South Pacific Regional Fisheries Management Organisation

1st Meeting of the Scientific Committee

La Jolla, United States of America, 21-27 October 2013

SC-01-09

Identification of vulnerable benthic taxa in the western SPRFMO Convention Area and review of move-on rules for different gear types

S. Hansen, P. Ward and A. Penney

Australian Government
Department of Agriculture, Fisheries and Forestry
ABARES

Identification of vulnerable benthic taxa in the western SPRFMO Convention Area and review of move-on rules for different gear types

S. Hansen, P. Ward and A. Penney

Research by the Australian Bureau of Agricultural and Resource Economics and Sciences

SPRFMO document number: SC-01-09
October 2013

Cataloguing data
Hansen, S., Ward, P., Penney, A., 2013, Identification of vulnerable benthic taxa in the western SPRFMO Convention Area and review of move-on rules for different gear types, SC-01-09 presented at the First meeting of the South Pacific Regional Fisheries Management Organisation (SPRFMO) Scientific Committee (La Jolla, 21–27 September 2013), Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), Canberra, October.

Internet
Identification of vulnerable benthic taxa in the western SPRFMO Convention Area and review of move-on rules for different gear types is available at: daff.gov.au/abares/publications.

Department of Agriculture
Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)
Postal address GPO Box 1563 Canberra ACT 2601
Switchboard +61 2 6272 2010|
Facsimile +61 2 6272 2001
Email info.abares@daff.gov.au
Web daff.gov.au/abares

Acknowledgements
Kim George and Chris Dick of Research Data Management, New Zealand Ministry for Primary Industries (MPI), provided access to historical scientific observer data on benthic bycatch by New Zealand vessels fishing in the SPRFMO Area. Ben Sharp and Geoff Tingley (New Zealand MPI) provided comments on an earlier version of this paper.

Contents

Executive Summary 1

Introduction 3

International requirements for high seas fisheries 3
Origins and history of move-on rules 5

Review of RFMO and flag state approaches 7

South Pacific Regional Fisheries Management Organisation 7
Commission for the Conservation of Antarctic Marine Living Resources 11
Atlantic RFMOs 15
General Fisheries Commission for the Mediterranean 17

Discussion 19

Key principles of VME identification 19
Attributes of effective move-on protocols 20
Considerations for an SPRFMO move-on rule 24

Conclusions 26

Appendix A Summary of VME move-on protocols 28

References 30

Tables

Table 1 Ratings of benthic habitat and bycatch impacts for each gear class 6

Table 2 Taxonomic groups identified as providing evidence of VMEs in the convention area of the South Pacific Regional Fisheries Management Organisation (SPRFMO), with two further groups identified as indicative of VME habitats. 7

Table 3 Tow length means and modes (nm) for Australian and NZ fishing fleets in the Tasman region 9

Table 4 Taxonomic groups that the 2009 CCAMLR workshop on VMEs identified as containing VME indicator species 13

Table A1 Summary of VME move-on protocols adopted by RFMOs and flag states 28

Figures

Figure 1 Illustration of the mean tow lengths in the Australian and New Zealand orange roughy (ORY) and alfonsino (ALF) fisheries in the SPRFMO Area, compared to the 5 nm move-on distance required under the SPRFMO interim measures for bottom fisheries 10

Summary

Regional Fisheries Management Organisations (RFMOs) or Regional Fisheries Management Arrangements (RFMAs) are a mechanism through which states that are party to a particular international fishery agreement cooperate to adopt and implement scientifically-based conservation and management strategies for transboundary, straddling and highly migratory fish stocks on the high seas. RFMOs adopt fisheries conservation and management measures which are binding on members. Engagement in RFMOs can be a mechanism for parties to give effect to their obligations under the *United Nations Convention on the Law of the Sea* (UNCLOS 1982) and the *Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks* (UNFSIA 1995) to cooperate with other countries in the management of highly migratory, straddling and shared fisheries resources. The Food and Agriculture Organization (FAO) of the United Nations has provided guidelines on how RFMOs are to approach the management of high seas resources, including the FAO Code of Conduct for Responsible Fisheries (2008) and the many technical guidelines published under this Code. Of direct relevance to the management of bottom fisheries, the FAO has provided the International Guidelines for the Management of Deep-Sea Fisheries in the High Seas (FAO 2009, referred to as the 'FAO Guidelines').

In 2007, the United Nations General Assembly (UNGA) adopted Resolution 61/105 that calls on high seas fishing nations and RFMOs to take urgent action to protect vulnerable marine ecosystems (VMEs) from destructive fishing practices, including bottom fishing, in areas beyond national jurisdiction. Key elements of Resolution 61/105 include undertaking impact assessments to determine whether bottom fishing activities would have significant adverse impacts on VMEs, identifying VMEs, establishing move on protocols, sustainably managing the exploitation of deep-sea fish stocks, and establishing appropriate monitoring, control and surveillance mechanisms. In 2009, UNGA adopted Resolution 64/72. While reaffirming Resolution 61/105, it asserted that measures should be implemented by flag states and RFMOs in accordance with the FAO Guidelines, prior to allowing or authorising bottom fishing in the high seas. Resolution 64/72 calls for States and RFMOs to conduct impact assessments on bottom fishing on the high seas and to ensure that vessels do not engage in bottom fishing until such assessments have been carried out.

