7TH MEETING OF THE COMMISSION

The Hague, The Netherlands, 23 to 27 January 2019

COMM 7 – Prop 03.1
A proposal for a revised Bottom Fishing Conservation and management Measure for SPRFMO

New Zealand

South Pacific Regional Fisheries Management Organisation

7th Meeting of the Commission

A proposal for a revised Bottom Fishing Conservation and Management Measure for SPRFMO

New Zealand

21 December 2018

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Purpose

The purpose of this paper is to accompany the proposal for a revision to CMM 03-2018 on the management of bottom fishing within the SPRFMO Convention Area (CMM COMM7-Prop16), jointly submitted by New Zealand and Australia, providing further background and rationale for the proposal.

Rationale for a Conservation and Management Measure

The revised CMM is a comprehensive set of rules based on a spatial management approach that aims to ensure the long-term conservation and sustainable use of deep-sea fishery resources. Australia and New Zealand's proposed approach aims, through the protection of a large proportion of the distribution of vulnerable marine ecosystems (VMEs), to provide an assurance that bottom fishing within the Evaluated Area will not have significant adverse impacts (SAI) on VMEs should the proposed measures be adopted. The SPRFMO Scientific Committee has reviewed and agreed that the methodology underpinning the proposal is appropriate. The proposal includes:

a) An Evaluated Area[1] within which the distribution of VME indicator taxa has been mapped to a depth of 3000 m using predictive models and which considers cumulative impacts of fishing, an improvement on the existing approach (which considers only individual flag State impact);
b) Three Management Areas within the Evaluated Area in which bottom fishing may be conducted, based on spatial prioritisation modelling, to be implemented consistently across the membership and differentiated by gear (bottom trawling, mid-water trawling and bottom longlining) according to their relative benthic impact;
c) A VME encounter protocol within the bottom trawling Management Area, to be implemented consistently across the membership.
d) Measures to assess, monitor and control bottom fisheries.

The revised CMM envisages two avenues for bottom fishing with a particular gear type in the SPRFMO Convention Area:

(1) In a Management Area[2] (within the Evaluated Area) for that gear type as defined in the revised CMM (CMM 03-2018), or
(2) Anywhere else in the Convention Area under CMM 13-2016 (Exploratory fisheries), or within the Management Area with a gear type other than that provided for in the revised CMM.

[1] The Evaluated Area is those that parts of the Convention Area that are within the area starting at a point of 24°S latitude and 146°W, extending southward to latitude 57° 30S, then eastward to 150°E longitude, northward to 55°S, eastward to 143°E, northward to 24°S and eastward back to point of origin.
[2] The three Management Areas are the 'open' areas, although each Management Area actually comprises several smaller, spatially discrete areas.

These elements of the CMM are discussed in this paper. Precautionary catch limits for orange roughy (*Hoplostethus atlanticus*), on the basis of advice from Scientific Committee, are proposed in the complementary CMM (COMM7-Prop16) (Management of Deepwater Species in the SPRFMO Convention Area). A number of consequential amendments are also proposed to CMM 13-2016 (Exploratory fisheries).

Spatial modelling underpinning proposed management areas

Work to underpin the development of a spatial management regime as part of the revised CMM has been ongoing for several years. At the third meeting of the Scientific Committee (SC-03) in 2015, Australia, New Zealand, and Chile agreed to work together on finalising the various components. After SC-04, a detailed update was provided to the Commission in early 2017 (see Bottom Fishing CMM Information Paper – COMM5-INF05), indicating that a revised bottom fishing CMM would be prepared for consideration by the Commission meeting in early 2018. That paper described progress on the two key pieces of work required to develop candidate spatial management areas: the predictive mapping of vulnerable marine ecosystems (VMEs); and the use of spatial decision-support software to design open and closed areas that would prevent Significant Adverse Impacts (SAIs) on VMEs and provide for a fishery.

Records of the location or density of VMEs or VME indicator taxa such as reef-forming corals within the SPRFMO Convention Area are sparse and inadequate to map the distribution of VMEs directly. This means that predictive models are required to map where VMEs are likely to occur. During 2017 and 2018, New Zealand concluded the work it has been conducting for many years, generating models that cover the Evaluated Area - from the South Tasman Rise in the west to the southern tip of the Louisville Ridge in the east (Figure 1). All available biological, physical and chemical information from depths between 200 and 3000 metres was used to predict habitat suitability (and hence the distribution) of a variety of VME indicator taxa (Georgian et al. 2019[3], e.g., Figure 2).

[3] Georgian, S. E., Anderson, O. F., & Rowden, A. A. (2019). Ensemble habitat suitability modeling of vulnerable marine ecosystem indicator taxa to inform deep-sea fisheries management in the South Pacific Ocean. *Fish Res*, *211*, 256-274.

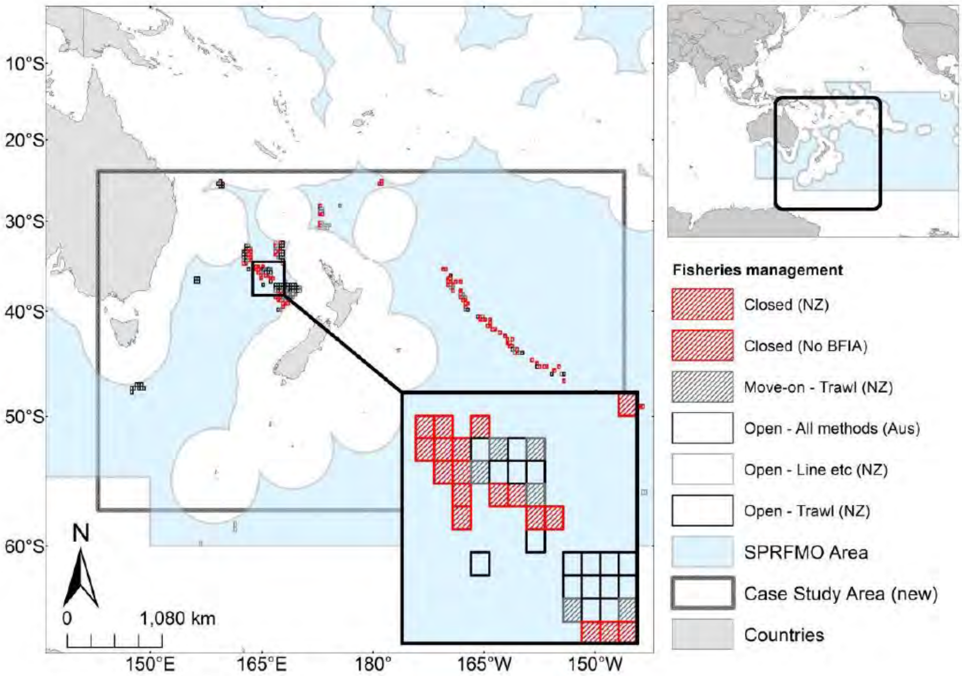


Figure 1: Location of the area within which the distribution of VME indicator taxa was modelled (grey box) overlaid with existing open, closed, and move-on management blocks.

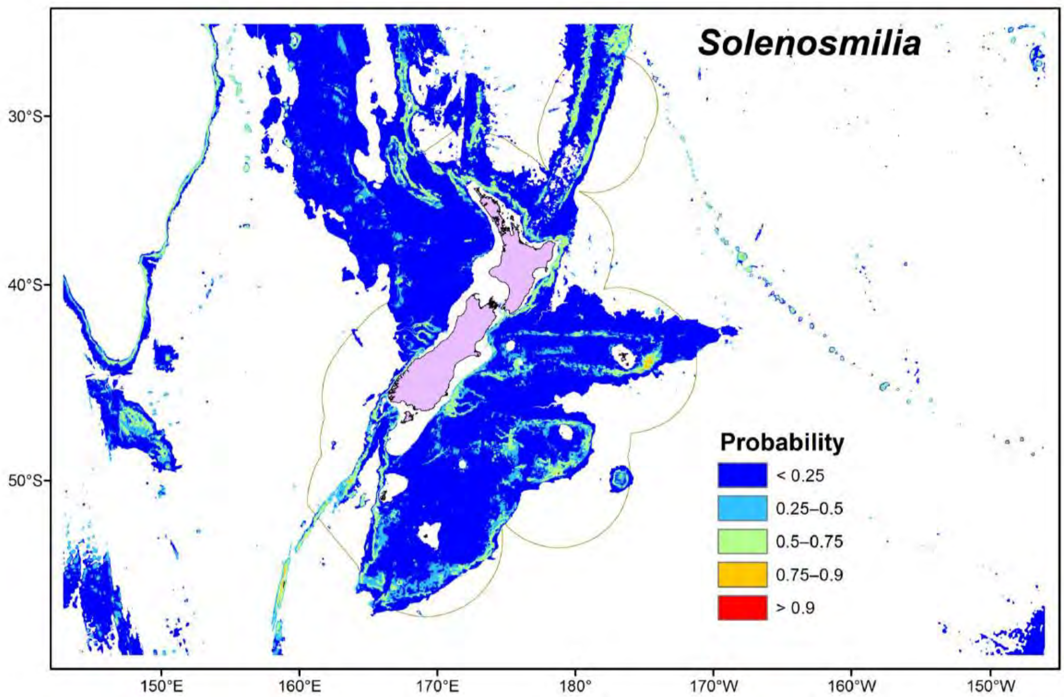


Figure 2: Example model predictions of habitat suitability for the stony coral *Solenosmilia variabilis*. Only information outside EEZs was used in the design of candidate spatial management areas for the bottom fishing CMM.

