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# A Framework for Identifying Vulnerable Marine Ecosystems in the North Pacific Ocean

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**Abstract**

The United Nations General Assembly called upon States to manage fisheries sustainably and protect vulnerable marine ecosystems (VMEs) from destructive fishing practices when they adopted Resolution 61/105 in 2006. The North Pacific Fisheries Commission (NPFC) has a mandate to identify and protect these ecosystems from significant adverse impacts (SAIs). Specifically, the Convention on the Conservation and Management of High Seas Fisheries Resources (henceforth the Convention) in the North Pacific Ocean requires NPFC members to develop a process to identify VMEs using the best scientific information available. NPFC identified four orders of corals as indicators of potential VMEs but has not yet developed objective and quantitative definitions of VMEs based on catches, visual surveys, predictive models, or other sources of information. We propose the first step in a framework to use the best available data to identify VMEs, including fisheries bycatch data, visual data, predictive models, and other sources of available information. Canada primarily has limited visual data and extrapolated model predictions of the distribution of VME indicator taxa in the northeast part of NPFC's Convention Area where it fishes for Sablefish (*Anaplopoma fimbria*). We propose to use these data to begin developing quantitative methods for VME identification that integrate these data in a manner that aligns with the precautionary approach, the Convention, and the research plan of NPFC's Scientific Committee.

## Introduction

Regional Fisheries Management Organizations (RFMOs), such as the North Pacific Fisheries Commission (NPFC), are mandated by the United Nations to identify and protect vulnerable marine ecosystems (VMEs) from bottom fishing. In 2006, the United Nations General Assembly Resolution 61/105 called upon "States to take action immediately, individually and through fisheries management organizations and arrangements, and consistent with the precautionary and ecosystem approaches, to sustainably manage fish stocks and protect VMEs, including seamounts, hydrothermal vents and cold water corals, from destructive fishing practices, recognizing the immense importance and value of deep sea ecosystems and the biodiversity they contain" (UNGA

2006).

Since the 1980s, there has been growing international interest and commitment to protecting biodiversity in the high seas, including areas that are affected by bottom contact fishing gear. The United Nations Convention of the Law of the Sea (UNCLOS)[1] called for an unequivocal need to protect and preserve marine environments. The Convention on Biological Diversity (CBD)'s Article 8(d) – *In-situ Conservation* – states: "Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings…" In its research plan, NPFC's Scientific Committee recognizes the importance of developing a process for identifying VMEs and so that they can be protected from bottom fishing practices.

Bottom fisheries can affect benthic ecosystems in several ways. The capture process can kill many non-target fishes and invertebrates as bycatch (Alverson et al. 1994). Removing or damaging species with influential roles, including biogenic taxa such as corals and sponges, can change the community structure (Thrush and Dayton 2002). Further, derelict fishing gear can continue to influence community structure for decades as ghost fishing gear (Du Preez et al. 2020). Discussions have been ongoing for >25 years about the importance of eliminating destructive impacts of bottom fishing in the high seas and establishing networks of protected areas (Druel and Gjerde 2014; FAO 2019).

Article 10(4) of the Convention on the Conservation and Management of High Seas Fisheries Resources in the North Pacific Ocean[2] (henceforth the Convention) asserts that the NPFC shall "develop a process to identify vulnerable marine ecosystems, including relevant criteria for doing so, and identify, based on the best scientific information available, areas or features where these ecosystems are known to occur, or are likely to occur..." The NPFC Scientific Committee 2017-21 Research Plan aims specifically to "develop consensus on criteria used to identify VMEs and how this might be applied in the NPFC." NPFC's Conservation and Management Measures (CMMs) 2019-05 and 2019-06 (NPFC 2019a, 2019b) provide science-based standards and criteria for identification of VMEs and states: "The purpose of the standards and criteria is to provide guidelines for each member of the Commission in identifying VMEs and assessing [significant adverse impacts] of individual bottom fishing activities on VMEs or marine species in the Convention Area." NPFC's Scientific Committee has yet to develop a process for identifying VMEs in the northwest (NW) or northeast (NE) part of the Convention Area (CA), although two areas of potential VMEs have been identified on the Hawaiian-Emperor Seamount Chain[3] in the NW part

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[1] https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf

[2] https://www.npfc.int/system/files/2017-01/Convention%20Text.pdf

[3] http://www.fao.org/in-action/vulnerable-marine-ecosystems/vme-database/en/vme.html

of the Convention Area.

