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Methods for designing spatial management areas using outputs from Zonation software and other spatial data

Martin Cryer, Shane Geange, & Tiffany Bock

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Methods of designing spatial management areas using outputs from Zonation software and other spatial data

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1. Purpose of paper

This paper provides SC-06 with more detail on the methods and processes used to design candidate spatial management areas using spatial data from Zonation decision-support software and other sources, primarily the location and value of fishing. This detail is provided because feedback from Members at SC-05 and Commission suggests that this critical step of the process was not sufficiently well-understood and had not previously been completely documented.

2. Introduction

Work to underpin the development of spatial management areas as part of the revised CMM for bottom fisheries in the western part of the SPRFMO Area (Figure 1) 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), 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 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 on VMEs and provide for a fishery.

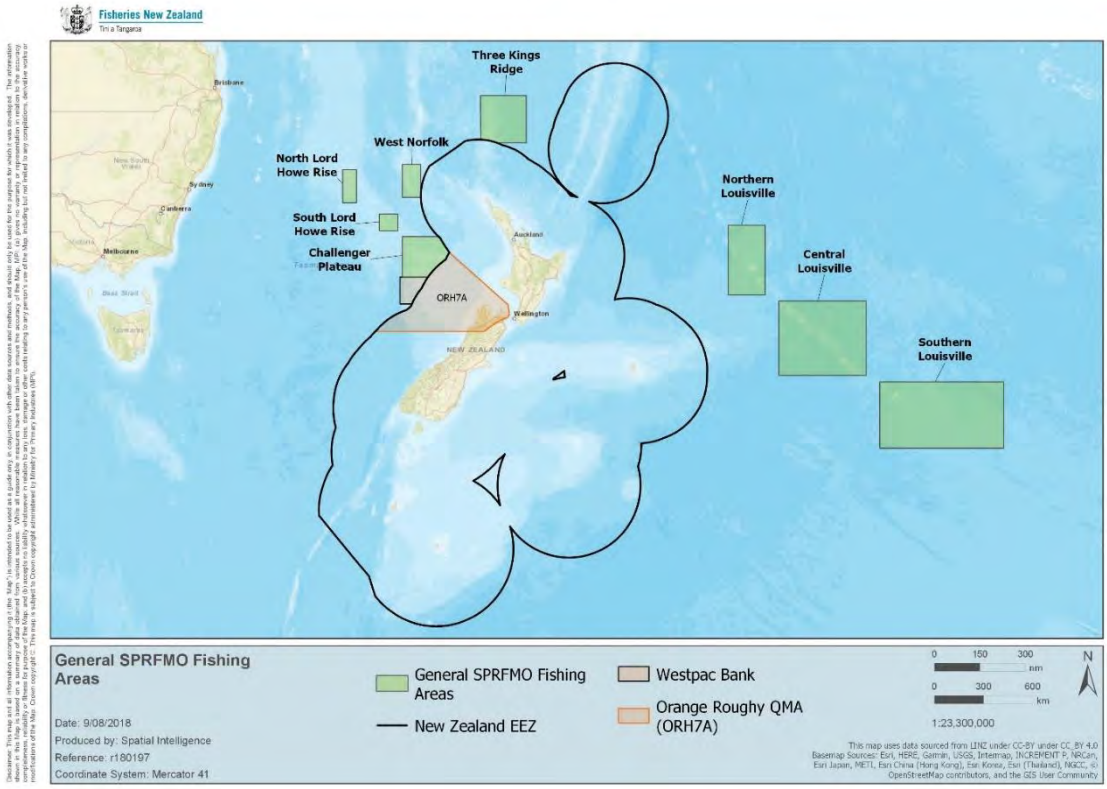


Figure 1: The general areas bottom fished by New Zealand trawlers in the SPRFMO Convention Area since 2006. Some other areas are fished using line methods and/or by Australia (visible in Figure 2).

Records of the location or density of VMEs or VME indicator taxa such as reef-forming corals within the SPRFMO Area are sparse and inadequate to map the distribution of VMEs directly. This means that predictive models are required to map VMEs. During 2017, New Zealand concluded the work it has been conducting for many years, generating models that cover the area from the South Tasman Rise in the west to the southern tip of the Louisville Seamount Chain in the east (Figure 2). 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 (e.g., Figure 3).