In response, and largely in the absence of alternative measures, many RFMOs have formalised ‘move-on rules’ that require fishing to cease when evidence of VMEs is encountered (typically based on some pre-determined minimum weight or volume threshold for bycatch of specified vulnerable taxa) and to move a predetermined distance from the location of the encounter to prevent further damage. These move-on protocols may trigger temporary or longer term closures to fishing operations to prevent further impacts. RFMOs and flag states in different regions have adopted widely differing move-on protocols, with different lists of VME indicator taxa, weight thresholds and move-on distances. Several RFMOs have recently started to move towards spatial management (closure or zoning of relatively large areas) to protect VMEs rather than relying on move-on-rules.

This review summarises key aspects of the different approaches taken in developing move-on rules in different regions. These are used to distil desirable characteristics of effective move-on rules to inform possible further discussions on development of encounter-protocols and move-on rules for the South Pacific Regional Fisheries Management Organisation (SPRFMO) Area. An important issue is that move-on protocols cannot be considered in isolation; they are often one

component of a package that includes measures such as spatial closures, impact assessments and limits on catches or fishing effort.

Key conclusions of our review include:

1) Past analyses indicate that lists of regionally specific VME indicator taxa should be identified for each fishery in the region of interest, particularly for fisheries using different gear types that may be expected to impact and retain different benthic VME species.

2) It is important for VME indicator taxa to be specified at a taxonomic level that is appropriate with using them as a reliable indicator of potential VMEs, while allowing for accurate and rapid identification by scientific observers at sea. This will generally require taxa to be specified at higher levels than species, typically at Order or Family level. The list of VME indicator taxa should be updated as new information becomes available as a result of implementation of scientific observer programs and data collection as part of encounter protocols.

3) Adequate levels of coverage by fishery-independent observers are an essential component of effective move-on rules. The appropriate level of observer coverage will depend on the technical complexity of the move-on rule and compliance risks related to implementation of the move-on rule. Complex rules that require expertise in identifying VME taxa are best dealt with by scientifically trained observers with the time to do the identification. Fishery-independent observers are also required if there is a risk that move-on rules will not be followed by fishers. High levels of observer coverage (such as the 100 per cent required by the implementation of the interim measures for bottom trawling in the SPRFMO Area) would be ideal, but lower levels might be justified following a risk-assessment to identify high risk areas or fishing operations on which to focus observer coverage.

4) Where minimum weight thresholds are used as evidence of a VME, they should be based on analysis of historical bycatch weights of these species and reflect a precautionary approach to the range of weights retained by each gear type, such as less than the 50th percentile of cumulative retained weights. This indicates that a range of weights for different taxa is more appropriate than a single weight threshold for all taxa combined. Inclusion of a biodiversity index (number of taxa) provides an indication of multi-species VMEs.

5) In the event of an encounter constituting evidence of a VME, the specified move-on area should be closed to fishing by all vessels of the same gear type until further analysis has been conducted to determine whether the area concerned is likely to contain VMEs or not.

6) In protecting VMEs, it is important that if area closures are implemented in response to encounters with evidence of a VME that they be adequate to encompass at least the area covered by typical fishing operations using that gear type.

7) Move-on protocols should be considered to be interim measures, providing some minimum degree of protection to areas that show evidence of containing VMEs until other management arrangements are established. In the long term, properly planned spatial closures might be effective in protecting areas known or likely to contain VMEs while allowing commercial fishing to occur in other areas, with appropriate rules applied when VME indicators are encountered.

Introduction

There is increasing emphasis on managing the ecological impacts of fishing, not just for bycatch species, but also on habitats and communities. Within territorial waters, nations are responsible for monitoring their fisheries and ensuring the sustainability of fishing operations. In areas beyond national jurisdiction (high seas fisheries), fishing is largely conducted under the supervision of the relevant Regional Fisheries Management Organisations or Arrangements (RFMOs/RFMAs).

This review provides a summary of the different approaches taken by RFMOs in managing fishing impacts on vulnerable marine ecosystems (VMEs) in order to identify key attributes of effective management of fisheries impacts on VMEs. It also summarises existing publications and data to identify VME taxa that characterise the south Pacific Ocean. This information is intended to help inform the development of conservation and management measures for bottom fishing under the new South Pacific Regional Fisheries Management Organisation (SPRFMO).

International requirements for high seas fisheries

Regional Fisheries Management Organisations (RFMOs) are a mechanism through which States that are party to a particular international fishery agreement cooperate to adopt and implement scientifically-based conservation and management strategies for transboundary, straddling and highly migratory fish stocks on the high seas. Engagement in RFMOs can be a mechanism to give effect to can be a mechanism for States Parties to give effect to their obligations under the *United Nations Convention on the Law of the Sea* (UNCLOS 1982) and the *Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks* (UNFSIA 1995) to cooperate with other countries in the management of highly migratory, straddling and shared fisheries resources. Further guidance is provided by the many technical guidelines published by the Food and Agriculture Organization of the United Nations (FAO). First of these was the FAO Code of Conduct for Responsible Fisheries (1995) which states that:

> States should prevent overfishing and excess fishing capacity and should implement management measures to ensure that fishing effort is commensurate with the productive capacity of the fishery resources and their sustainable utilization. States should take measures to rehabilitate populations as far as possible and when appropriate.

The code of conduct goes on to make the a specific mention of habitat degradation as a result of human activity:

> Particular effort should be made to protect habitats from … significant impacts resulting from human activities that threaten the health and viability of the fishery resources.

The subsequent FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (2009) state that the two main objectives of the management of deep-sea fisheries are to ensure the 'long-term conservation and sustainable use of marine living resources', and to prevent significant adverse impacts on VMEs (paragraph 11, FAO 2009).

Following these UN instruments and FAO guidelines, the United Nations General Assembly (UNGA) has recently called for RFMOs and flag states to undertake a series of actions to address the impact of fisheries on VMEs.