The modelled distribution maps of VMEs and the reported distribution of fishing can be used within spatial decision-support software to prioritise areas to be closed to fishing (to prevent SAIs on VMEs) and areas to be opened to fishing (to provide for a viable fishery). New Zealand has been using Zonation software for this purpose (Moilanen et al. 2009[4]) because it provides a flexible and powerful tool for policy makers, scientists and stakeholders to explicitly consider the costs and benefits of opening or closing particular areas to bottom fishing. Zonation produces a nested hierarchical prioritization of the landscape based on the representation of the VME indicator taxa included within the analysis. Highly ranked cells within the prioritization are those locations that contribute most to VME representation and where impacts of fishing should be minimized, and low ranked cells are those areas that contribute least to VME representation and are more compatible with bottom fishing. The low ranked areas within the Zonation outputs have contributed to informing the location of the Management Areas; consequently, most of the areas that are predicted to contain VMEs occur in closed areas and are protected from fishing impacts. Although both the habitat suitability models and the outputs of the Zonation model are spatialized at the scale of 1 km x 1 km squares, the proposed spatial management areas have been designed at a minimum scale of approximately 6 minutes of arc (or approximately 10 km). This is the finest scale that the Scientific Committee has previously recommended would be useful for management.

In the months leading up to the fifth meeting of the Scientific Committee (SC-05) in September 2017, New Zealand and Australia convened five workshops (a meeting of the Scientific Committee' Deep Water Working Group, chaired by Chile, in May 2017 in Hobart, primarily scientific, and four in Wellington in July-August 2017 involving Australian and New Zealand stakeholders). These workshops sought to guide the development of appropriate models to predict the distribution of VME indicator taxa and agree on the objectives and key settings for the application of Zonation software. The outputs from these workshops and other research relevant to the revised CMM were considered in detail by SC-05, who appreciated that significant improvements in the protection of VMEs could probably be achieved at reduced cost to the fishing industry. SC-05 agreed that the scientific approach was appropriate and, in particular, in its report, SC-05:

- Noted (para 108) the substantial progress made in capacity development and agreement on analytical methods that can be used in the design of candidate spatial management areas to meet the objective of the SPRFMO Commission;
- Agreed (para 108) that the analytical approach using Zonation decision-support software is scientifically defensible and appropriate;
- Agreed (para 111) that the proposed spatially explicit bottom fishing impact evaluation methodology is appropriate for assessing the impacted area, intensity of impact by location, and likely impact on benthic epifauna;
- Noted (para 114) that further work is required and that New Zealand and Australia will continue to progress the development of a revised bottom fishing CMM in order to submit a proposed draft CMM to the Commission meeting in early 2018;

[4] Moilanen, A., Kujala, H., Leathwick, J. (2009) The Zonation framework and software for conservation prioritization. Pp. 196-210 in Moilanen, Wilson and Possingham (Eds.), Spatial Conservation Prioritization, Oxford University Press.

- Agreed (para 108, 114) to convene or otherwise support an additional workshop in October / November 2017 to finalise the Zonation analyses and oversee scientific analyses required to underpin the design of candidate spatial management areas.

Following SC-05, and in line with its advice, New Zealand convened two further stakeholder workshops in Wellington in November 2017 to further develop the Zonation analyses and provide for the scientific analyses on the design of candidate spatial management areas. These areas were included in an information paper and a descriptive supporting paper to Commission in early 2018 (COMM6-INF09). Australian and New Zealand stakeholders, and both scientific and policy personnel from both nations were included in these meetings. As with previous stakeholder workshops, the focus of the discussions was around maps showing relative priorities for fishing and protection of VMEs, and the relative performance of different candidate spatial management areas offered by New Zealand officials as a basis for discussion. Two of the sets of candidate areas were designed using different automated GIS procedures using 6-minute-of-arc grid squares. A third set of candidate areas was designed by officials by combining the two automated selections and "nuancing" the boundaries to achieve better protection for VMEs and better access for the fishery.

The process used to design and refine the draft spatial management areas, using input data from Zonation and other spatial information, was not well-understood by all stakeholders or by Members attending SC-05 and the Commission in 2018. Therefore, more detail on the methods for designing spatial management areas using outputs from spatial planning software was presented at the sixth meeting of the Scientific Committee (SC-06) in September 2018. Following further consideration of the methodological approach, SC-06 agreed that the scientific approach was appropriate and, in particular, in its report, SC-06:

- Noted that the process used to design proposed spatial management areas for a bottom fishing CMM combined outputs on conservation priority (for prevention of SAIs on VMEs) from Zonation decision-support software with information on the distribution and relative value for bottom fishing in different locations;
- Noted that the scale of the Zonation input data layers (~1 km) is too fine for realistic Management Areas (~10s of km);
- Agreed that, given the scale mismatch, the use of automated GIS searches followed by expert-based adjustment and consultation with stakeholders is an appropriate process for designing spatial management areas;
- Noted that New Zealand and Australia will conduct additional workshops and consultation and may fine-tune the boundaries of proposed spatial management areas for the new bottom fishing CMM;
- Noted the fine tuning that has occurred since the Commission meeting in 2018 to the scientific analyses required to underpin a comprehensive bottom fishing CMM for the SPRFMO Area;
- Noted that further work is required, and New Zealand and Australia will continue to progress the development of a revised bottom fishing CMM in order to submit a proposed draft CMM to the Commission meeting in early 2019;

- Agreed that the scientific approaches applied by Australia and New Zealand can be used to underpin a revised bottom fishing CMM;
- Agreed to support, if necessary, an additional workshop in October or November 2018 to finalise the boundaries of spatial management areas or other management controls with stakeholders.

Following SC-06, and in line with its advice, New Zealand convened two further stakeholder workshops in Wellington in October and November 2018 to further refine the proposed spatial management areas, including exploring opportunities to improve conservation benefits within EBSA 17, while allowing for fishing. Having agreed the boundaries with stakeholders, Zonation analyses were finalized in December 2018, which allowed a final scientific assessment of the likely performance of the spatial management areas in the proposed revision to CMM-03.

During the various scientific and stakeholder workshops, we explored and evaluated the likely performance of candidate spatial management areas using maps showing the distribution of priority areas for conservation relative to candidate spatial management areas (e.g., Figure 3), conservation benefit curves (e.g., Figure 4) and summary tables (e.g., Table 1). In this paper, we present summary tables for the Evaluated Area (Table 1), and for each distinct fishery management area within the Evaluated Area (Tasman Sea, South Tasman Rise, Louisville Seamount Chain, split into Northern, Central and Southern areas in line with the orange roughy assessment and Management Areas, and "other" areas)(Figure 5, Table 2). We also provide assessments for each relevant Global Marine Biological Realm, or bioregion, occurring within the Evaluated Area (Figure 6, after Costello et al. 2017[5]). These various analyses represent the geographic scale at which we consider it realistic and appropriate to consider impacts on VMEs. We have not conducted performance analyses at smaller scales such as individual seamounts or other underwater topographical features.

Table 1 shows protection statistics that indicate that the proposed spatial management areas would provide substantially greater protection for stony corals and other VME indicator taxa than the existing management areas implemented by Australia and New Zealand under CMM03-2018. The proportion of the predicted distribution of VME indicator taxa protected from any adverse effects of fishing would increase from 60–70% under the existing measures to over 80% across the whole Evaluated Area, were the proposed areas to be implemented (Table 1). There is some regional variation in these proportions; about 90% of the predicted distribution of VME indicator taxa would be protected in the Tasman Sea fishery areas and the northern parts of the Louisville Seamount Chain, compared with about 50% further south on the Louisville Seamount Chain (Table 2 and Table 3). For the bioregional analysis, the proportion of VME indicator taxa was greater than 80% across all bioregions (Table 3).

[5] Costello MJ, Tsai P, Wong PS, Cheung A, Basher Z., Chaudhary C. (2017). Marine biogeographic realms and species endemicity. *Nature Communications* 8 (1057).