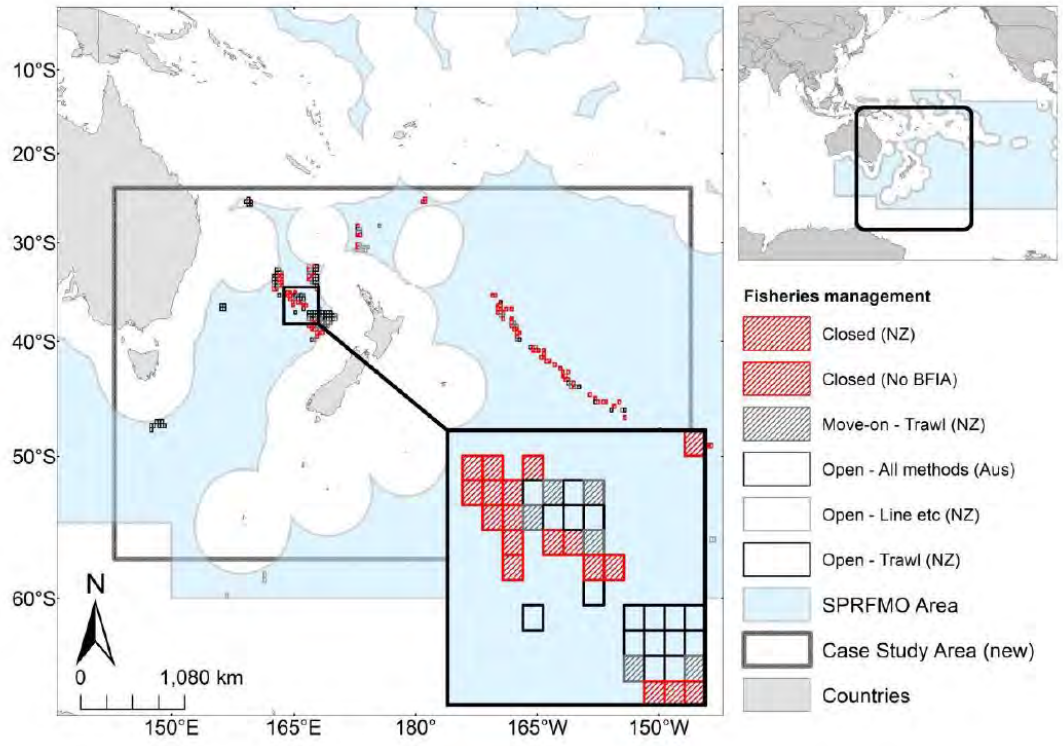


Figure 2: Location of the area within which the distribution of VME indicator taxa was modelled (grey box) overlaid with the existing open, closed, and move-on management blocks in CMM-03-2018. The SPRFMO Area is shaded pale blue.

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 significant adverse impacts 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. 2011) 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.

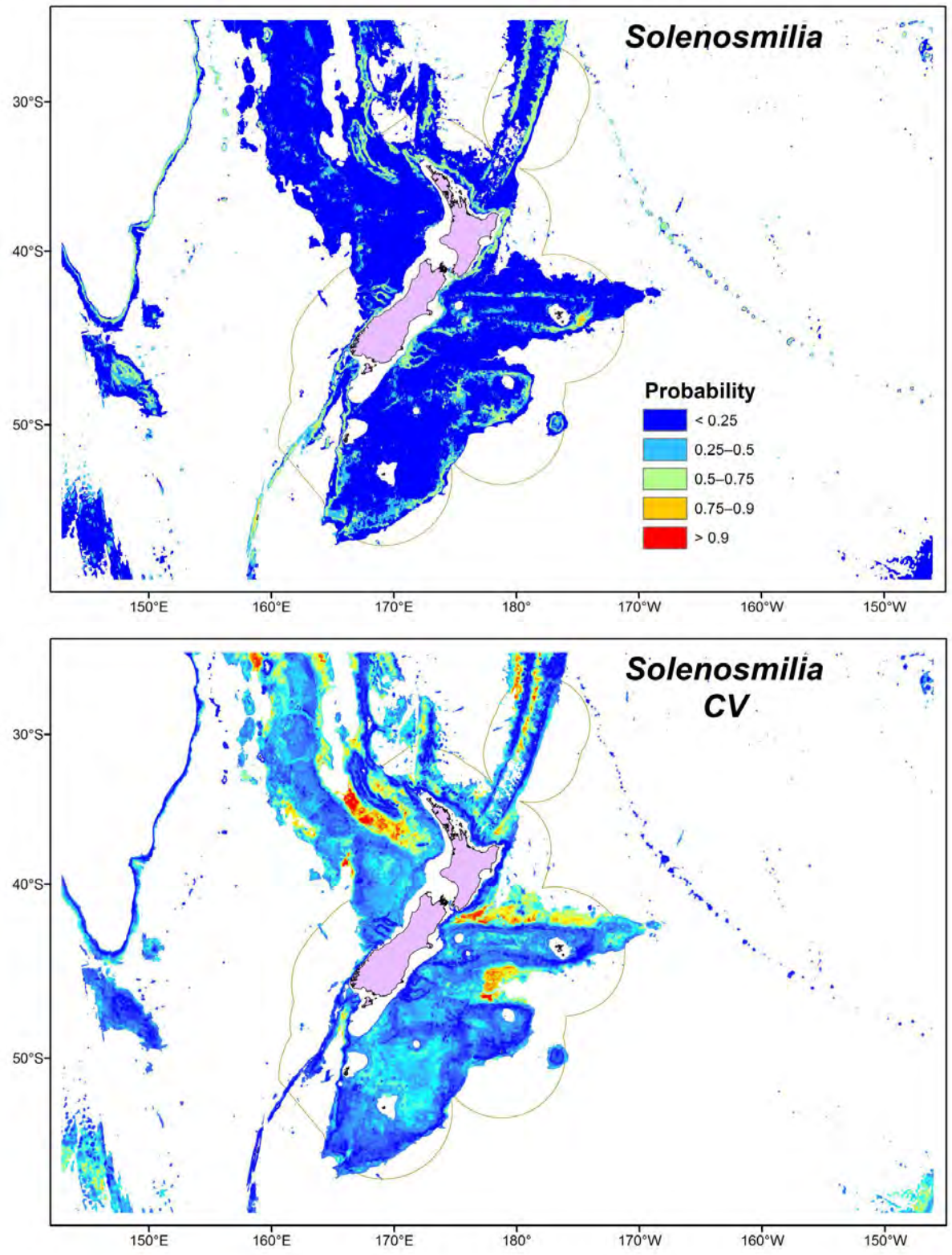


Figure 3: Example model predictions of habitat suitability (likelihood of occurrence) for the stony coral *Solenosmilia variabilis*. The bottom panel shows the estimated coefficient of variation (CV) for the predictions. This model includes predictions for the New Zealand EEZ as well as for parts of the SPRFMO Area but only information outside EEZs was used in the design of candidate spatial management areas. Habitats in waters deeper than 3000 m are not included in the model and are shown white.