In 2007, UNGA Resolution 61/105 called upon RFMOs:

> 83 d) To require members of the regional fisheries management organizations or arrangements to require vessels flying their flag to cease bottom fishing activities in areas where, in the course of fishing operations, vulnerable marine ecosystems are encountered, and to report the encounter so that appropriate measures can be adopted in respect of the relevant site.

Paragraphs 67–69 of Resolution 61/105 went further in calling on states and RFMOs to implement appropriate response protocols in cases where VMEs are encountered. However, these UNGA Resolutions are non-binding and it is therefore left up to RFMOs and flag states to give effect to these requirements in the manner most appropriate and effective for each specific region.

The four key requirements of Resolution 61/105 in relation to protection of VMEs are:

- to assess the impacts of individual bottom fishing activities and act to prevent such impacts from occurring (Paragraph 83a)
- to identify VMEs and to assess whether bottom fishing activities will negatively influence the long term survival and sustainability of such ecosystems (Paragraph 83b)
- in areas where VMEs are known or likely to occur, 'to close such areas to bottom fishing and ensure that such activities do not proceed unless conservation and management measures have been established to prevent significant adverse impacts on vulnerable marine ecosystems' (Paragraph 83c)
- to implement move-on protocols that require the cessation of fishing operations in cases that VMEs are encountered (Paragraph 83d).

In 2009, the UNGA reaffirmed this requirement for the protection of VMEs with Resolution 64/72, and further called on flag states and RFMOs to conduct impact assessments for exploratory fisheries before fishing operations commence. Resolution 64/72 acknowledged that Resolution 61/105 had not been implemented sufficiently in the given timeframe, and called for flag states and RFMOs to enact the necessary measures before proceeding with bottom fishing on the high seas (Rogers & Gianni 2010; UNGA 2010). More recently Resolution 66/68 (2011) noted that despite the progress made in recent years, the urgent actions called for in Resolutions 61/105 and 64/72 had not been fully implemented. Additionally, Resolution 66/68 (2011) encouraged marine scientific research, including the use of seabed mapping programmes, to identify VMEs (UNGA Resolution 66/68 adopted by the General Assembly on 6 December 2011, paragraph 131).

The SPRFMO responded to these calls during the early stages of negotiation of the SPRFMO Convention by adopting interim, non-binding measures for bottom fisheries, that reflected the requirements of the above UNGA resolutions. The requirements to conduct impact assessments was included in these interim measures and the interim Scientific Working Group (SWG) was tasked with developing guidelines for preparation of such assessments. The resulting SPRFMO Bottom Fishing Impact Assessment Standard was adopted in 2012. Bottom fishing impact assessments were prepared under a draft version of these guidelines by New Zealand (in 2007) and Australia (in 2011), each of which included details of how the countries concerned intended to monitor and respond to interactions with evidence of VMEs encountered during bottom fishing operations in the SPRFMO Area.

RFMOs have adopted a range of move-on rules to manage the impact of fishing on VMEs (Rogers & Gianni 2010; Kenchington 2011). The absence of specific or detailed management requirements in the UNGA resolutions has allowed RFMOs and flag states to institute regionally specific management measures for their fisheries. However this flexibility has resulted in varied and sometimes inadequate measures by different RFMOs, with some measures considered to afford little protection to VMEs (Rogers & Gianni 2010).

Origins and history of move-on rules

Move-on rules, also referred to as encounter protocols[1], were initially instituted in the early 1990s in Canadian snow crab fishery and groundfish fisheries to reduce wastage of unmarketable catches of target species (Kenchington 2011). In response to the UNGA requirements to 'prevent significant adverse impacts' to areas where VMEs are 'known or likely to occur', numerous RFMOs have adopted move-on rules as a first measure to prevent ongoing fishing in areas where 'evidence' of VMEs is encountered during fishing operations (Rogers & Gianni 2010; Kenchington 2011). This proceeded in the absence of spatial management approaches that several RFMOs are now beginning to develop, e.g. the North East Atlantic Fisheries Commission (NEAFC). These move-on rules require fishing vessels to move a predetermined minimum distance from locations where some pre-determined quantity of species indicative of VMEs are captured in fishing gear (FAO 2010; Rogers & Gianni 2010). In the event that a fishing vessel exceeds a predetermined threshold (weight, volume and/or biodiversity) of VME indicator species, a move-on rule may be triggered requiring the vessel to move a predetermined minimum distance from its current fishing area.

While the FAO guidelines (FAO 2009) provide broad definitions to guide RFMOs in the identification of VMEs, they do not advise on specific subsequent actions. The guidelines do, however, assert that states should 'require vessels flying their flag to cease fishing activities at the site and report the encounter ... to the relevant RFMO/A and flag State' (FAO 2009). The guidelines go on to propose that 'in areas where VMEs have been designated, or are known or likely to occur ... States and RFMO/As should close such areas to DSFs [deep-sea fisheries] until appropriate conservation and management measures have been established to prevent significant adverse impacts on VMEs and ensure long-term conservation and sustainable use of deep-sea fish stocks.' It is up to RFMOs and their flag states to tailor their rules so that they are practical and appropriate for their region and fisheries while meeting the requirements of the FAO management framework.

The FAO guidelines note that vulnerability stems from the likelihood of substantial alteration in populations, communities or habitats after short-term or chronic disturbance (FAO 2009). There are certain characteristics that may provide indications of the vulnerability of specific species or habitats. The FAO lists five characteristics that may help determine the vulnerability of different ecosystems:

1) uniqueness or rarity of the assemblage
2) functional significance of the habitat
3) fragility
4) life-history traits of component species that make recovery slow or difficult
5) structural complexity characterized by complex physical structures created by biotic and abiotic features.