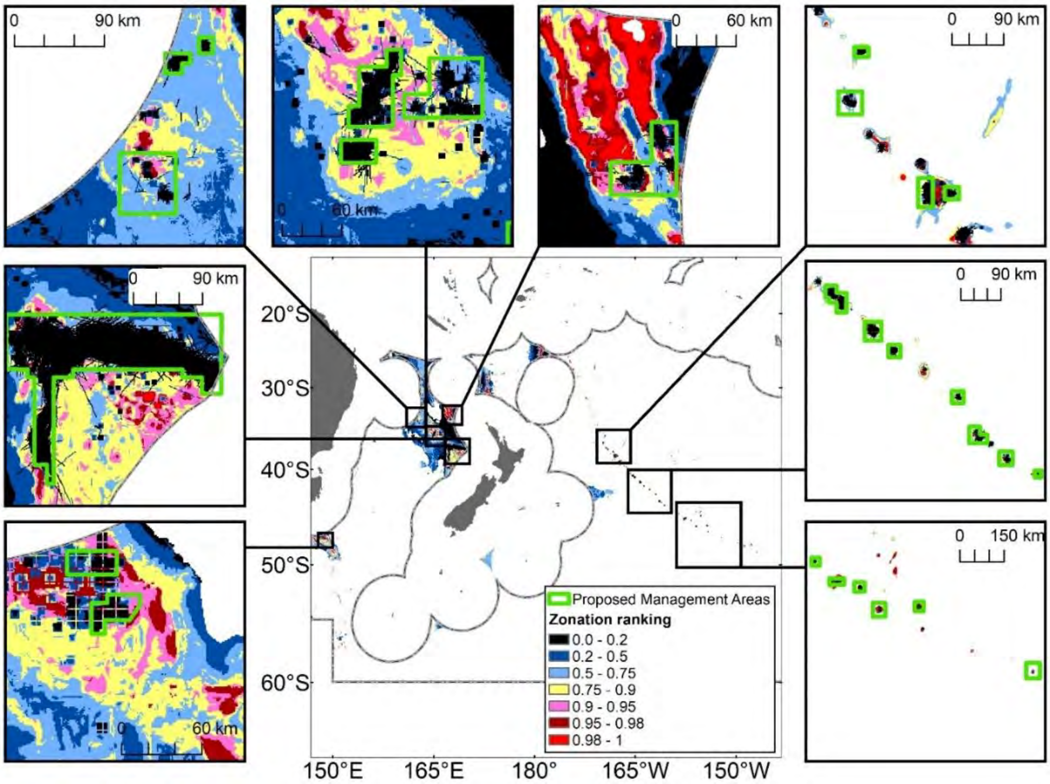


Figure 3: Map showing priority areas for conservation (protection of VMEs) generated by a Zonation prioritisation model including both discounting for lost naturalness and consideration of costs to the fishing industry. The proposed spatial management areas are shown in green.

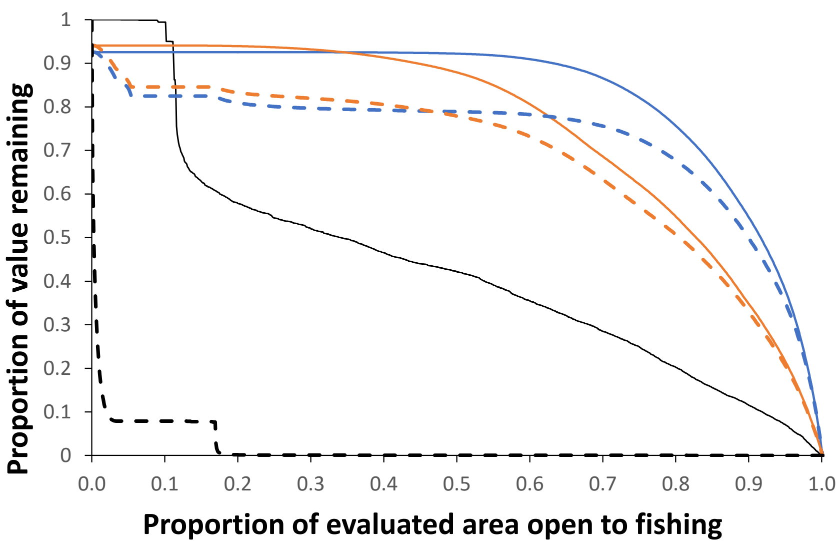


Figure 4: Example conservation benefit curve used by stakeholders to understand the likely performance of candidate fine-scale spatial management areas. Blue lines relate to stony corals, orange lines relate to other VME indicator taxa, and black lines relate to the index of "cost" (loss of access to space that the fishing industry value for fishing). Solid lines relate to models where costs to the fishing industry are ignored and dotted lines relate to models where those costs are taken into account. "Proportion of value remaining" relates to the proportion of the distribution of VME indicator taxa outside areas open to fishing (coloured lines) or to the proportional "cost" to the fishing industry (black lines). The proportion of the distribution of VME indicator taxa outside areas open to fishing does not peak at 100% because historical impacts of fishing have been accounted for in the models (i.e., 5-7% of the distribution of VME indicator taxa is estimated to have been lost).

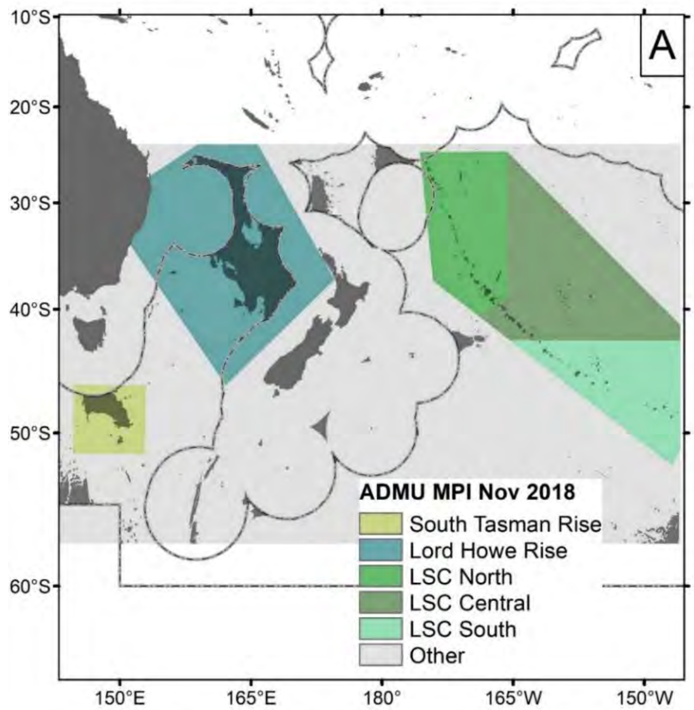


Figure 5: The boundaries of the five fisheries areas (administrative units, ADMU) used to evaluate the performance of candidate spatial management areas.

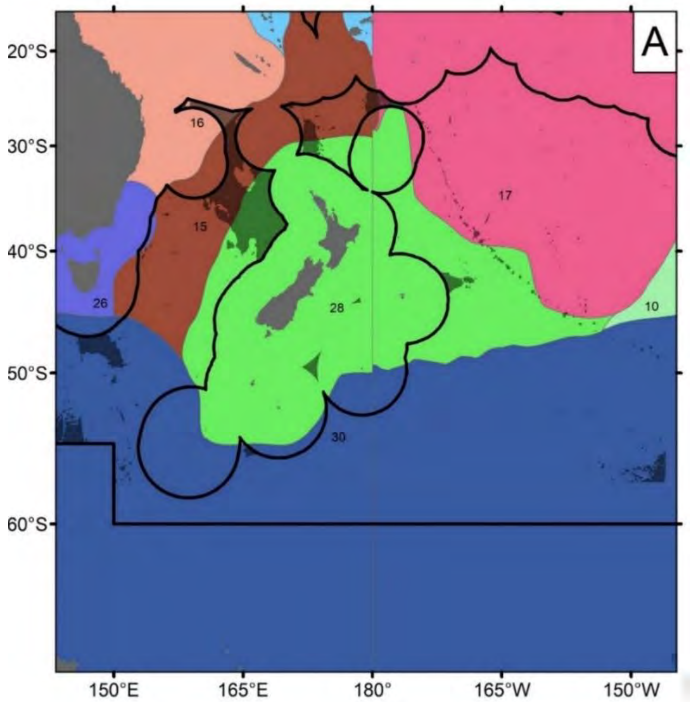


Figure 6: The boundaries of the seven Global Marine Biological Realms, or bioregions from Costello et al. (2017)[6] used to evaluate the performance of the candidate spatial management areas.

[6] Costello MJ, Tsai P, Wong PS, Cheung A, Basher Z., Chaudhary C. (2017). Marine biogeographic realms and species endemicity. *Nature Communications* 8 (1057).