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 domestic stakeholders) 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 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;
- **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 finalise the Zonation analyses that would provide the basis for informing the design of candidate spatial management areas and to consider draft spatial management areas drawn up by officials. 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 (e.g., Figure 4), and the relative performance of different candidate spatial management areas offered by New Zealand officials as a basis for discussion.

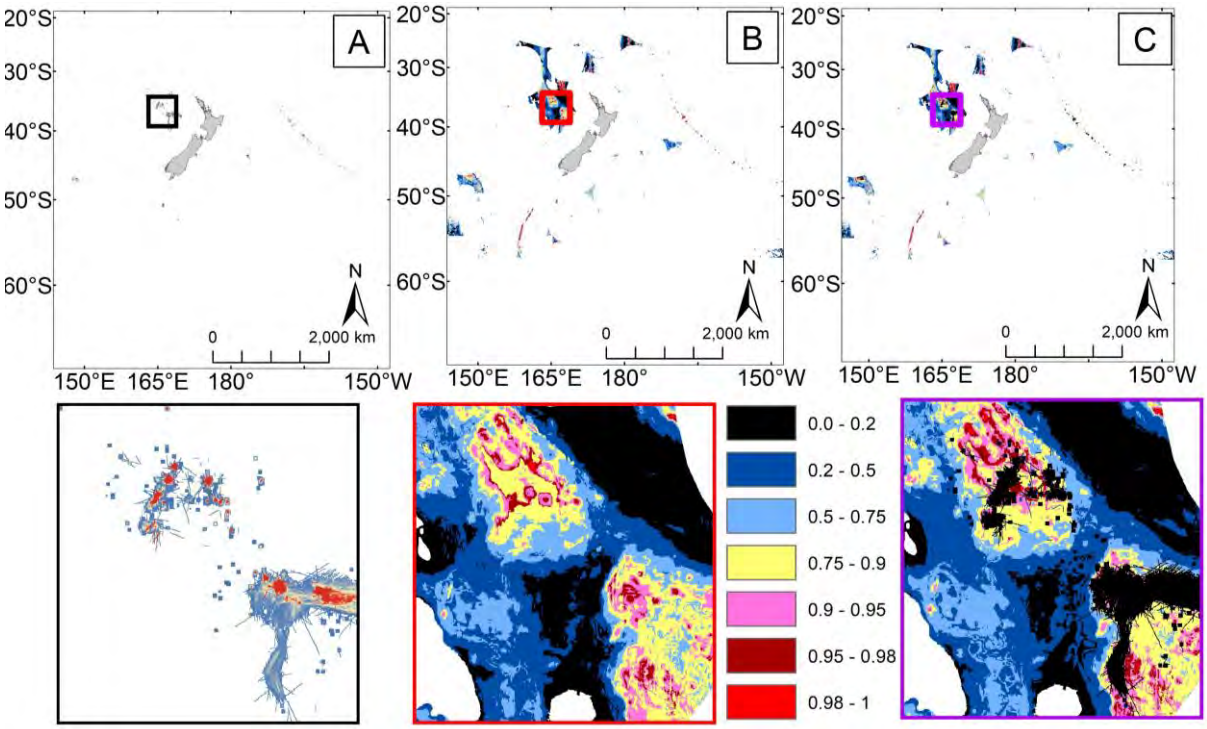


Figure 4: Example maps of the main Tasman Sea fishery areas discussed by stakeholders in 2017 showing the value for fishing operations of different 1 km^2 cells (left), Zonation's estimated priorities for different 1 km^2 cells disregarding any potential cost to fishing (middle) and Zonation's revised estimated priorities for different 1 km^2 cells after taking into account the potential costs to fishing (right). Zonation's estimated priorities are shaded black through red, habitats in waters deeper than 3000 m are not included in the model and are shown white.

3. Process used to design spatial management areas

The process used to design and refine the draft spatial management areas using input data from Zonation and other spatial information appears not to have been well-understood by all stakeholders or by Members attending SC-05 and the Commission in 2018. More detail is, therefore, provided here. The process used by officials from New Zealand's Ministry for Primary Industries and Department of Conservation convened, together with GIS experts, and followed the following procedure:

- Develop a grid of 6 minute-of-arc (m.o.a.) cells[1], boundaries aligned to degrees of latitude and longitude, as a starting point for designing boxes to declare open for fishing (this is the finest scale that SC has considered feasible for management areas in the past);
- Overlay the 6 m.o.a. grid on layers showing Zonation-derived priorities[2] for VME protection, the value to the fishery, and trawl events, all plotted at a scale of 1 km * 1 km grid squares (at 40 °S, a 6 m.o.a. cell will contain ~95 x 1 km^2 cells) (Figure 5);

[1] A minute of arc (m.o.a.) is a unit of angular distance equal to one-60th of a degree (in this case, of latitude and longitude). Thus, 1 m.o.a. of latitude is a distance at the Earth's surface of 1.0 nautical miles, 1.852 km, and 1 m.o.a. of longitude is a distance at the Earth's surface of 1.0 nautical miles multiplied by the cosine of the latitude (in degrees) at that location.

[2] Zonation software was used to generate maps wherein each cell had an estimated priority to include in areas protected from disturbance agents (in this case, fishing). A high Zonation priority implies high conservation value (in this case, for VMEs).