Part of the reason that a process for identifying and protecting VMEs has not been established yet by NPFC Members, is the lack of clarity around the definition of what constitutes a VME. Although NPFC currently recognizes four taxonomic groups of corals (Alcyonacea, Antipatharia, Gorgonians, Scleractinia) as VME indicator taxa, “there is no definitive list of specific species or areas that are to be regarded as VMEs” (see CMM2019-05 and CMM2019-06, NPFC 2019a, 2019b). Moreover, NPFC has not developed objective and quantitative definitions of VMEs based on catches, visual surveys, predictive models, or other sources of information. A number of VME indicator data sources exist, such as visual data from drop cameras, remotely operated vehicles (ROVs) or autonomous underwater vehicles (AUVs) in the NPFC CA (e.g. Curtis et al 2015; Du Preez et al. 2016; Miyamoto and Kiyota 2018; Baco et al. 2020; Dautova 2019; Dautova et al 2019; Du Preez et al 2020 and see contributions in Curtis and Kiyota 2020). Species distribution models (SDMs) have also been developed that could be useful in predicting the distribution of VME indicator taxa in the NE and NW Pacific Ocean (e.g. Chu et al 2019 and see contributions to Curtis and Kiyota 2020).

In this working paper we propose a decision tree to guide NPFC Members in identifying the best scientific information available to assess potential VMEs in the NPFC CA and meet the objective of defining VMEs in the NPFC Scientific Committee’s Research Plan and article 10(4) of the Convention.

**Current VME identification strategies in the NPFC**

The Food and Agriculture Organization (FAO) developed guidelines on VME identification in its International Guidelines for the Management of Deep-Sea Fisheries in the High Seas (FAO 2009)[4] and identified criteria for what constitutes a VME: uniqueness or rarity, functional significance of habitat, fragility, life history traits of component species that make recovery difficult, and structural complexity. The FAO also defined vulnerability in the context of how easily disturbed and slow to recover an ecosystem is following disturbance. Specifically, the FAO noted that ecosystems that take 5-20 years to recover are vulnerable, especially if the frequency of disturbance is faster than the time to recover. These criteria have been used with visual and fisheries data to identify areas that are potentially VMEs on Koko, Kammu, and Colahan Seamounts in the Emperor Seamount Chain (Miyamoto and Kiyota 2018).

VME indicator taxa are recognized by many RFMOs around the world. These usually include taxa,

[4] http://www.fao.org/fishery/topic/166308/en

such as deep-sea corals and sponges, that have late maturity, and are fragile, structurally complex, and support diverse communities of associated species. The four taxonomic groups of corals currently recognized by NPFC as VME indicator taxa meet these criteria. Annex 2.1 of NPFC's CMM2019-05 and CMM2019-06 lists examples of potential vulnerable taxa, communities, and habitats that potentially support VMEs. In addition to the four taxonomic groups of corals recognized by NPFC, taxa meeting the criteria include hydrocorals, communities of some sponges, other dense emergent fauna (e.g. hydroids, bryozoans), and endemic vent and seep communities. Physical features recognized as potentially supporting VMEs include seamount summits and flanks, canyons, and hydrothermal vents (NPFC 2019a, 2019b). The South Pacific Regional Fisheries Management Organization (SPRFMO) [5] recognizes corals (Scleractinia, Anthoanthecata, Antipatharia, Pennatulacea), sponges (Demonspongiae, Hexactinellid) and echinoderms (Brinsingida, Crinoidea) as VME indicators. Other RFMOs recognize additional taxa as indicators of VMEs (see Du Preez et al 2020).

Experts recognized that potential VMEs differ in the eastern and western parts of the NPFC CA. Although sponges and corals occur on both sides of the North Pacific Ocean, sponges are reported to be more common in the east than in the west. By contrast, Gorgonian and Scleractinian corals may be more prevalent in the Emperor Seamounts than the seamounts in the NE Pacific Ocean (Rooper and Kiyota 2018).