Although the Zonation analyses and priority maps used to design the proposed spatial management measures were based on data for stony corals and six other specific VME indicator taxa, the performance of the proposed open and closed areas for other biological and ecological features can also be estimated. For instance, an estimated 68% of the distribution of "rare or unique" species[7] fell within the closed areas (Table 1). These species were not considered useful VME indicators for the analysis but were identified through the stakeholder workshops as biodiversity features that were useful to assess. Similarly, 100% of hydrothermal vents are likely to be protected and 77–100% of the area of the seven Ecologically or Biologically Significantly Areas (EBSAs) within the modelled area (Table 1).

Table 1: Estimated overall performance of the proposed spatial Management Areas compared with the existing Management Areas implemented by Australia and New Zealand. The percentage (averaged across all taxa and areas) of the total distribution of stony corals and other VME indicator taxa protected from bottom fishing is given. The proportion of each relevant Ecological or Biologically Significant Area, EBSA, hydrothermal vent fauna, and rare records of individual (non-VME) taxa are also shown, together with an estimate of the index of lost value for the fishing industry (percentage of access to valuable fishing lost).

Attribute	Existing Management Areas	Proposed Management Areas
Stony coral	62.0	82.2
Other VME indicator taxa	67.6	84.2
EBSA5	84.7	100.0
EBSA6	100.0	100.0
EBSA7	100.0	100.0
EBSA15	90.8	98.1
EBSA17	48.6	76.9
EBSA20	100.0	100.0
EBSA21	99.7	99.7
Point records of rare taxa	48.0	68.0
Hydrothermal vents	100.0	100.0
Percent of Evaluated Area open to fishing	11.1	5.5
Index of lost value for the fishing industry	8.7	6.6

Scientific guidance on the protection of VMEs from SAIs provided by Fisheries and Oceans Canada[8] recommends that, where 100% of VMEs cannot be protected, protection of 70% of the total extent of each VME in each bioregion is expected to be enough to maintain ecosystem functionality. Expert opinion, based on existing information and analysis, suggests that low risk of SAIs appears to be associated with protection of ~70% (or more)

[7] The distribution of rare or unique species was indexed by using all location records for taxa that occur only once in species record databases for the Evaluated Area.

[8] Guidance on the level of protection of significant areas of coldwater corals and sponge-dominated communities in Newfoundland and Labrador waters. Canadian Science Advisory Secretariat. Science Response 2017/030

of VMEs in each bioregion. Tables 2 and 3 suggests that these levels of protection are afforded by the proposed spatial management areas for all bioregions (Table 3, 80–100% protected) but that protection is more patchy among fisheries management areas (see Table 2). In the Tasman Sea and in the northern parts of the Louisville Seamount Chain, 85–95% of the distribution of VME indicator taxa is protected but, in the central and southern parts of the Louisville Seamount Chain this declines to 50–65% (Table 3).

Table 2: Estimated performance of the proposed spatial management areas in terms of the percentage of the total distribution of stony corals and other VME indicator taxa protected from bottom fishing. Overall means are averaged across all taxa and areas (details of estimated performance by taxon are shown in Annex 1). Ecological or Biologically Significant Area 17 (EBSA17) is the only EBSA significantly overlapped by the areas proposed to be opened to fishing. The performance for hydrothermal vent fauna and for rare records of individual (non-VME) taxa are also shown, together with an estimate of the index of lost value for the fishing industry (percentage of access to valuable fishing space lost) in each area.

Attribute	Overall	S. Tasman Rise	Tasman Sea	L'ville North	L'ville Central	L'ville South	Other areas
Stony coral	82	95	86	83	62	47	100
Other VME indicator taxa	84	95	87	86	69	51	100
EBSA17	77	n/a	n/a	77	n/a	n/a	n/a
Rare species (point records)	68	57	77	92	14	n/a	100
Hydrothermal vents	100	n/a	n/a	n/a	n/a	n/a	100
Lost value for industry (%)	7	0	2	3	43	2	6

However, it is recognised that VME indicator taxa and habitat found in the deeper parts of the areas open to bottom trawling are unlikely to be impacted by bottom trawling because they are too deep to be trawled using existing technology. Our analysis (Figure 7) suggests that bottom trawling is very rare in waters deeper than 1250 m and has never been reported deeper than 1400 m, meaning that any part of the distribution of a VME indicator taxon that is inside the areas proposed open to bottom trawling but deeper than 1400 m is not likely to be disturbed by trawl gear in the foreseeable future. We therefore evaluated (Table 3) the performance of the proposed spatial management areas based on nominal protection (the percentage of the predicted distribution of VME indicator taxa outside the areas open to bottom trawling) and effective protection (the percentage of the predicted distribution of VME indicator taxa outside the areas open to bottom trawling plus those parts of the proposed open areas that are deeper than 1400 m). Including these additional areas in the calculations makes little difference in some areas but, on the Louisville Seamount Chain, it greatly increases the percentage of the predicted distribution of VME indicator taxa that is unlikely to be impacted by fishing (Figure 8). Consideration of effective protection increases the proportion of VME indicator taxa not exposed to fishing to more than 70% across all fisheries management areas and bioregions (Table 3).

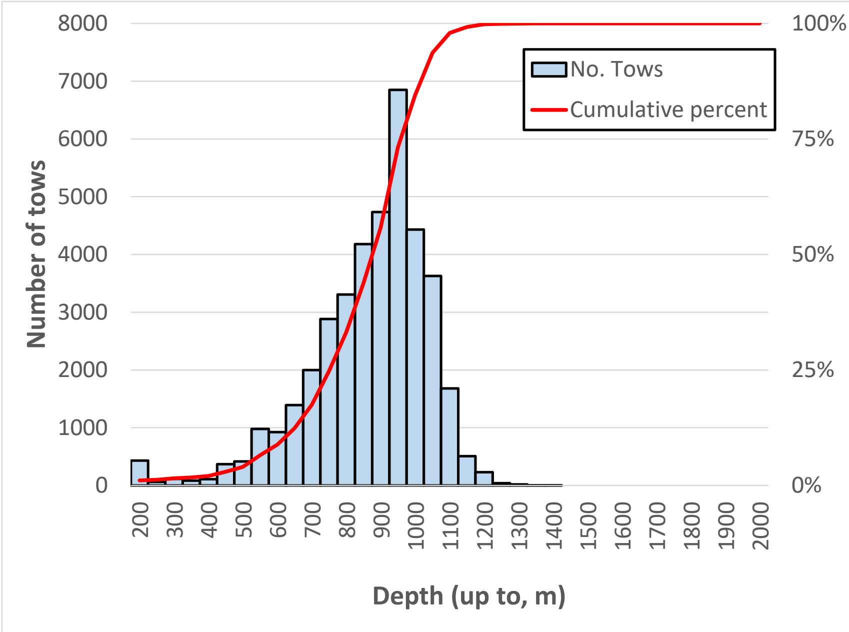


Figure 7: Distribution of the reported depth of bottom trawl tows in the SPRFMO Area (New Zealand data).

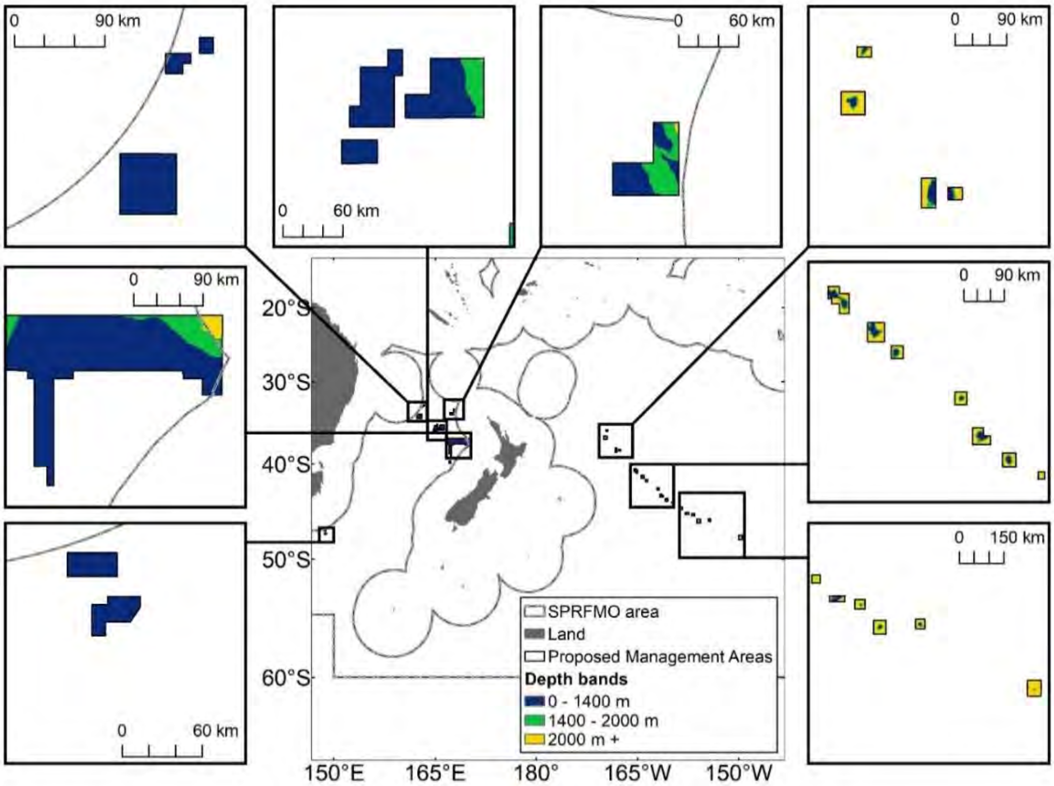


Figure 8: The distribution of depth bands 0–1400 m, 1400–2000 m, and 2000+ m within the proposed spatial management areas.