- Conduct a search in GIS to identify all 6 m.o.a. cells with at least 50% of their constituent 1km^2 cells containing a fishery value that was at least 1% of the maximum fishery value or where 10% of their constitute 1km^2 cells containing a fishery value that was at least 10% of the maximum fishery value; these are the priority cells to open for fishing from a "least cost to users" perspective (Figure 6);
- Conduct a search in GIS to identify all 6 m.o.a. cells that contained at least 30% of constituent 1km^2 cells with a VME priority value of 0.2 or lower; these are the priority cells to open for fishing from a "least risk to VMEs" perspective (Figure 6);
- The two sets of selected 6 m.o.a cells were intersected so only those 6 m.o.a cells which met all selection criteria remained (Figure 7); these are the cells that form the starting point for designing management areas;
- Inspect boundaries using expert judgement to identify:
    - Locations where high-priority 1km^2 cells for VME protection occurred within the 6 m.o.a. grid cells proposed to be opened;
    - Locations where high-value 1km^2 cells for fishing occurred outside the 6 m.o.a. grid cells proposed to be opened;
    - Locations where the fishable part of a 6 m.o.a. grid cell proposed to be opened could not be realistically fished, given the "run up" distance required to deploy a deepwater trawl.
- Adjust the boundaries of the areas proposed to be opened to fishing to include fewer high priority 1km^2 cells for VME protection and more 1km^2 cells of high value for fishing (Figures 8 and 9);
- Adjust the boundaries of the areas proposed to be opened to fishing to simplify boundaries where possible (Figure 9);
- Where fishing has historically been focussed on relatively small areas and seabed features ("seamounts"), mostly on the Louisville Seamount Chain, and where it is extremely hard to design management areas to include few high priority 1km^2 cells for VME protection and mostly 1km^2 cells of high value for fishing, a different approach was taken to close some features to fishing and open others:
    - Using GIS, the aggregate (sum) of the fishing value layer and the VME priority layer were calculated for each feature on the Louisville Chain;
    - Features for inclusion in the areas proposed to be opened to fishing were chosen on the basis of a high ratio of value to fishing compared with VME priority;
    - Features for exclusion from the areas proposed to be opened to fishing were chosen on the basis of a high ratio of VME priority compared with value to fishing.

This process is summarised graphically in Appendix 1.

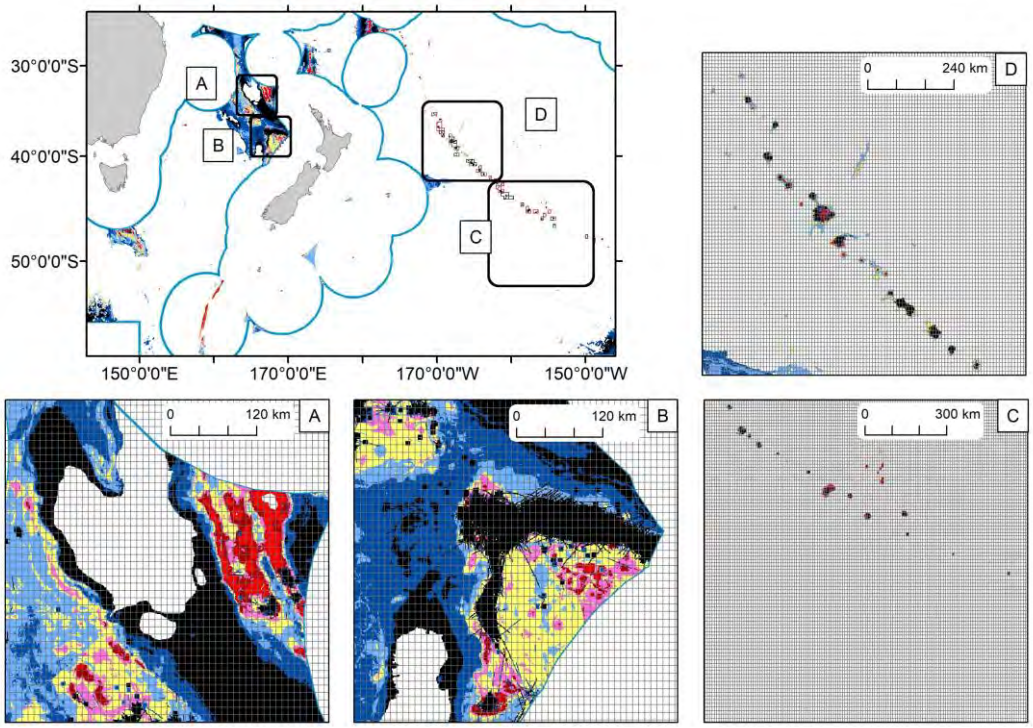


Figure 5: Map showing the overlay of a 6 m.o.a. grid on the Zonation and other data layers comprising 1 km^2 cells. Zonation's estimated priorities are shaded black through red, habitats in waters deeper than 3000 m are not included in the model and are shown white.