Defining the amount of a VME indicator taxon that constitutes a VME has proven difficult. As Kenchington et al. (2014) noted: "The FAO guidelines do not explicitly define the distinction between a VME and a VME indicator species/taxon, although it is clear that a single occurrence of an indicator does not constitute a VME, neither does the full distribution of a species/taxon. However, under the FAO criterion of structural complexity the term "Significant concentration" is used to identify the level of aggregation which is expected, even though it is given without an operational context." There is limited data in the NPFC CA to identify areas of "significant concentration" compared to the volume of data available in the North Atlantic Ocean (see Kenchington et al. 2014 and Morato et al 2018).

Although NPFC Members have limited amounts of data available in the CA, the Preamble to the CBD notes that "… where there is a threat of significant reduction of loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat." The CBD's approach is followed by many other organizations, including NPFC (see Annex 2 of NPFC's CMM2019-05 and CMM2019-06, NPFC 2019a and 2019b). Data are usually limited in the high seas and uncertainty in scientific information may be used to justify

[5] https://www.sprfmo.int/

inaction (Walters and Martell 2004, as in Clark and Dunn 2012). Thus, we encourage NPFC Members to move forward with using the best available information to assess areas that may be VMEs even when there is uncertainty associated with those data. We also encourage NPFC Members to continue developing methods for quantitatively identifying VMEs. Relying on expert judgment to identify VMEs is usually inconsistent and uncertainty associated with expert definitions is poorly characterized (see Burgman et al 2011 and Martin et al 2012 in Morato et al 2018). Indeed, use of expert judgement alone can be criticized for inconsistency and lack of transparency (Morato et al. 2018).

**Proposed first step in quantitatively identifying VMEs**

Before decisions are made on VME designation and protection, it is important to first choose an appropriate spatial scale for the ecological units. Understanding the resolution of relevant data, including environmental variables and the accuracy of fisheries data can help inform this decision. For example, environmental data for use in developing SDMs are available for each 1 $km^2$ in the North Pacific Ocean (Curtis and Kiyota 2020), whereas the location of fisheries landings may be available at a larger resolution. Another way to make decisions about the spatial resolution of areas to assess is to consider the type of geological feature that may host VMEs. Annex 2 of CMM2019-05 and CMM2019-06 (NPFC 2019a and 2019b) encourages scientists to use the FAO criteria for identifying VMEs to select the appropriate spatial scale (e.g. within or among seamounts and within or among complexes of seamounts). When the spatial resolution of the ecological unit is selected, scientists can begin making decisions about what types of data are available to assess the potential for VMEs to occur in an ecological unit.

In general, approaches for identifying VMEs can be grouped into three categories: the first is based on analysis of catches, the second is based on analysis of visual data from cameras, and the third is based on predictions from SDMs. In practice, the methods used to identify VMEs differ among RFMOs (Ardron et al 2014). For instance, the Northwest Atlantic Fisheries Organization (NAFO) analyzes catch data with a kernel density method to identify areas with significant concentrations of VME indicators (Kenchington et al. 2014). Similarly, Morato et al. (2018) developed a Multi Criteria Assessment (MCA) method to analyze VME indicator catch data in the Northeast Atlantic Fisheries Organization (NEAFO). SPRFMO has utilized SDMs extensively to define VMEs and combined this with visual groundtruthing data (Rowden et al. 2017; Anderson et al. 2016). For the NPFC, Annex 2 of CMM2019-05 and CMM2019-06 specifically identifies biological samples, visual data, and “other information that is relevant to inferring the likely presence of VMEs” to be used in defining VMEs (NPFC 2019a and 2019b). In practice, two VME closures in the NPFC CA have been based in part on visual survey data (Fisheries Agency of Japan 2008).

The main challenge with using biological samples obtained from fisheries bycatch to identify VMEs is that catches may not represent the true benthic community structure and density of VME indicator taxa (Auster et al 2011, as in Morato et al 2018). For instance, longline trap gear, which is used by Canada to catch Sablefish (*Anaplopoma fimbria*) in the NE Pacific Ocean, does not retain NPFC indicator taxa very well even though that gear has been shown to damage VME indicator taxa in Canadian waters (Gauthier 2017). The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) acknowledges longline gear is not designed to capture and retain VME indicators and the absence of VME indicators in longline gear catch does not signify an absence of VMEs in the areas fished (Cryer and Soeffker 2019).

