (Table 3), but when the lower (0.5 indicator taxa m^{-2}) and upper (0.7 indicator taxa m^{-2}) 95% confidence interval threshold values are used, 10 and 2 VMEs are identified on Cobb Seamount, respectively (Figure 6). Similarly, when the Cobb Seamount-specific lower (0.5 indicator taxa m^{-2}) and upper (0.7 indicator taxa m^{-2}) 95% confidence interval threshold values are applied regionally to identify likely VMEs, they correspond to identification of 155 and 69 km^2 total area on the Cobb-Eickelberg seamount chain, respectively. Only 0.001% of the Cobb-Eickelberg seamount chain was assessed for the presence of VMEs with visual surveys in 2012 (Curtis et al. 2015) between 400 and 1,200 m depth, leaving additional areas of VMEs probably undetected on Cobb Seamount and other seamounts in the study area (Figure 1).

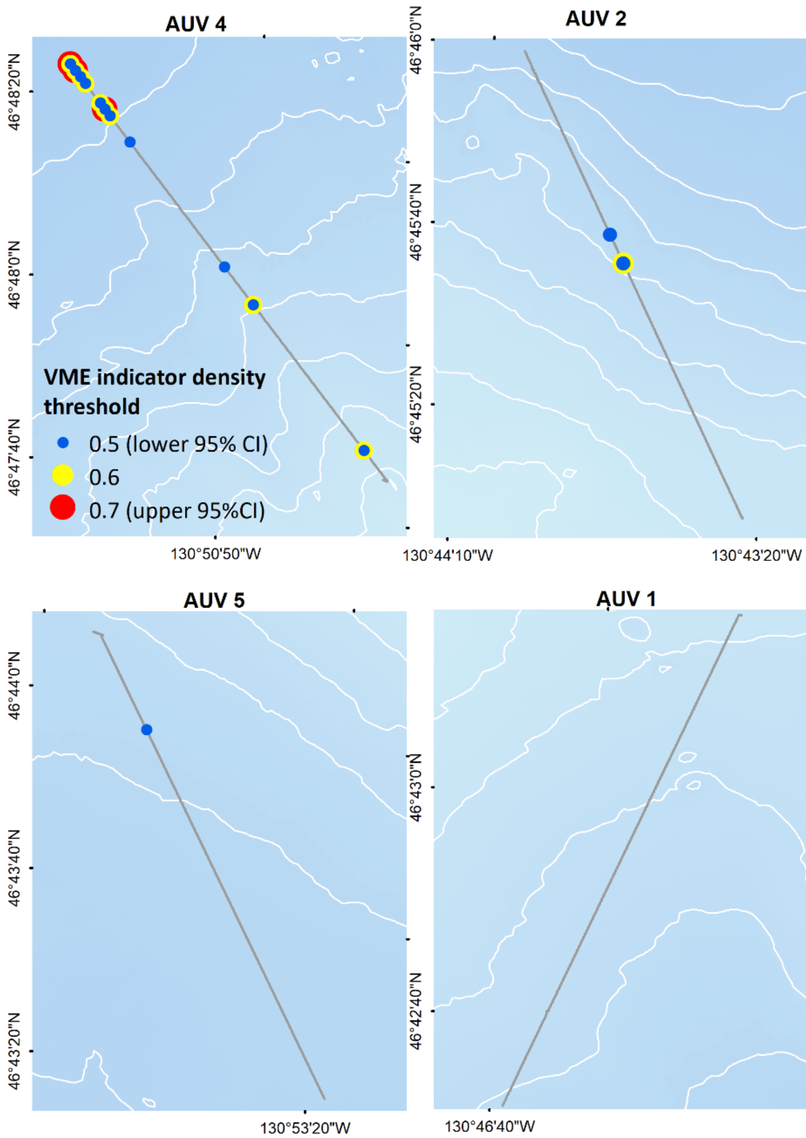


Figure 6. VMEs identified on Cobb Seamount using the mean threshold value of 0.6 (yellow circles) as well as the lower and upper 95% confidence interval threshold values (blue and red circles, respectively). White lines are 100 m depth contour lines and grey lines are AUV transect lines (see Curtis et al. 2015).

The representativeness of Cobb Seamount and extrapolation to nearby seamounts that may differ:

The visual data collected on Cobb Seamount were used to predict the distribution of likely VMEs on six other seamounts and one ridge in the Cobb-Eickelberg seamount chain. These seven geological features may or may not be similar in terms of benthic community structure or environmental variables that influence the distribution of seamount taxa. For example, additional NPFC VME indicator taxa are known to occur on other nearby seamounts (e.g., bubblegum corals on Warwick Seamount), but are not recorded on Cobb Seamount AUV transects. Cobb Seamount is unusual in that its summit is within 30 m of the surface (Parker and Tunnicliffe 1994), whereas most seamounts in this region are much deeper (Table 4).

Moreover, the small sample size (n = 4 AUV transects) used to calculate VME indicator densities and the non-random sampling design (Curtis et al. 2015) could have introduced spatial bias in the dependent data used to predict the distribution of likely VMEs.

Areas outside the depth range remain unassessed:

Because the available visual data are from 436–1,154 m in depth on Cobb Seamount, shallower and deeper areas on Cobb Seamount have not been assessed in terms of the location of VMEs. Moreover, the density of VME indicators were only predicted at depths of 400–1,200 m throughout the Cobb-Eickelberg seamount chain. Thus, areas shallower than 400 m and deeper than 1,200 m have not been assessed in terms of the location of likely VMEs.