[1] The terms 'move-on rules' and 'encounter protocols' are used interchangeably in this paper.

Following these broad guidelines, each RFMO and flag state has undertaken work to identify specific VME taxa in their respective areas of competence and then used these to develop move-on protocols tailored to the species in their region (see Appendix A for a summary of current move-on protocols in various areas).

In developing move-on rules, it is important for each RFMO to consider its specific fishery operations, and not rely on data from other fisheries. VME assemblages vary depending on the gear-types used and the longitude, latitude and depth of each operation (Kaiser et al. 2006; Rogers et al. 2008; Williams et al. 2011). Much of the work to identify vulnerable taxa has been based on data from bottom trawling, this being the gear type with most contact with the seabed, and therefore potentially able to cause the most damage to VMEs (Chuenpagdee et al. 2002, Table 1). However, bottom trawl gear has been shown to be a poor sampling tool for attached benthic species, particularly where these are fragile or flexible species, as the animals often fragment and are lost through the net (Rogers & Gianni 2010; Kenchington 2011).

While it has been shown that bottom longline sets retain lower volumes of habitat-forming VME indicator taxa, and have a far smaller impact area than trawl nets, there are concerns that lines may cause unobserved damage through the lateral movement of the mainline (or 'backbone') and chain due to currents or while hauling (Sharp et al. 2009). Multiple deployments of low-impact fishing gears in the same area may also result in significant adverse impacts (SAIs) to benthic communities or reduce the capacity of these habitats to recover (Williams et al. 2011).

The extent of damage cause by repeated disturbance is highlighted in the FAO guidelines that specify significant adverse impacts are those that 'compromise ecosystem integrity in a manner that ... (iii) causes, on more than a temporary basis, significant loss of species richness, habitat or community types'. As such, the guidelines require the duration and timing of disturbance in conjunction with the likely recovery rate of the ecosystem into account when determining the scale and significance of an impact. Impacts should be considered 'temporary' when an ecosystem is likely to recover in 5–20 years (as decided on a case-by-case basis). However, when the interval between disturbance events is shorter than the expected recovery time, the impact should be considered more than temporary (FAO 2009)

Table 1 Ratings of benthic habitat and bycatch impacts for each gear class

Gear class	Benthic habitat		Suggested consideration
	Physical	Biological	
Dredge	5	5	Not assessed
Gillnet – bottom	3	2	Not assessed
Gillnet – midwater	1	1	Not assessed
Hook and line (dropline)	1	1	None proposed
Longline – bottom	2	2	Impact on biological habitat likely higher than previously recognized
Longline – pelagic	1	1	Not assessed
Pots and traps	3	2	None proposed
Purse seine	1	1	Not assessed
Trawl – bottom	5	5	None proposed
Trawl – midwater	1	1	Some mid-water trawls targeting bentho-pelagic species come in contact with bottom

Sources: impact ratings were by Chuenpagdee et al. (2002) with rating considerations proposed by Williams et al. (2011), who only assessed and proposed considerations for gear types used by the Australian fishing fleet in the SPRFMO area.
Note: Ratings scale from 1 (very low) to 5 (very high).

Review of RFMO and flag state approaches

South Pacific Regional Fisheries Management Organisation

VME identification and move-on protocols

In 2009, New Zealand completed an assessment of its high-seas fisheries in the convention area of the South Pacific Regional Fisheries Management Organisation (SPRFMO; Parker et al. 2009b). This study identified eight taxonomic groups as being vulnerable to bottom trawl fisheries and capable of being retained in trawl nets, with a further two groups identified as VME habitat indicators due to their frequent association with VME habitats and taxa (Table 2). In developing this list of SPRFMO VME taxa, the New Zealand study adapted the general FAO VME criteria for the fishery characteristics and region, refining the criteria as follows:

1) fragility to fishing gears
2) functional significance to the community or ecosystem
3) uniqueness, rarity or endemism
4) low productivity due to life-history traits
5) previous encounters as bycatch
6) easy identification by scientific observers, without having to resort to complex characteristics or methods such as microscopy or meristics.

Criteria 1–4 drew heavily on the FAO guidelines, while criteria 5–6 were proposed by Parker et al. (2009b).

Table 2 Taxonomic groups identified as providing evidence of VMEs in the convention area of the South Pacific Regional Fisheries Management Organisation (SPRFMO), with two further groups identified as indicative of VME habitats.

Taxonomic level	Common name	Weight threshold (kg)	VME Indicator Score
Vulnerable taxa			
Phylum Porifera	Sponges	50	3
Phylum Cnidaria			
Class Anthozoa			
Order Actinaria	Anemones	0	1
Order Scleractinia	Stony corals	30	3
Order Antipatharia	Black corals	1	3
Order Alcyonacea	Soft corals	1	3
Order Gorgonacea	Sea fans		3
Order Pennatulacea	Sea pens	0	1
Class Hydrozoa			
Order Anthoathecatae			
Family Stylasteridae	Hydrocorals	6	3
Habitat indicators			
Phylum Echinodermata			
Class Crinoidea	Sea lilies		
Class Asteroidea		0	1
Order Brisingida	Armless stars	0	1

Source: Parker et al. (2009b).

Higher taxonomic groupings (Phylum, Class or Order) were used to ensure the speed and ease of identification by scientific observers, without reliance on complex identification characteristics or methods. It is likely that some species within taxonomic groupings may not be vulnerable to fishing activity due to their specific life history traits, but the need for rapid identification of taxa at sea makes the use of individual species impractical (Parker et al. 2009b).