Ideally, VMEs are identified with the use of visual data from drop cameras, ROVs, or AUVs similar to data collected by Japan, Russia, and the United States on the Emperor Seamounts (Miyamoto and Kiyota 2018; Dautova 2019; Dautova et al 2019; and see contributions in Curtis and Kiyota 2020) and Canada in the NE Pacific Ocean (Curtis et al. 2015; Du Preez et al. 2016, 2020). Such visual data allows more accurate and quantitative descriptions of the benthic community composition, including densities (see Fabri et al 2014, as in Morato et al 2018) and size classes. Experts around the world are actively in the process of developing quantitative definitions of VMEs based on visual data (Amy Baco-Taylor, pers. comm.). The challenge with visual data is that they are costly to collect and analyze and are only available for tiny fractions of the seabed (Morato et al 2018).

Species distribution models are increasingly used to predict the distribution of VME indicators in the deep sea where data are limited or absent (Vierod et al 2014, as in Anderson et al. 2016). Japan has used SDMs to identify potential VMEs on the outer margins of main fishing grounds on the Emperor Seamounts (Miyamoto and Kiyota 2018; Rooper and Kiyota 2018). One of the benefits of using predictive models is the capacity to extrapolate or interpolate in unsampled areas or where data are sparse (Kenchington et al. 2014). Moreover, spatially-explicit measures of uncertainty can be developed for model predictions (Anderson et al 2016; Chu et al 2019) and predictions can be validated with catch or visual data available in an area of interest.

In keeping with NPFC's approach to use the best available scientific data (see CMM2019-05 and CMM2019-06 in NPFC 2019a, 2019b), we propose to use a decision tree as the first step in the identification of VMEs using the best information available (Figure 1). Our proposed decision tree is related to use of bycatch data, visual data, predictive models, and other sources of available information.