The "cost" to the fishing industry of implementing the proposed spatial management measures, in terms of access to fishing locations of industry interest (value), is estimated to be slightly lower than the "cost" of the existing measures. Overall, the "cost" of the proposed measures would involve loss of access to 6.6% of the area the industry value compared with 8.6% under the existing measures (Table 1). However, there are large differences between locations. Were the proposed measures to be implemented, in the South Tasman Rise, the industry would have no access to <1% of the area they consider valuable for fishing and, in the Tasman Sea, this would be about 2% (Table 2). On the northern and southern parts of the Louisville Seamount Chain, industry would have no access to about 2 to 3% of the area they consider valuable for fishing but, in the central Louisville, they would have no access to over 40% of the space they value (Table 2). Relative to the existing measures, the reduced overall "cost" to industry and increased conservation benefits of the proposed measures suggests an attractive win-win outcome.

We also evaluated the potential for recovery of VME indicator taxa resulting from the proposed spatial management areas by calculating the difference between the conservation prioritisations with and without naturalness discounting[9] (Figure 9). Areas with higher conservation rankings in the absence of the naturalness layer are areas that may have some potential for recovery of VME indicator taxa. Within these areas, more than 70% of the predicted distribution of stony coral VME indicator taxa with a Habitat Suitability Index (HSI) greater than 0.5 occurred outside of areas open to bottom fishing, indicating that most of areas suitable for the recovery of VME indicator taxa would be protected from fishing were the proposed measures to be implemented. This metric of recovery potential reduces to more than 60% on the Louisville Seamount Chain sub-area (Table 4 and Annex 2). Overall, the proposed spatial management areas would close relatively large areas of habitat suitable for VME indicator species that have probably been somewhat degraded by historical fishing activity and potentially allow for recovery of VME taxa in those areas. Conversely, the proposed spatial management areas would open only relatively small parts of existing closed areas to potential new impacts.

[9] "Naturalness discounting" refers to procedures within the spatial prioritisation modelling to reduce the priority for conservation of areas of habitat suitable for VME indicator taxa that are estimated to have been degraded by historical fishing activity. See also a map of the spatial distribution of estimated naturalness in Annex 3.

Table 3: Estimated performance of the proposed spatial management areas in terms of the percentage of the predicted distribution of each VME taxon protected from bottom fishing. Overall means averaged across all taxa and areas, subsequent rows show estimated performance in each relevant Global Marine Biological Realm and in fisheries management areas. Nominal protection is the percentage of the predicted distribution of VME indicator habitat that occurs outside the areas proposed open to bottom trawling, whereas effective protection is the percentage of the predicted distribution of VME indicator habitat that occurs outside areas proposed open to bottom trawling plus those parts of areas proposed open to fishing that are deeper than 1400 m (for details by individual VME indicator taxon see Annex 1). The overall maximum possible protection is less than 100% because the estimated impact of historical fishing has been accounted for in the models.

Region	Stony corals (4)		Other VME taxa (6)		All VME taxa (10)	
Overall max possible	93		94		94	
	nominal	effective	nominal	effective	nominal	effective
Overall	82	85	84	88	84	87
Marine Biological Realms (bioregions):						
Realm 15	97	97	95	95	96	96
Realm 16	100	100	100	100	100	100
Realm 17	89	93	90	96	90	95
Realm 28	81	85	82	86	82	85
Realm 30	96	96	97	97	96	97
Fishery areas:						
S Tasman Rise	95	95	95	95	95	95
Tasman Sea	86	87	87	87	86	87
Louisville North	83	89	86	93	85	91
Louisville Central	62	80	69	89	66	85
Louisville South	47	71	51	81	49	77
Other fishing areas	100	100	100	100	100	100

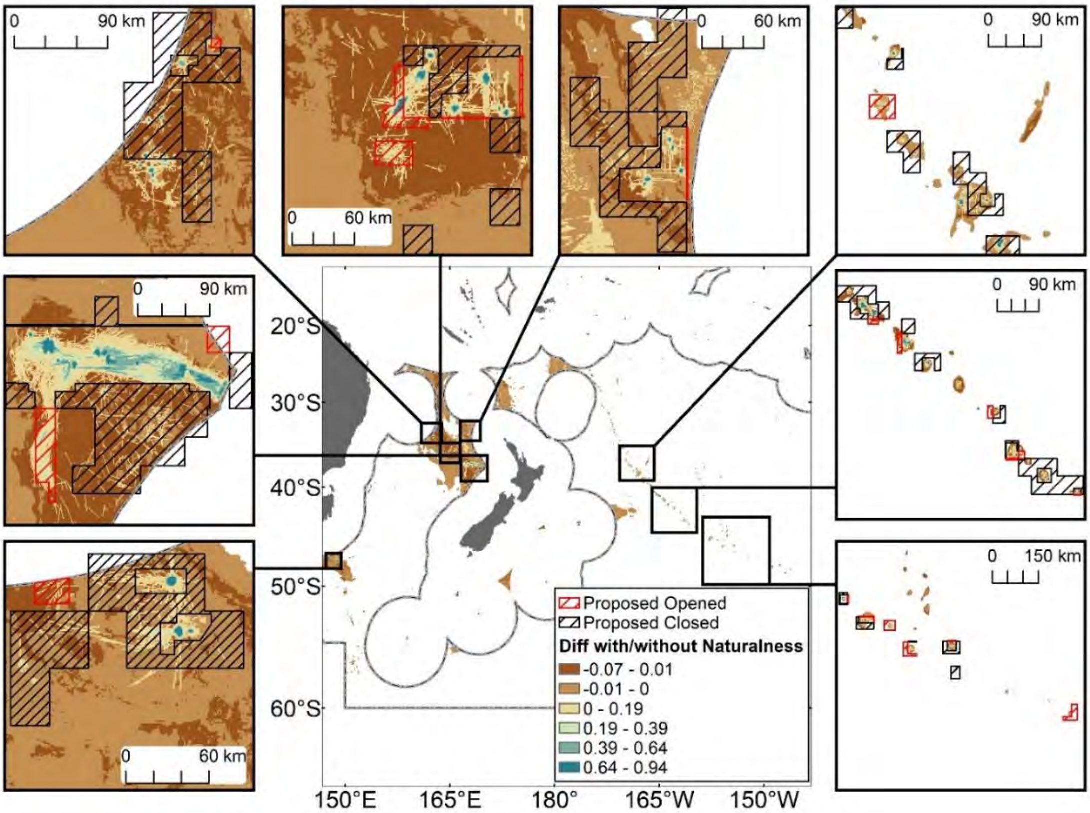


Figure 9: Difference between the VME conservation prioritisation with and without naturalness discounting as an indication of recovery potential based on trawl history, for areas proposed open and areas proposed closed. Bluer colours indicate areas with the greatest increase in conservation priority when discounting for historical impacts is switched off and browner colours indicate areas with little change.

Table 4. Recovery potential (calculated as the difference between the VME conservation prioritisation with and without naturalness discounting) for stony coral species across the Evaluated Area and for the Louisville Seamount Chain sub-area. Recovery potential is expressed as the area (km^2) of habitat suitability models with HSI values > 0.5 occurring within proposed closed areas (for recovery) and proposed open areas (potential for impact), and the percent protected under the proposed spatial management measures.