The New Zealand VME Evidence Protocol based on the above taxa incorporates different weight thresholds for different taxa, based on an analysis of bycatch weight-frequency distributions in historical trawl catches. Using the 50th percentile of the cumulative weight-frequency distributions, this protocol uses different bycatch thresholds for each taxa (Table 2) to trigger a move-on. This protocol is also unique, so far, in including a biodiversity threshold, summing the scores for presence of each taxon and requiring a move-on if any three of the listed VME taxa are caught, even if individual weight thresholds are not breached (Parker et al. 2009b). Further, a three-level weighting was applied to each of the VME taxa groups based on the known importance of each group. Groups that exhibit life history characteristics that are known to contribute to higher vulnerability to fishing activities were scored high. While other groups that may be less vulnerable themselves, but indicate the presences of habitats containing VMEs, were scored low. If the total VME indicator score is three or greater, the area is considered to have evidence of a VME (Parker et al. 2009b).

Kenchington (2011) questions the effectiveness of the biodiversity thresholds introduced by New Zealand as being too severe, potentially leading to excessive movement of vessels, and the displacement of fishing effort into a previously undisturbed location. However, by introducing a biodiversity score into the protocol, New Zealand has addressed the possibility of low retention rates and low retained weight of small, fragile coral species.

Scientific observers on Australian vessels utilise the same VME indicator species as used by New Zealand (Williams et al. 2011). However, the Australian fleet operates under a simpler protocol with a single bycatch weight threshold of 50 kg of coral and/or sponge in one trawl. The Australian high-seas fishery makes more use of bottom longlines and drop lines and, for non-trawl vessels, this threshold is reduced to 10 kg of coral and/or sponge per 1000 hook section of line or 1200 m section of line, whichever is shorter. If this threshold is breached, the fishing vessel must cease operations and a temporary closure of 5 nm radius is implemented around the area of the trigger operation. This closure remains in place for all Australian flagged fishing vessels using the same gear for the life of the permits (reissued each year).

In 2008, the European Union presented a draft fishing plan for proposed gillnet fishing by in the SPRFMO area. This assessment included a move-on protocol similar to measures implemented by RFMOs in the Atlantic (SPRFMO 2008) and was criticised for proposing bycatch weight thresholds that were considered excessively high: 1000 kg of sponge and 100 kg of coral (Kenchington 2011).

VME move-on distances

The SPRFMO interim management measures for bottom fishing state that participants will 'require that vessels flying their flag to cease bottom fishing activities within five nautical miles of any site in the Area where, in the course of fishing operations, evidence of VMEs is encountered' (SPRFMO 2007). It should be noted that the SPRFMO interim measures do not distinguish between bottom fishing methods, nor do they indicate a required a duration of the closure.

Under the New Zealand SPRFMO Area VME Evidence protocol, in the event that the bycatch or biodiversity thresholds are breached by a New Zealand fishing vessel, the vessel concerned is required to cease fishing operations and move 5 nm away from the position of the end of the trawl. This 5 nm radius closure remains active only for that vessel and only for the duration of that particular trip. Despite the requirements of the SPRFMO interim measures for bottom fishing, under the New Zealand measures, there is no requirement for other fishing vessels flying their flag to remain outside the encounter area. Furthermore, the area remains closed only for the current fishing trip, allowing the vessel that exceeded the threshold to return to the encounter location on a subsequent trip (Kenchington 2011). In contrast, in the event that a move-on is triggered for the Australian fleet, the resulting 5 nm closure applies to the entire length of the trawl tow or line set and remains active for all vessels fishing under the Australian flag for the remaining duration of the annual fishing permits. All VME evidence must also be reviewed before the issuing of new permits (Williams et al. 2011). The Australian approach seems to be more compatible with the UNGA expectations and with the SPRFMO requirement for all participants to provide data on VME encounters so that these can be further reviewed by the Scientific Committee to determine the likelihood of presence of VMEs in areas where evidence of VMEs was found.

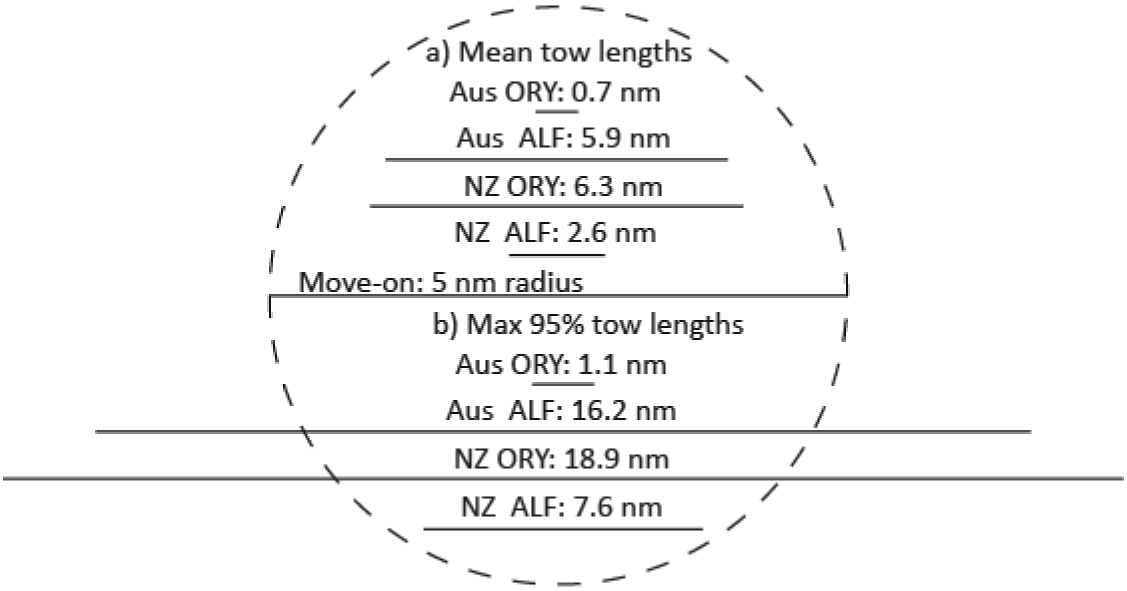
The question of where to move away from is a difficult one. Due to the length of trawls, it will be unknown where exactly within a trawl any retained VME taxa were actually caught. Moving away from the end position, for a long trawl, might result in the start position remaining outside a 5nm closure. The Australian move-on protocol requiring vessels to move-on 5 nm from any point along the trawl track recognises the possibility that the VME evidence could have been caught anywhere along the trawl (Kenchington 2011; AFMA 2013).