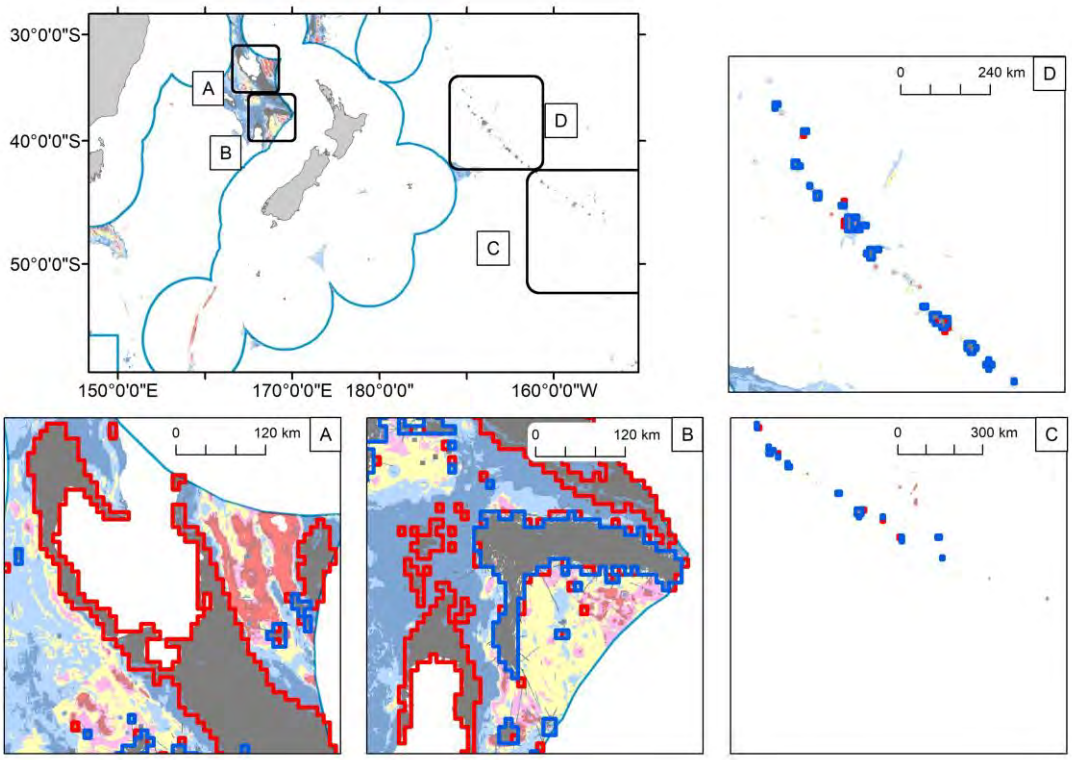


Figure 6: Map showing the two automated GIS searches for 6 m.o.a. grid cells with a high priority for inclusion in areas open to fishing from a least risk to VMEs perspective (red lines surrounding grey shading) and least cost to fishing perspective (blue lines surrounding grey shading).

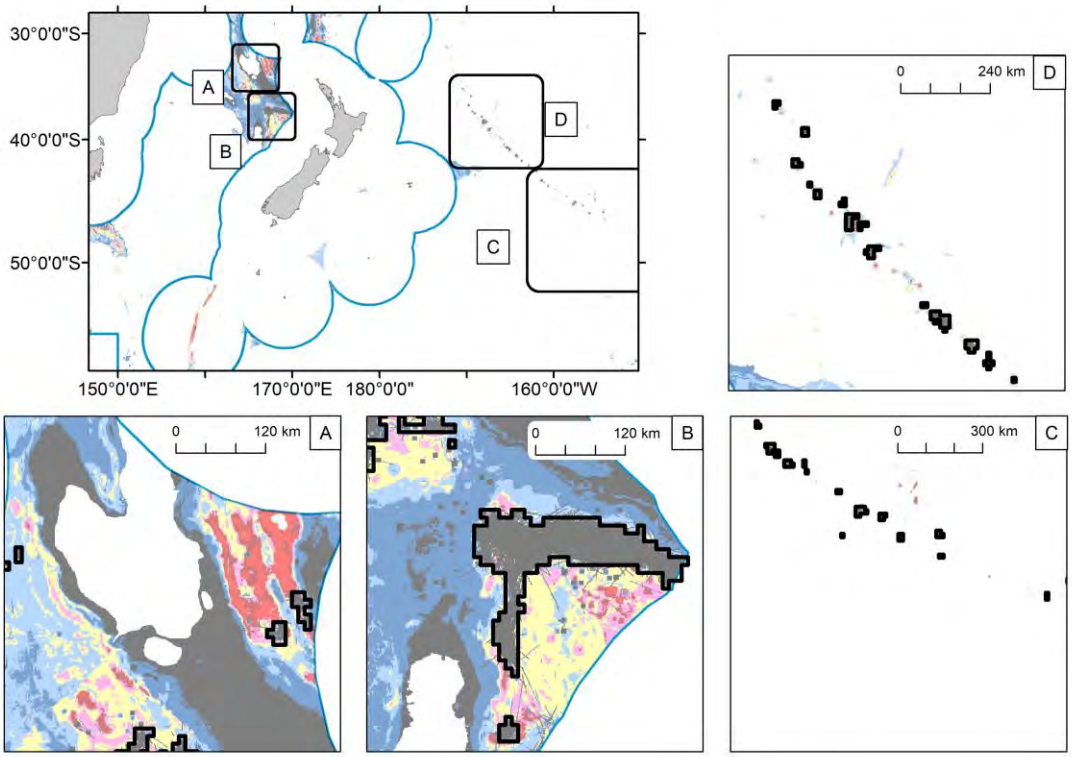


Figure 7: Map showing the intersection of the two automated GIS searches for 6 m.o.a. grid cells with a high priority for inclusion in areas open to fishing (black lines surrounding grey shading) after discarding those cells with no previous fishing.