		Evaluated Area			Louisville Seamount Chain		
VME indicator taxa	FAO code	Recovery potential in closed areas	Recovery potential in open areas	Percent recovery potential protected in closed areas	Recovery potential in closed areas	Recovery potential in open Areas	Percent recovery potential protected in closed areas
Solenosmilia variabilis	RZT	1,909	263	88%	827	260	76%
Enallopsammia rostrata	FEY	745	185	80%	399	185	68%
Goniocorella dumosa	GDV	1,236	196	86%	340	196	63%
Madrepora oculata	MVI	1,727	694	71%	587	203	74%

VME encounter protocol

Recognising that there is a level of uncertainty associated with the VME habitat suitability models (as there is with all models), the revised CMM also incorporates an encounter protocol which requires an immediate management response to the "unexpected" capture of large amounts of VME indicator taxa in open areas. This approach is consistent with the United Nations General Assembly resolutions noted in the preamble, and the FAO Deep-Sea Fisheries Guidelines with respect to RFMO/As having an appropriate protocol identified in advance for how fishing vessels in deep sea fisheries should respond to encounters in the course of fishing operations with a VME, including defining what constitutes evidence of an encounter and requiring vessels to cease bottom fishing activities at the site and to report the encounter.

It is important that the encounter protocol be considered as part of a broader bottom fishing conservation management measure that also incorporates a spatial management component. Areas closed to bottom trawling include, on average, about 83% of the modelled distribution of VME indicator taxa (82–100% by bioregion) and effective protections is even higher (see Table 4). It is this high level of protection that we believe provides an assurance that bottom fishing within the Evaluate Area will not have significant adverse impacts (SAI) on VMEs should the proposed measures be adopted. Consequently, the encounter protocol alone is not intended to prevent SAIs on VMEs. Rather, it is a tool that provides a "backstop" to provide a rapid response to unexpected new information as the new spatial management approach is implemented.

SC-05's and SC-06's advice was followed in designing the VME encounter protocol, in that the threshold for the move-on rule was set at a level that would be triggered only when weights of bycatch of benthic fauna would suggest that the spatial models used to predict the distribution of VME indicator taxa are misleading. The encounter protocol therefore provides for an immediate management response where threshold weights or biodiversity scores are exceeded. In other words, this protocol ensures that the Commission can respond rapidly to information which may indicate that fishing may pose a higher risk to VMEs than the existing modelling implies and that the underpinning models and the boundaries of the spatial management areas may need to be reviewed.

SC-06 noted that insufficient data from bottom longline fisheries exist to develop a data-informed VME indicator taxa threshold for that method, but within this context noted that, based on the cumulative impact assessment for bottom line fishing, line fishing within candidate areas open to fishing are likely to have risks to VMEs several orders of magnitude lower than bottom trawl fishing. Therefore, SC-06 agreed that VME encounter protocols should be developed for bottom trawl fishing only and should include a weight threshold and a biodiversity threshold.

In the absence of data allowing the calculation of biomass-derived thresholds (e.g. taxa-specific biomass estimates, VME patch size estimates, taxon-specific catchability, probability of encounter with bottom trawl gear, etc.), calculations were based on observed benthic bycatch of VME indicator taxa from the New Zealand bottom trawl fishery.

Australian data were not included in this analysis because benthic bycatch records are not captured in databases with the same precision and resolution as New Zealand benthic bycatch data. Inclusion of these lower-resolution data would degrade the usefulness of the existing New Zealand data. The data explored included 8850 tows with records of benthic bycatch taken by observers in the SPRFMO Area between 2008 and 2018. Only trawls for black oreo (*Allocyttus niger*) alfonsinos (*Beryx splendens* and *B. decadacylus*), cardinal fish (*Epigonus telescopus*), orange roughy (*Hoplostethus atlanticus*) and spiky oreo (*Neocyttus rhomboidalis*) were used, and VME indicator taxa were assessed using the modified criteria of Bowden et al. (Table 5).

The FAO guidelines recommend that VME indicator taxa weight thresholds should ideally be specific to area and taxon. Although the Evaluated Area can be divided into two distinct geographic areas, the Louisville Seamount Chain to the east of New Zealand, and various Tasman Sea fisheries to the west of New Zealand, there was insufficient data for many taxa within each area to enable the generation of area-specific weight thresholds. Therefore, VME indicator taxon-specific weight thresholds were generated for the entire Evaluated Area. Recognizing that the presence of a small amount of a single VME indicator taxon is unlikely to indicate an encounter with a VME, and that the presence of several VME indicator taxa in a single tow may indicate that the fishing event has encountered an area with a diverse seabed fauna, potentially constituting evidence of a VME, the encounter protocol includes both weight and biodiversity thresholds.

Weight and biodiversity thresholds were identified from taxon-specific plots of the cumulative distribution of historical non-zero catch weights using the points at which each curve begins to flatten (sometimes called inflexion points) (Figure 10). Thresholds indicating unexpectedly large catches should ideally fall to the right of such points, whereas "biodiversity weights" indicating increasing numbers of taxa in a single tow at weights below the threshold trigger might occur to the left. The choice of a percentile to the left or right of the threshold value depends on the desired sensitivity of the encounter protocol. Weight thresholds for Porifera, Gorgonacea, Scleractinia, Antipatheria, Actiniaria and Alcyonacea were set equal to the 99th percentiles (with some rounding), which fell to the right of taxon-specific "inflexion points" on the curves. This ensures the encounter protocol is not too sensitive and responds only to very unusual events that suggest the models that underpin the spatial management areas may be misleading.

Table 5: VME indicator taxa identified for the southwest Pacific by Parker et al (2009)[10] as modified by Bowden et al. (in prep.)

FAO Code	Taxon	Comments	Relationship to FAO listings
PFR	Porifera (Phylum) *Sponges*	Include both classes (Demospongiae and Hexactinellida). These are found in the deep sea, can form complex structures and are vulnerable to disturbance by fishing gears. Longevity and resilience of cold-water sponges is unknown.	Sponge dominated communities are specifically listed by the FAO guidelines as vulnerable ecosystem components to protect. Sponge fields and large colonies form complex structures and may provide habitat for many species.
CSS	Scleractinia (Order) *Stony corals*	Includes six complex branching, thicket or mound forming genera matching VME criteria: *Solenosmillia; Goniocorella; Oculina; Enallopsammia; Madrepora*, and *Lophelia*.	Specifically listed by FAO guidelines as one of the main target taxonomic groups of the VME definition. They are slow growing, structure-forming species vulnerable to disturbance by fishing gear, with unknown recovery rates. Accordingly, a high importance is given.
AQZ	Antipatharia (Order) *Black corals*	All taxa are structure forming, fragile and associated with habitats that tend to be more diverse (heterogeneous seabed with accelerated current flow).	Specifically listed by FAO guidelines as one of the main target taxonomic groups of the VME definition. They are low productivity, structure-forming species vulnerable to fishing gears.
AJZ	Alcyonacea (Order) *Soft corals*	Deep-sea species may be erect, large and branching, providing structural habitats and associated with other VME indicator taxa.	Specifically listed by FAO guidelines as one of the main target taxonomic groups of the VME definition. If found in high densities, they would be vulnerable to fishing gear.
GGW	Gorgonacea *Gorgonian octocorals*	Gorgonacea (Gorgonian octocorals) have been revised and subsumed into the Alcyonacea (soft corals) but are left separated here as important VME indicator taxa that may be complex, large, fragile, and form complex biogenic structure.	Specifically listed by FAO guidelines as one of the main target taxonomic groups of the VME definition. This group includes several large structure-forming species that may provide habitat to other species.
NTW	Pennatulacea (Order) *Sea pens*	They are typical of softer substrates but do provide complex structure, have been associated with fish species and are vulnerable to trawl gear because they can be tall and often live in trawlable habitat.	Specifically listed as VME examples by FAO guidelines, but do not indicate hard substrate or stony corals. They do, however, suggest a different type of VME. They are scored as an indicator of habitat containing vertical structure.
ATX	Actiniaria (Order) *Anemones*	Anemones are not listed by FAO (2007) but can be large and are indicators of hard substrate and habitats that support corals, so are included as an indicator of vulnerable species.	As an indicator of other VME components.
AXT	Stylasteridae (Subclass or Family) *Hydrocorals*	Covers a wide range of taxa from small (cm scale) to massive *Macropora* reef, but if big enough to be caught by fishing gear, they are indicative of VME.	Specifically listed by FAO guidelines as one of the main target taxonomic groups of the VME definition. They can form very large complex, yet brittle structures.
BHZ	Brisingida (Order) *'Armless' stars*	All taxa are fragile and associated with habitats that tend to be more diverse (Heterogeneous seabed with accelerated current flow)	Not specifically identified by FAO guidelines, but identified by Parker (2008) as a habitat indicator of VME indicator taxa. Once detected, armless stars are an indicator of suitable VME substrate.
CWD	Crinoidea (Class) *Sea lillies*	All taxa are fragile and associated with habitats that tend to be more diverse (heterogeneous seabed with accelerated current flow)	Not specifically identified by FAO guidelines, but identified by Parker (2008) as a habitat indicator of VME indicator taxa. Once detected, crinoids are an indicator of suitable VME substrate.