The typical frequency distribution of tow lengths should be analysed before setting the move-on distance for move-on rules. The Australian and New Zealand trawl fisheries in the south Pacific mainly target orange roughy (*Hoplostethus atlanticus*) and alfonsino (*Beryx* spp.). An analysis of tow lengths in these fisheries shows that the mode and mean tow lengths are less than 10 nm, so a 5 nm move-on distance should be adequate for most trawls in the SPRFMO Area (Table 3 and Figure 1). However, New Zealand trawls targeting orange roughy in certain areas can occasionally be longer than 18 nm and Australian trawls for alfonsino can exceed 16 nm in length. For these longer trawls, a 5 nm move-on from the tow end position may result in sections of the trawls being left open to fishing. This illustrates the importance of setting the move-on distance based on the typical length of the trawling operations for each fishery. Given that trawl lengths vary between fleets and targeted species, even within the same region, it becomes necessary to choose some compromise move-on distance that affords adequate protection across a wide range of tow lengths. This also highlights a problem with move-on rules, in that the size and exact location of the potential VME remains unknown and, if the VME is small, a considerable amount of fishing ground could be closed unnecessarily, especially for longer tow lengths.

Table 3 Tow length means and modes (nm) for Australian and NZ fishing fleets in the Tasman region

Fishing fleet	Target species	Length of trawl (nm)		
		Mode	Mean	95% CI
Australia	orange roughy	0.54	0.73	1.08
	alfonsino	1.08	5.94	16.20
New Zealand	orange roughy	1.08	6.30	18.90
	alfonsino	1.62	2.59	7.56

Figure 1 Illustration of the mean tow lengths in the Australian and New Zealand orange roughy (ORY) and alfonsino (ALF) fisheries in the SPRFMO Area, compared to the 5 nm move-on distance required under the SPRFMO interim measures for bottom fisheries.



Protection of VMEs

Under the SPRFMO Interim Measures for bottom fisheries, participants are required to 'Not expand bottom fishing activities into new regions of the Area where such fishing is not currently occurring'. This has been interpreted (following recommendations from the interim Scientific Working Group) to mean that states should not fish outside any 20-minute latitude-longitude block fished over the reference period 2002–2006. Maps of 20-minute blocks fished over 2002–2006 are referred to as 'fishing footprint' maps and limiting fishing to within such footprints has been internationally referred to as the 'freeze the footprint' approach, the intention of which is to at least prevent the spread of fishing impacts until other protective measures can be developed and implemented.

For areas where VMEs are known to occur or are likely to occur, the interim measures also require participants to 'close such areas to bottom fishing unless … conservation and management measures have been established to prevent significant adverse impacts on vulnerable marine ecosystems and the long-term sustainability of deep sea fish stocks or it has been determined that such bottom fishing will not have significant adverse impacts on vulnerable marine ecosystems or the long term sustainability of deep sea fish stocks.'

As part of their SPRFMO bottom fishing impact assessment (Ministry of Fisheries 2008) New Zealand classified areas within their 2002–2006 trawl footprint as being heavily, moderately or lightly fished by its bottom trawl fishing fleet. Effort thresholds were chosen to divide the total footprint approximately into thirds. Any 20-minute block with fewer than 2 trawls over 2002–06 was termed 'lightly' fished and was closed to fishing, resulting in a 30 per cent closure to protect undamaged VMEs in such areas. Blocks that had experienced 3–49 sets in the same time period were termed 'moderately' fished, while those blocks fished more than 50 times were termed heavily fished, and an additional 10 per cent of blocks in these two tiers were closed, resulting in a total 40 per cent closure of previously fished areas (Penney et al. 2009). These closures were designed to meet the UNGA requirements of 'preventing significant adverse impacts' on VMEs, with New Zealand considering that this 40 per cent closure, together with closures of unfished areas outside the footprint, were adequate to prevent adverse impacts in fished from being significant. As a corollary, New Zealand has only implemented their move-on protocol in the moderately fished tier, leaving the heavily fished tier open to fishing without any move-on provisions. Importantly, this approach includes considerable area with the open footprint that has not been fished, much of which is also unlikely to be fished in the future due either to lack of fish resources in the area or unfishable ground; no account of this area has been made in considering habitat protection.

Following depletion of orange roughy resources on the South Tasman Rise, the area was closed to Australian vessels under the Australian orange roughy conservation plan, and subsequently closed to both Australian and New Zealand vessels in 2007 under a joint agreement (although New Zealand has not fished there since the end of the 2000–01 fishing season; Williams et al. 2011). This has resulted in closure of nine of the 20-minute blocks in the Australian SPRFMO bottom fishing footprint.