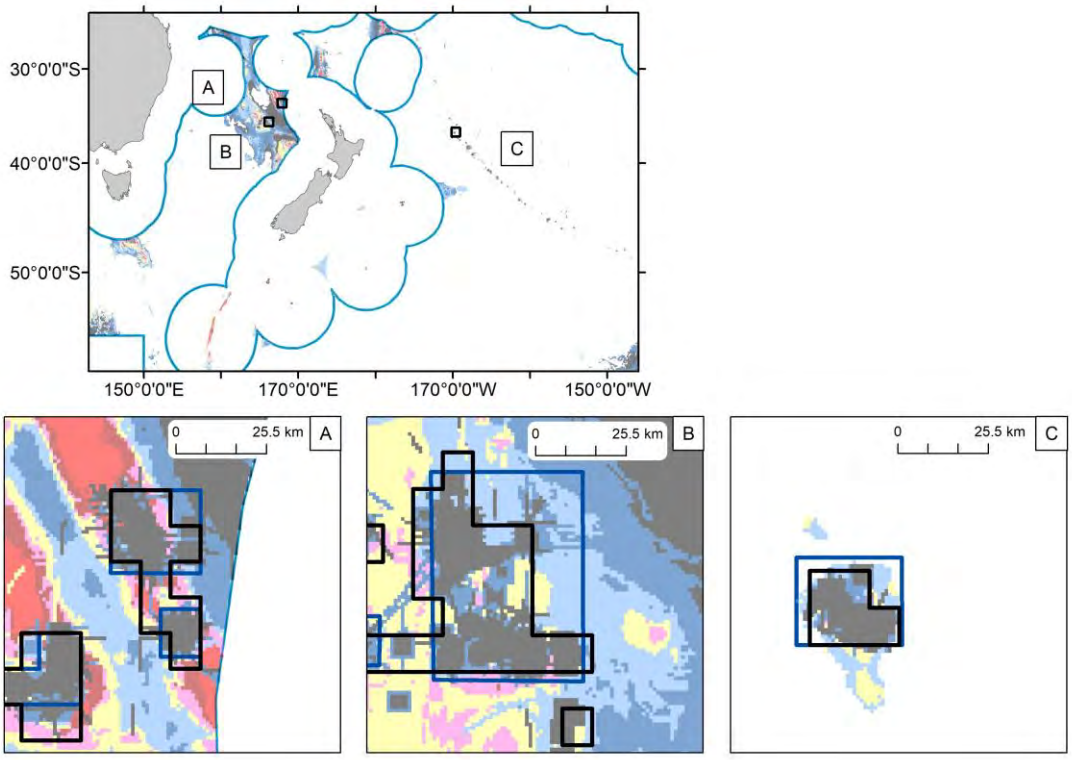


Figure 8: Map showing changes to boundaries made to proposed areas open to fishing (black lines) by New Zealand officials to exclude high priority 1 km^2 cells for VME protection, include high priority 1 km^2 cells for fishing, or simplify boundaries.

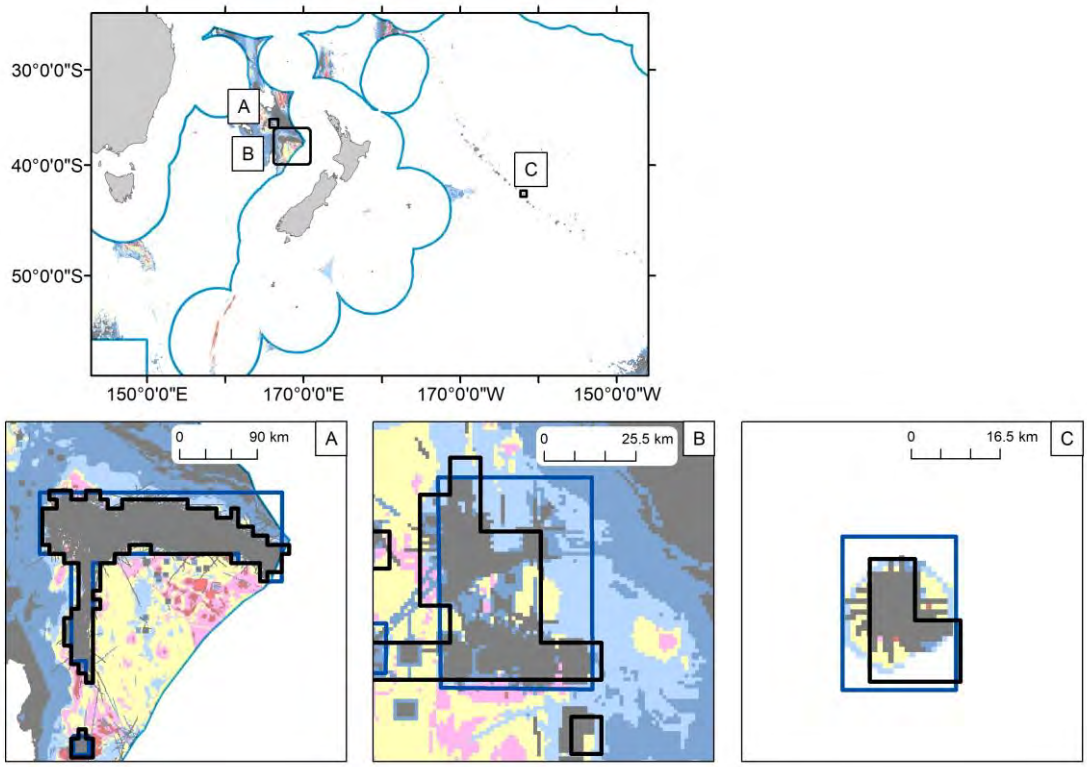


Figure 9: Map showing changes to boundaries made to proposed areas open to fishing (black lines) by New Zealand officials to exclude high priority 1 km^2 cells for VME protection, include high priority 1 km^2 cells for fishing, or simplify boundaries.

Performance of the three sets of candidate spatial management areas (based on an automated least cost to the fishery approach, and automated least risk to VMEs approach, and the "nuanced" intersected layers, were assessed from both a fishery and conservation perspective in Zonation using conservation benefit curves (e.g., Figure 10) and summary tables (having the type of information shown in Table 1). These were presented to stakeholders for their information and feedback.