[10] Parker S.J.; Penney A.J.; Clark M.R. (2009). Detection criteria for managing trawl impacts on vulnerable marine ecosystems in high seas fisheries of the South Pacific Ocean. *Marine Ecology Progress Series*, 397: 309–317. (doi: 10.3354/meps08115)

There was insufficient bycatch data to construct cumulative bycatch distributions and assign weight thresholds to Stylasteridae, Pennatulacea, Crinoidea and Brisingida. Consequently, these taxonomic groups are included only in the biodiversity threshold (Table 6). Biodiversity qualifying weights for Porifera, Gorgonacea, Scleractinia, Antipatheria, Actiniaria and Alcyonacea were set at the 80th percentiles to ensure the encounter protocol is not too sensitive, and for Stylasteridae, Pennatulacea, Crinoidea and Brisingida (taxa for which cumulative bycatch distributions and thresholds could not be calculated due to insufficient data) set at 1 kg (Table 6). The biodiversity component of the encounter protocol would be triggered if three or more VME indicator taxa are encountered in a bottom trawl exceeding their taxa-specific biodiversity qualifying weights. The weight and biodiversity thresholds agree by SC-06 are presented in Table 6.

Table 6: Percentiles of observed catch weights for four VME indicator taxa using New Zealand bottom trawl tows in the SPRFMO Area 2012−2017. The threshold weights for these taxa are indicated in the right-hand column.

FAO Code	Taxon	Ref point (kg)	0.8	0.9	0.95	0.97	0.98	0.99	0.995	Threshold Weight (kg)	Biodiversity Weight (kg)
PFR	Porifera (Phylum) *Sponges*	9.70	3.3	7.8	13.9	20	25	50	95	50	5
CSS	Scleractinia (Order) *Stony corals*	7.97	5	10	20	40	60	250	700	250	5
AQZ	Antipatharia (Order) *Black corals*	2.58	1	2	2.9	3.9	4.8	5.5	7.6	5	1
AJZ	Alcyonacea (Order) *True Soft corals*	5.65	1	2.3	13.2	24.1	30	60	125.1	60	1
GGW	Gorgonacea (Order) *Seafan octocorals*	2.66	0.6	1	2	5	7.2	15	21.3	15	1
NTW	Pennatulacea *Sea pens*	-	-	-	-	-	-	-	-	-	1
ATX	Actiniaria (Order) *Anemones*	11.58	7.24	12	20	24.5	30	38	41	30	5
AXT	Stylasteridae *Hydrocorals*	-	-	-	-	-	-	-	-	-	1
BHZ	Brisingida *'Armless' stars*	-	-	-	-	-	-	-	-	-	1
CWD	Crinoidea *Sea lillies*	-	-	-	-	-	-	-	-	-	1

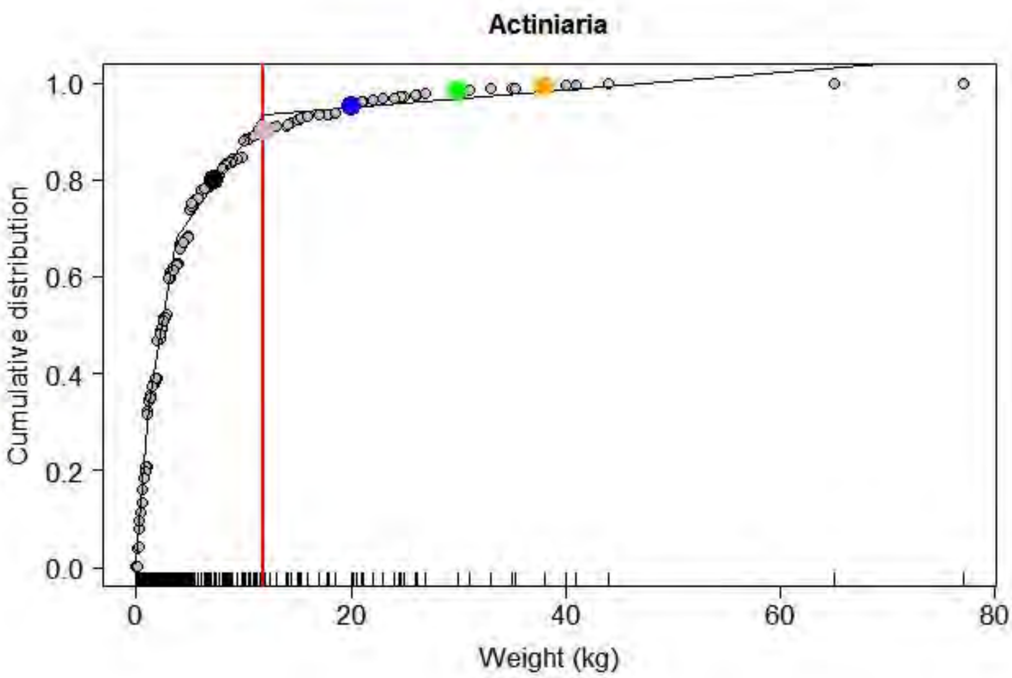


Figure 10. Cumulative distribution of bottom trawl catch weights (kg) for Actinaria showing reference points for where the curve begins to flatten toward the asymptote (red vertical line), and the points of the 80th (black points), 90th (grey points), 95th (blue points), 98th (green points) and 99th percentiles (orange points).

SC-06 recommended a mandatory review process for VME indicator encounters (annual), benthic data (annual), and models underpinning spatial management approaches (roughly every 5 years or when evidence suggests those models may be misleading). The Scientific Committee also recommended including the development of a review process in the Scientific Committee work plans for consideration by the Commission. The CMM provides for the Scientific Committee to review the VME indicator thresholds and size of the closed encounter area (one nautical mile) contained in paragraph 35 of the CMM no later than its 2020 meeting, to ensure their appropriateness for achieving the CMM's objective.

Marine Mammals, seabirds, reptiles, and other species of concern

The objective of the revised CMM requires an ecosystem approach to managing bottom fishing that ensures the long-term conservation of non-target and associated or dependent species. This section of the measure defines non-target and associated or dependent species as marine mammals, seabirds, reptiles (turtles) (as referenced in Article 1, para f (iv) of the Convention) and other species of concern (as defined in Annex 14 of CMM 02-2017 (Data standard)). It requires vessels undertaking bottom fishing to implement existing CMMs on seabird bycatch mitigation (CMM 09-2017) and data standards (CMM 02-2017). It also seeks specific advice from the Scientific Committee on interactions of bottom fisheries with marine mammals, seabirds, reptiles and other species of concern and potential management actions. The Scientific Committee's considerations and advice may include risk assessments, important bird areas or other information relating to the non-target or associated or dependent species caught as bycatch by bottom fisheries.

Assessment of proposed bottom fishing

The revised CMM establishes a centralised assessment process for proposals to undertake bottom fishing activities. This process is modelled on the approach used by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), particularly its Conservation Measure 22-06, adapted for the SPRFMO context which includes trawl as well as line fishing and a smaller secretariat.

The aim is to determine, based on the best available scientific information, if proposed bottom fishing activities, taking account of the history of bottom fishing in the areas proposed and the cumulative impacts of the proposed activities, would contribute to having significant adverse impacts on VMEs. If it is determined that bottom fishing activities would make such contributions, the revised CMM also aims to ensure that they are managed to prevent such impacts or they are not authorised to proceed.

Each Member or CNCP proposing to participate in bottom fishing activities will be required to submit to the Scientific Committee a proposed assessment based on the SPRFMO Bottom Fishery Impact Assessment Standard (BFIAS). SC-05 recommended to the Commission that the Scientific Committee's work plan include preparation of a revised and updated SPRFMO BFIAS for agreement no later than the Scientific Committee's meeting in 2019. The revised CMM would also require an updated proposed assessment to be submitted to the Scientific Committee where there is a material change to the SPRFMO BFIAS or a substantial change in the fishery, such that it is likely that the risk or impact of the fishery may have changed.

Under the proposed revised CMM, the Scientific Committee would be required to undertake a review of the proposed assessment and the Commission would then, on the basis of the proposed assessment and the Scientific Committee review and advice, determine:

- the extent to which the proposal should be authorised;
- which, if any, additional measures are required pursuant to Article 20 of the Convention; and
- any additional precautionary measures required where it cannot adequately be determined whether VMEs are present or whether fishing could cause significant adverse impacts on VMEs.

Members or CNCPs that have previously undertaken and submitted an impact assessment consistent with paragraph 30(d) would not need to submit a further proposed assessment where these requirements have already been met.

The proposed revised CMM provides for the secretariat to make all proposed assessments publicly available on the SPRFMO website, as well as the Scientific Committee's review of such assessments in accordance with its usual procedures. These procedures are that the documents are uploaded to the SPRFMO website in advance of the relevant meetings, so that they are publicly available in sufficient time for review. Members, CNCPs and observers will all have access to the documents at the same time.