Impact of pre-existing fishery damage:

Bottom-contact fishing is known to damage corals and sponges and other epifauna (see review by Clark et al. 2016). There is a long history of bottom-contact fishing on Cobb Seamount (Du Preez et al. 2020). Historical fishing-related impacts have potentially reduced the abundance and density of NPFC's VME indicators and associated epifauna on Cobb Seamount. A lower density of VME indicators and associated species richness would influence the calculation of a regional VME indicator density threshold if there are fewer data points at higher densities of VME indicators and/or associated species richness of epifauna and fishes. By the same token, a narrower range of VME indicator densities could also mean a smaller environmental niche space used to predict the density of VME indicators and identify the location of likely VMEs.

Exclusion of potential VME indicator taxa:

There are structure-forming organisms excluded in calculations of the VME indicator density threshold because they were not considered by the NPFC as VME indicator taxa. For example, pennatulacean species were present on the AUV transects and are tall, structure-forming organisms. Excluding these taxa likely influenced the calculation of the regional VME indicator density threshold used to identify the location of VMEs and likely VMEs.

Limiting the assessment to only one of the five FAO VME criteria:

This science advice draws on only one of five FAO criteria for identifying VMEs: structural complexity (FAO 2009). Future research that focuses on one or more of the other four FAO VME criteria (uniqueness or rarity; functional significance of the habitat; fragility; life history traits of component species that make recovery difficult) may lead to additional VMEs and likely VMEs identified along the Cobb-Eickelberg seamount chain.

Selection and resolution of modelled environmental variables:

It is possible that the suite of independent data layers used to model the relationship between VME indicator density and associated richness of epibenthic species was incomplete. Indeed, based on model results it is suggested that there are likely other factors influencing species richness, as it was noted that high diversity was sometimes observed at zero or low densities of VME indicator taxa. Similarly, the suite of environmental layers used to predict the density of VME indicators throughout the Cobb-Eickelberg seamount chain may have been incomplete. One key environmental factor that could not be modelled in either case was the type of substrate, which may contribute to structural complexity in some places and to suitable habitat for corals and sponges (Guinotte and Davies 2014; Masuda and Stone 2015) and associated fishes and epifaunal species. Also, the grid size of environmental data layers (100 m by 100 m) limits identifying smaller areas of likely VMEs.

CONCLUSIONS AND ADVICE

The method developed by Rowden et al. (2020) to identify VMEs in the South Pacific Ocean was adapted to the eastern NPFC CA to identify VMEs and likely VMEs. Five observed VMEs were identified by applying a VME indicator density threshold to available visual data on Cobb Seamount.

Models predict that there are areas with high VME indicator density on all seamounts in the Cobb-Eickelberg seamount chain. Likely VMEs were predicted to exist on seven seamounts and one ridge in the study area (Figure 5). Cobb Seamount had the largest total area identified as likely VMEs.

Key conclusions and advice:

- FAO's VME identification criterion of structural complexity was used to provide advice on the location of VMEs and likely VMEs in the eastern part of the NPFC's CA, specifically along the Cobb-Eickelberg seamount chain.
- Five areas were identified as VMEs on Cobb Seamount ranging in size from approximately 50 m^2 to 200 m^2 with a combined area of 508 m^2.
- Likely VMEs were identified on seven seamounts and one ridge in the study area. These were patchily distributed and the total area per geological feature ranged from 2.1 km^2 to 27.6 km^2.
- The total area of likely VMEs identified over the entire seamount chain is 99 km^2, which covers about 10% of the area in the depth range of 400–1,200 m.
- This work is a good first step that identifies VMEs and likely VMEs using the FAO criterion of structural complexity. Application of the adapted methodology, however, does present some underlying uncertainties, particularly with identification of likely VME areas.
- Other VMEs and likely VMEs will probably be identified as new data become available and any of the four other FAO criteria for identifying VMEs are evaluated.

Future Research

Periodic review of methods and data is a key step of the NPFC's framework for identifying VMEs and likely VMEs (Warawa et al. 2022). Future research that would support this periodic review includes:

1. Collecting new visual data on the distribution of VME taxa, associated taxa, and geological features of the Cobb-Eickelberg seamount chain to evaluate the variability of the regional VME indicator density threshold across seamounts and depths;
2. Refining calculation of the regional VME indicator density threshold when new visual survey data become available;
3. Improving predictions of the location of likely VMEs when new visual data become available;
4. Ground-truthing predicted areas of likely VMEs with visual surveys; and
5. Investigation of other approaches to identify VMEs and likely VMEs based on the other four FAO VME criteria.

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Warawa	Devon	DFO Science

SOURCES OF INFORMATION

This Science Advisory Report is from the January 23–25, 2024 regional peer review on the Identification of Vulnerable Marine Ecosystems on Seamounts in the North Pacific Fisheries Commission Convention Area using Visual Surveys and Distribution Models. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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ISSN 1919-5087
ISBN 978-0-660-71906-1 Cat No. Fs70-6/2024-038E-PDF

Correct Citation for this Publication:

DFO. 2024. Identification of Vulnerable Marine Ecosystems on Seamounts in the North Pacific Fisheries Commission Convention Area using Visual Surveys and Distribution Models. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/038.

Aussi disponible en français :

MPO. 2024. Recensement des écosystèmes marins vulnérables des monts sous-marins dans la zone de la Convention de la Commission des pêches du Pacifique Nord au moyen de relevés visuels et de modèles de répartition. Secr. can. des avis. sci. du MPO. Avis sci. 2024/038.