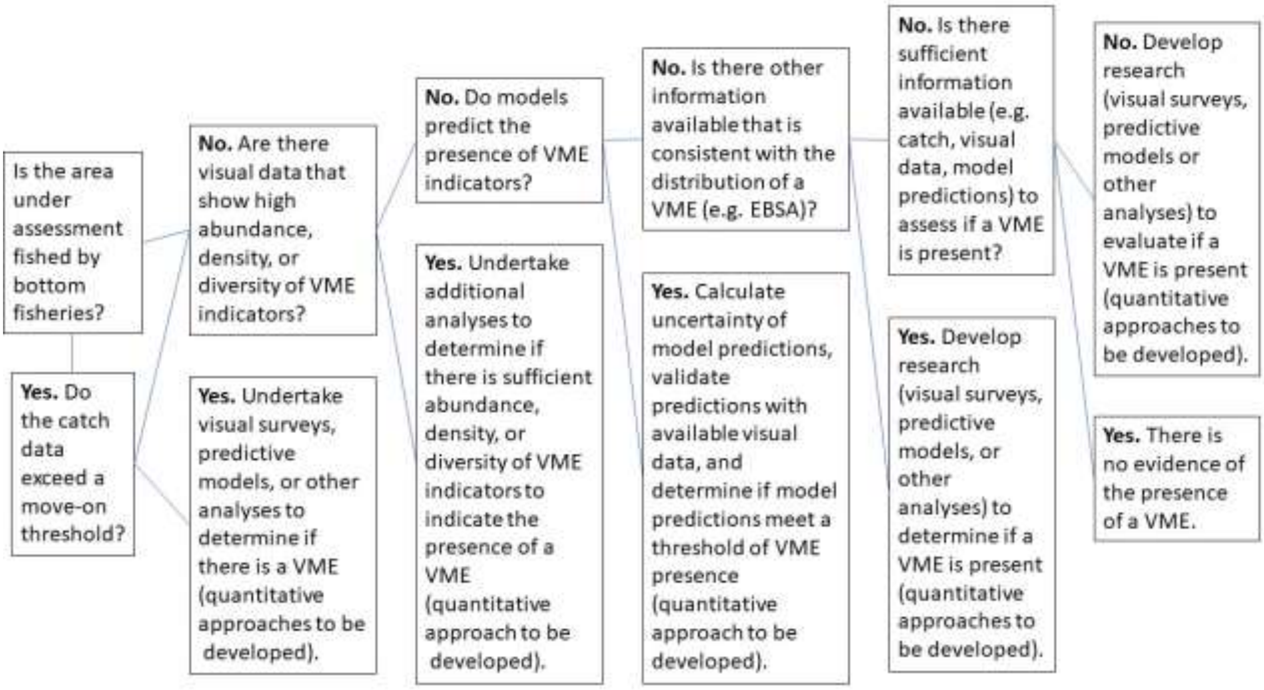


*Figure 1. Proposed decision tree to identify data that can be used to identify VMEs in the NPFC CA.*

**An example application in the NE Pacific Ocean**

CMM2019-05 and CMM2019-06 (NPFC 2019a, 2019b) state "Each member of the Commission, using the best information available, is to decide which species or areas are to be categorized as VMEs, identify areas where VMEs are known or likely to occur, and assess whether individual bottom fishing activities would have SAIs on such VMEs or marine species." There is limited data available to identify VMEs in the NE Pacific Ocean on seamounts currently fished for Sablefish. Although corals and sponges are known or assumed to occur on the seamounts where Sablefish are caught in the NPFC CA, bycatch of NPFC indicator taxa have never exceeded 50 kg and triggered corresponding management action.

However, a joint visual survey by Fisheries and Oceans Canada (DFO) and the United States' National Ocean and Atmospheric Administration (NOAA) was undertaken in 2012 on Cobb Seamount, just outside of national waters in the NPFC CA (Curtis et al. 2015, Du Preez et al. 2016, 2020). ROVs and an AUV were used to collect video and still photographs of organisms living on the seafloor. The survey aimed to identify the species and occurrences of coldwater corals and sponges, collect data to characterize benthic community structure and habitat, and document any evidence of fishing gear or related impacts (Curtis et al. 2015). Approximately 1600 images of the seafloor collected between 34 and 1154 m depth were used to describe the distribution of benthic communities on the seamount (Du Preez et al. 2016). NOAA undertook a survey of Warwick Seamount in 2002, which is also in the NE part of the NPFC CA. There have been a few other visual surveys of seamounts in the NE Pacific Ocean. Collectively, these visual surveys represent a small area of the NPFC CA that has historically been fished for Sablefish and other bottom fishes by Members.

Although Canada has limited catch and visual data of NPFC indicator taxa that could be used to identify VMEs in the CA, it does have considerable data in its national waters to predict the distribution of suitable habitat of VME indicator taxa in the NE part of the NPFC CA. Those data were used to predict the distribution of suitable habitat for Alcyonacea (including gorgonians), Antipatharia, and Scleractinia, as well as taxa recognized as VME indicators in other RFMOs: Pennatulacea, glass sponges, and demosponges (Chu et al 2019). The predicted distributions of VME indicator taxa were supported by data collected during visual surveys of seamounts in Canada's national waters (Chu et al 2019) and by models developed by a PICES working group (WG 32, see contributions in Curtis and Kiyota 2020).

Apart from limited visual data of VME indicator taxa in the NPFC CA and model predictions that are based on catch data in national waters, there is other information that is consistent with the distribution of VMEs in the northeastern part of the NPFC CA. Specifically, ecologically and biologically significant areas (EBSAs), which share characteristics with VMEs, were identified by the CBD in 2013. Those EBSAs include more than 33 seamounts within eight complexes in the NE Pacific Ocean and range from the Gulf of Alaska to the coasts of British Columbia, Canada, and Washington and Oregon in the USA (CBD 2014; Secretariat of the Convention on Biological Diversity 2018).

Using the best available data such as these, Canada and other Members can identify potential VMEs that are characterized by one or more of FAO's VME criteria. The precautionary approach encourages Members to protect such areas even when there is uncertainty in the available data. A thorough utilization of existing data guided in part by the framework described above will allow NPFC Members to begin to identify and protect VMEs in the CA in a manner that is consistent with the precautionary approach. Combining assessment of ecosystems in the NPFC CA using the best available data with periodic analyses when new information becomes available will allow the NPFC to remain in compliance with the Convention and related CMMs.

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