Annex 1: Nominal and effective protection for the ten VME indicator taxa

VME taxa			Stony corals							Other VME taxa
NZ code	ERO	GDU	MOC	SVA	COB	COR	DEM	HEX	PTU	SOC
FAO code	FEY	GDV	MVI	RZT	AQZ	AXT	DMO	HXY	NTW	AJZ
Overall max possible	90	94	90	96	91	94	94	95	96	94
Overall nominal	77	85	78	89	78	86	85	85	89	84
Overall effective	79	89	80	91	90	88	87	88	91	86
Realm 15 nominal	99	95	98	98	93	96	93	94	97	95
Realm 15 effective	99	95	98	98	93	96	93	94	97	95
Realm 16 nominal	100	100	100	100	100	100	100	100	100	100
Realm 16 effective	100	100	100	100	100	100	100	100	100	100
Realm 17 nominal	86	91	89	91	91	91	89	90	90	92
Realm 17 effective	90	96	92	96	94	95	96	97	97	96
Realm 28 nominal	80	84	78	82	76	83	82	84	87	82
Realm 28 effective	82	90	80	88	78	87	87	88	91	84
Realm 30 nominal	93	97	95	98	94	96	97	97	98	96
Realm 30 effective	94	98	95	98	95	96	98	97	99	96
STR nominal	93	97	93	97	94	95	93	96	98	95
STR effective	93	97	93	97	94	95	93	96	98	95
Tasman nominal	85	89	83	88	82	88	87	87	90	86
Tasman effective	85	90	84	89	82	89	87	87	91	87
L'ville N nominal	80	88	80	85	82	86	87	88	88	87
L'ville N effective	85	93	86	93	87	92	94	95	96	93
L'ville C nominal	57	71	52	67	58	68	74	74	73	69
L'ville C effective	71	90	73	86	79	88	92	94	94	88
L'ville S nominal	45	54	45	43	46	49	54	54	55	50
L'ville S effective	63	84	61	76	67	77	86	87	89	78
Other nominal	100	100	100	100	100	100	100	100	100	100
Other effective	100	100	100	100	100	100	100	100	100	100

Annex 2: Assessment of areas for potential recovery for the four species of stony coral

Table A1.1: Stony coral species across the whole Evaluated Area for HSI values >0.3 and 0.5 in proposed closed areas (for recovery) and proposed open areas (potential for impact).

A. Closed areas	FNZ code	FAO code	Without Naturalness layer (i.e. no discounting)		With Naturalness layer		Difference with/without naturalness	
			Prob occ > 0.3	Prob occ > 0.5	Prob occ > 0.3	Prob occ > 0.5	Prob occ > 0.3	Prob occ > 0.5
Solenosmilia variabilis	SVA	RZT	24,618	13,937	23,397	12,028	1,221	1,909
Enallopsammia rostrata	ERO	FEY	12,319	6,645	11,327	5,900	992	745
Goniocorella dumosa	GDU	GDV	26,853	8,547	25,190	7,311	1,663	1,236
Madrepora oculata	MOC	MVI	27,738	13,877	26,521	12,150	1,217	1,727

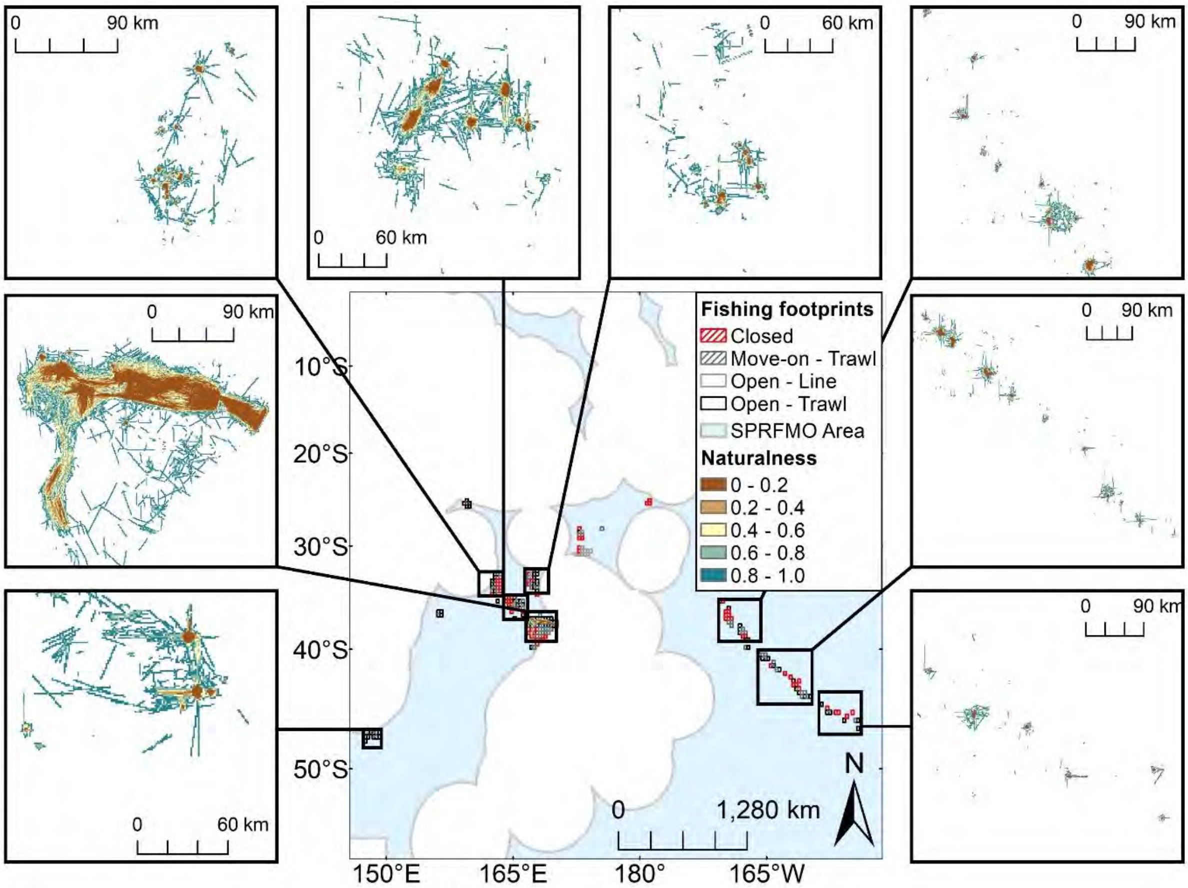
B. Open areas	FNZ code	FAO code	Without Naturalness layer		With Naturalness layer		Difference with/without naturalness	
			Prob occ > 0.3	Prob occ > 0.5	Prob occ > 0.3	Prob occ > 0.5	Prob occ > 0.3	Prob occ > 0.5
Solenosmilia variabilis	SVA	RZT	1,071	604	847	341	224	263
Enallopsammia rostrata	ERO	FEY	1,301	416	733	231	568	185
Goniocorella dumosa	GDU	GDV	1,148	473	952	277	196	196
Madrepora oculata	MOC	MVI	3,657	1144	2,487	450	1,170	694

Table A1.2: Stony coral species across the Louisville region only (aggregate of the LSC North, Central and South FMAs) for HSI values >0.3 and 0.5 in proposed closed areas (for recovery) and proposed open areas (potential for impact).

A. Closed areas	FNZ code	FAO code	Without Naturalness layer		With Naturalness layer		Difference with / without naturalness	
			Prob occ > 0.3	Prob occ > 0.5	Prob occ > 0.3	Prob occ > 0.5	Prob occ > 0.3	Prob occ > 0.5
Solenosmilia variabilis	SVA	RZT	4,316	2,612	3,848	1,785	468	827
Enallopsammia rostrata	ERO	FEY	2,321	1,492	1,861	1,093	460	399
Goniocorella dumosa	GDU	GDV	3,626	988	3,098	648	528	340
Madrepora oculata	MOC	MVI	2,894	2,425	2,545	1,838	349	587

B. Open areas	FNZ code	FAO code	Without Naturalness layer		With Naturalness layer		Difference with / without naturalness	
			Prob occ > 0.3	Prob occ > 0.5	Prob occ > 0.3	Prob occ > 0.5	Prob occ > 0.3	Prob occ > 0.5
Solenosmilia variabilis	SVA	RZT	865	543	701	283	164	260
Enallopsammia rostrata	ERO	FEY	497	416	372	231	125	185
Goniocorella dumosa	GDU	GDV	1,090	473	926	277	164	196
Madrepora oculata	MOC	MVI	588	479	462	276	126	203

Annex 3: Map showing the distribution of naturalness used in the Zonation spatial prioritisation models



This distribution was used as a layer in the Zonation spatial prioritisation models to discount or down-weight the priority of areas of habitat suitable for VME indicator taxa that have probably been modified by historical fishing activity.