Commission for the Conservation of Antarctic Marine Living Resources

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) was established in 1982. The objective of the Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention) is the conservation of Antarctic marine living resources, where the term 'conservation' includes rational use. CCAMLR has adopted conservative biomass targets for target stocks (i.e. 50 per cent or 75 per cent of unfished biomass depending on the trophic role of the target species). The CAMLR Convention requires that any harvesting activities are conducted in accordance with the following principles of conservation: that ecological relationships are maintained, that depleted populations are restored and that all ecosystem changes associated with harvesting activities be reversible on the scale of two to three decades. The FAO considers the region to be an example of successful fisheries management, with more than 20 of its fish stocks currently classified as moderately exploited or under-exploited (Rogers & Gianni 2010).

The currently remaining active fisheries in the CCAMLR Convention Area target krill (using midwater trawls), mackerel icefish (primarily using midwater trawls) and toothfish, using mid-water trawling and bottom longlining, with some experimental fishing for toothfish using pots (Rogers & Gianni 2010). The only Antarctic fisheries currently employing bottom trawls are for toothfish and icefish in the Australian EEZ around Heard and McDonald Islands. This fishery is not a CCAMLR fishery, but rather an Australian fishery that applies CCAMLR rules in addition to other Australian legislation and policies which establish spatial closures to manage benthic impacts.

Relevant CCAMLR Conservation Measures

In response to UNGA Resolution 61/105, CCAMLR adopted Conservation Measure (CM) 22-05 that prohibited bottom trawling within high-seas areas of its regulatory waters, except for scientific trawling or where other specific CMs are in force for bottom trawling gear (CCAMLR 2012b). In 2007 CCAMLR adopted CM22-06 requiring all flag states wishing to undertake fishing activities in high-seas areas using bottom fishing methods other than trawls (i.e. bottom longlines and pots) to evaluate the known or anticipated impacts of their proposed fishing activity on VMEs. CM22-06 also requires Members encountering evidence of VMEs in research activities (e.g. using underwater cameras or research trawls) to notify the Secretariat so that appropriate actions can be taken on advice of the Scientific Committee (CCAMLR 2012b).

In 2008, CCAMLR adopted CM22-07 as an interim measure requiring that vessels participating in exploratory fisheries monitor VME bycatch on longline hooks and implement a move-on rule where bycatch exceeds a pre-defined trigger limit. Trigger locations are subsequently closed to fishing until their status is reviewed by the CCAMLR Scientific Committee (CCAMLR 2012b).

Recognising the higher prevalence and abundance of fragile benthic communities (including VMEs) in shallower water, in 2009 CCAMLR adopted CM22-08 prohibiting all bottom fishing in high seas areas shallower than 550 m, except for scientific research (CCAMLR 2012b).

In 2010 CCAMLR adopted CM 22-09 establishing a list of 'registered VME' locations and associated fishing closures for VMEs identified using data reported under CM22-06 and agreed by the Scientific Committee (CCAMLR 2012b).

VME taxonomic classification

The selection of CCAMLR VME indicator species was initially based on the SPRFMO VME taxa list developed by New Zealand's for their high-seas fisheries in the south Pacific Ocean (Table 2; Parker et al. 2009b). CCAMLR subsequently revised and expanded this list of taxa at a dedicated VME identification workshop held in 2009 (CCAMLR 2009). This workshop produced a revised list of VME characteristics/criteria for the CCAMLR area:

1) Functional significance of habitat forming taxa.

2) Longevity as indicative of potential recovery time in the event of disturbance. This was judged on a three-tier scale: low (<15 years), medium (15–30 years) or high (>30 years).

3) Slow growth rate as a contributor to long recovery times. Judged on a three-tier scale: low for fast growth rates, medium for moderate growth or high for slow growth rates.

4) Fragility or susceptibility to physical damage from fishing gear. Judged on a three-tier scale: low for high resistance, medium for moderate resistance or high for tall, brittle or easily damaged taxa.

5) Potential for larval dispersal as an indicator for potential of recolonisation after disturbance event. Judged on a three-tier scale: low for broadcast spawners, high for brooding taxa or medium when a combination of both types was observed.

6) Lack of adult motility. Motility may not necessarily preclude taxa from vulnerability to habitat disturbance, however lack of motility may increase risk and decrease resilience because adults are unable to move away from danger or recolonise a previously disturbed location. Motility was judged on a three-tier scale: low for typically motile groups, medium for taxa with limited potential for movement or high for completely sessile groups.

7) Rare or unique populations. Dense or isolated populations are intrinsically vulnerable to disturbances due to their reduced potential for recovery. Motility was judged on a three-tier scale: medium or low for increasing patch size or increasing frequency of occurrence or high for isolated populations.

Using these criteria, the workshop then identified 21 taxonomic groups (including, or subdividing, the 10 identified by Parker et al. 2009b) considered to constitute VME taxa or taxa that are often found in association with VME taxa in the CCAMLR area (Table 4). Higher taxonomic groupings (Phylum, Class or Order) were retained to facilitate VME taxa identification, again resulting in the likelihood that some species within these taxonomic groupings may not be vulnerable to fishing activity due to their specific life history traits (Parker et al. 2009b). These higher taxonomic groups inevitably contain species with a variety of life-history traits, in which case the most precautionary value was used to assess the vulnerability of the group as a whole (CCAMLR 2009).

By introducing criteria based on previous occurrence as bycatch, CCAMLR's taxa list ensures that the indicator species are relevant to the fishery. However, it should be noted that the list provided by Parker et al. (2009b) is based on bottom trawl fisheries, using fishing gears that are excluded from CCAMLR exploratory fisheries, and that there are far fewer data available for bycatch of longline fisheries. Nonetheless, the fact that longlines may be unlikely to catch some of the taxa concerned does not detract from the fact that those taxa, if caught, would be indicative of the presence of a VME.