Following the feedback from the various workshops and additional discussions with scientists, experts and stakeholders, New Zealand officials and scientists from key departments worked together to design the final proposals contained in the draft CMM. In particular, the proposed open areas were further refined to ensure they were large enough to allow trawl fishing operations to be conducted following industry feedback. The performance of the revised proposed areas for protecting VMEs and providing for a viable fishery was then reassessed (results shown in Table 1).

Following presentation of a draft new bottom fishing measure as an information paper and a descriptive supporting paper to Commission in early 2018, New Zealand officials began refining the developing CMM. The opportunity was also taken to consider whether changes to the boundaries of the spatial management areas put forward in the information paper could better meet stakeholders' objectives and the requirements of the Convention and UNGA resolutions. Ideas on potential boundary movements were sought form stakeholders, scientists,

and officials, and an additional workshop was arranged for late August 2018 to view the likely performance of different candidate areas. **The results of this reassessment were not available at the time of submitting this paper.**

4. Estimated performance of spatial management areas

The performance of all candidate areas was assessed using conservation benefit curves and summary tables (see Figure 3 and Table 1). Based on the available information on the distribution of VME taxa and historical fishing, and acknowledging the uncertainty in that information, the proposed spatial management measures would provide substantially greater protection for stony corals and other VME taxa than the existing management measures implemented by Australia and New Zealand. Overall, the proportion of the distribution of VME taxa protected from any adverse effects of fishing would increase from 65% to 86% were the proposed measures to be implemented. There is some regional variation in this proportion; about 90% of the distribution of VME taxa would be protected in the Tasman Sea fishery areas compared with just under 80% on the Louisville Seamount Chain. In the main fishery areas in the Tasman Sea and on the Louisville Seamount Chain, the proposed new management areas would provide 50–60% greater protection for stony corals than the existing arrangements and impose slightly lower cost (in terms of lost fishing opportunities) on the fishing industry (somewhat higher cost on the Louisville Seamount Chain and lower in the Tasman Sea). The average proportions of stony corals and other VME taxa likely to be protected are similar.

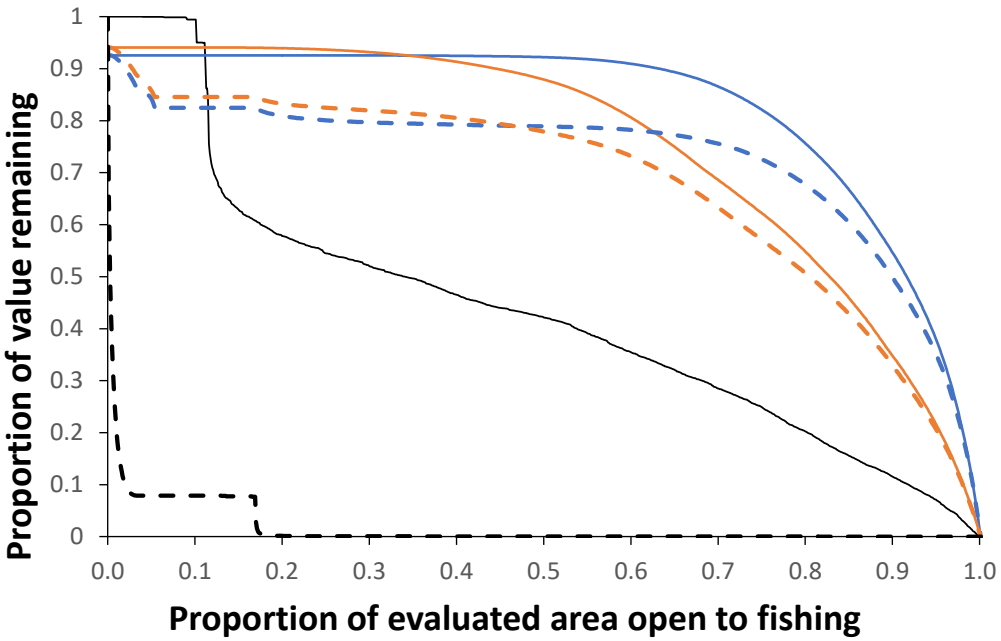


Figure 10: Example conservation benefit curve used by stakeholders to understand the likely performance of candidate fine-scale spatial management areas. In this example, blue lines relate to stony corals, orange lines relate to other VME taxa, and black lines relate to the "cost" to the fishing industry in terms of space wherein fishing would be prohibited. 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.

It is likely that the estimates of the proportion of VME taxa protected from any adverse effects of fishing in Table 1 are underestimates (but, because of the uncertainty inherent in the habitat suitability modelling, not necessarily minimum estimates). Because current technology precludes fishing much deeper than about 1600 m, no VME taxa found deeper than this will be contacted by trawl gear (aside from very occasional accidents). Thus, VME taxa found in water between ~2000 m and 3000 m (the limit of VME habitat suitability models) within the areas proposed to be open to fishing are safe from any adverse effects of fishing. In addition, the SPRFMO definition of fishing includes shooting and hauling a trawl net, and several kilometres are required to deploy or retrieve a trawl in deep water. Thus, VME taxa found close to the boundaries of areas proposed to be open to fishing are also safe from any adverse effects of fishing.

Table 1: Estimated performance of the spatial management areas proposed to Commission in January 2018 compared with the existing areas as implemented by Australia and New Zealand for the western SPRFMO Area shallower than 3000 m depth. Note the greatly improved protection for VMEs provided by the proposed areas and the slightly lower cost to the fishing industry in the main fishery areas. All estimates are conditional on the models and data layers used.

	Percent of fishing industry value layer lost	Overall percent of VME habitat protected	Percent of stony coral habitat protected	Percent of habitat for other VME taxa protected
Proposed open and closed areas				
Overall	7.9	86.4	85.2	87.1
Tasman Sea	2.9	89.8	89.7	89.9
Louisville	12.7	79.9	77.3	81.6
Other areas	100.0	100.0	100.0	100.0
Existing open and closed areas				
Overall	8.6	65.4	62.0	67.6
Tasman Sea	10.7	61.0	56.1	64.2
Louisville	6.3	56.2	51.8	59.1
Other areas	95.8	86.2	84.9	87.1

5. Discussion

New Zealand and Australia, with support from other Members, especially Chile and the EU, brought together the best available information on the distribution of VME indicator taxa, the distribution and value of historical bottom fishing, and bathymetry within a decision support framework designed to identify candidate spatial management areas that best meet the diverse objectives of stakeholders and managers and the objectives and requirements of the SPRFMO Convention and relevant UNGA resolutions. In essence, this is a conditional optimisation problem whereby the “best” consideration of stakeholders’ and managers’ objectives can be

sought, conditional on achieving the requirements of the Convention text (*through the application of the precautionary approach and an ecosystem approach to fisheries management, to ensure the long-term conservation and sustainable use of fishery resources and, in so doing, to safeguard the marine ecosystems in which these resources occur*) and UNGA resolutions (*to prevent significant adverse impacts on vulnerable marine ecosystems*). We believe it is for the Commission to decide whether the spatial management approach that New Zealand and Australia will propose to the 2019 meeting meets these two requirements and, if so, whether the consideration of conservation, utilisation, and operational management objectives (largely for simplicity) is an acceptable one. We do not seek guidance from SC-06 on the matters above, rather we seek SC-06 agreement that the approach to design we have taken is scientifically appropriate.

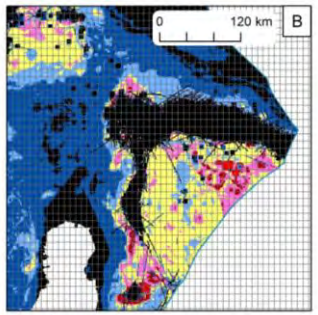
6. Recommendations

It is recommended that the SC:

- **Notes** that the process used to design proposed spatial management areas for a bottom fishing CMM combined outputs on priority (for VME protection) from Zonation decision-support software with information on bathymetry and the distribution and relative value for bottom fishing of different locations;
- **Notes** that the scale of these input data layers (~1 km) is too fine for realistic management areas (~10s of km);
- **Agrees** 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;
- **Notes** 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.

Appendix 1: Flow chart to illustrate some of the key steps in the design of spatial management areas using finer-scale data layers from Zonation, commercial bottom fishing returns, bathymetry, and the "naturalness" layer. The key of the objectives of the design were to include as much fishing value and operational capability in the areas open to fishing as possible, to exclude as much of the high priority areas for VME protection as possible, and to maintain simple boundaries

Image 1. (see step 2)



1. Creation of 6 minute-of-arc grid for the study region

2. Overlay grid on zonation derived proprieties (including naturalness and value to the fishery)

3. GIS search – priority cells to open for fishing from a "least cost to users" perspective.

(blue lines)

4. GIS search – priority cells to open for fishing from a "least risk to VMEs" perspective

(red lines)

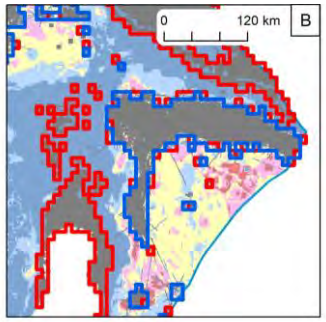


Image 2. (steps 3 and 4)

5. Intersection of automated spatial mgmt. areas from GIS searches

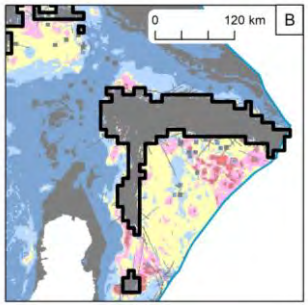
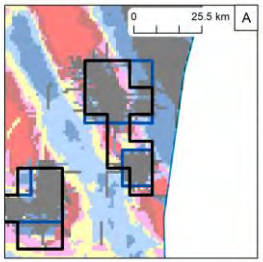
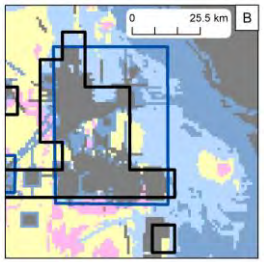


Image 3. (step 5)

6. Inspect boundaries of open areas to identify:
   a) High priority VME cells inside boundaries
   b) High fishing value cells outside boundaries
   c) Extended space for run-ups if needed

Image 4 a & b. (Steps 6 and 7)





7. Adjust boundaries include to address criteria in step 6

8. Adjust the boundaries of the areas proposed to be opened to fishing to simplify boundaries where possible

9. Louisville Seamount Chain adjustments using expert judgment

Spatial mgmt. areas proposed for consultation

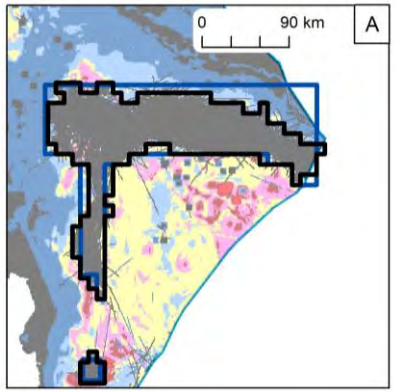


Image 5. (Steps 7 and 8)