The workshop on VMEs did not consider this list of 21 taxonomic groups as final, but part of a living document, to be periodically reassessed and updated to incorporate improvements in the best available scientific evidence available (CCAMLR 2009).

Table 4 Taxonomic groups that the 2009 CCAMLR workshop on VMEs identified as containing VME indicator species

Taxonomic Level	Common Names
Phylum Porifera	
Class Hexactinellida	Glass sponges
Class Demospongia	Siliceous sponges
Phylum Cnidaria	
Class Anthozoa	
Order Actinaria	Anemones
Order Scleractinia	Stony corals
Order Antipatharia	Black corals
Order Alcyonacea	Soft corals
Order Gorgonacea	Sea fans
Order Pennatulacea	Sea pens
Order Zoanthida	Zoanthid corals
Class Hydrozoa	
Subclass Hydroidolina	Hydroids
Family Stylasteridae	Hydrocorals
Phylum Bryozoa	Lace corals
Phylum Echinodermata	
Class Crinoidea	
Order Non-Comatulid	Stalked crinoids (sea lilies)
Class Echinoidea	
Order Cidaroida	Pencil sea urchins
Class Ophiuroidea	
Order Euryalida	Basket and snake stars
Phylum Chordata	
Class Ascidiacea	Ascidians
Phylum Brachiopoda	Lamp shells
Phylum Annelida	
Family Serpulidae	Serpulid worms
Phylum Arthropoda	
Infraclass: Cirripedia	
Family Bathylasmatidae	Goose and acorn barnacles
Phylum Mollusca	
Family Pectinidae	
Adamussium colbecki	Antarctic scallop
Phylum Hemichordata	
Class Pterobranchia	Acorn worms
Domain Eukarya	
Phylum Foraminifera	
Class Xenophyophorea	Xenophyophores

Chemosynthetic communities

Source: CCAMLR (2009)

Photographic identification guides have been developed to allow for rapid identification of VME taxa in the SPRFMO and CCAMLR fisheries based on non-technical and easily discernible characteristics (Parker et al. 2009c). These identification cards are designed to be used by scientific observers to ensure, in conjunction with specific training, the accurate identification of key VME taxa by observers at sea. In 2009, an evaluation of CCAMLR scientific observer identification of VME taxa found that observers were reasonably accurate in their identifications, and were readily able to distinguish between the listed VME and non-VME taxa (Parker et al. 2009a). Parker et al. (2009a) did identify some concerns with identification of certain taxonomic groups, or with specific observers, but were confident that these issues would be overcome with refinement of the identification cards (completed in 2009) and further observer training.

VME impact assessment

Since 2007 under CM22-06, CCAMLR Members fishing in CCAMLR high-seas areas using bottom longlines have been required to evaluate the known or anticipated impacts on VMEs of their proposed fishing activities. Member-specific impact assessments are reviewed annually by CCAMLR scientific working groups. Between 2008 and 2011 a considerable body of additional scientific analysis was produced and reviewed within CCAMLR to better inform this process, including the development of a quantitative, spatially explicit impact assessment methodology applying precautionary assumptions to estimate cumulative impacts of bottom fishing gears on potential VME habitats at a user-defined scale. The method (based on Sharp et al. 2009 and subsequent updates) was adopted by CCAMLR in 2011, and is implemented annually using software linked with CCAMLR databases to produce updated maps of cumulative historical bottom fishing impacts at a circumpolar and regional scale (CCAMLR 2012a). Evidence considered in the adoption and parameterisation of the impact assessment method for longline fisheries included:

1) the use of tethered cameras to estimate lateral longline movement in contact with the seafloor during hauling
2) the use of VME bycatch to map the distribution of common VME taxa within the fished footprint (Parker et al. 2010)
3) use of a spatially explicit dynamic VME population model including management strategy evaluation (Dunn et al. 2010)
4) investigation of potential spatial associations between the occurrence of VME taxa and target fish species (Parker & Smith 2011)
5) spatial habitat classification based on environmental proxies known to affect benthic invertebrate community distribution (Sharp et al. 2010).

The impact assessment estimates that impacts of bottom longlines on benthic communities including potential VMEs in the CCAMLR Area is very low (i.e. 99 per cent of fished cells have experienced impacts <1 per cent; CCAMLR 2012a). Parameterisation of the impact assessment method to obtain comparable estimates for trawl and pot fisheries has not been undertaken.

VME notification and move-on protocols

Under CM22-07 vessels participating in exploratory fisheries are required as an interim measure to monitor VME bycatch (i.e. VME indicator taxa retrieved on hooks), and notify the

CCAMLR Secretariat where VME bycatch exceeds 10 VME units from a single 1 km section of longline, triggering a move-on rule. One VME unit consists of 1 litre of VME indicator organisms in a 10 litre container, or 1 kg of organisms that do not easily fit into a container. This move-on rule therefore differs from most others in relying more on a measure of volume, rather than weight, of VME indicator species.

In the event that a move-on protocol is triggered, the vessel is required to move 1 nm from the mid-point of the line segment on which the VME taxa were encountered and the area concerned is then declared a 'VME risk area' and closed on an interim basis. Risk areas remain in force in subsequent seasons on until their status is reviewed by the CCAMLR Scientific Committee; to date no such reviews have taken place. Where more than five VME units are encountered from a single section of longline, the location of the encounter must be reported to the Secretariat. If five such encounters occur in an area of 0.5° latitude by 1.0° longitude, the secretariat notifies all fishing vessels of the potential for VMEs occurring in the area (CCAMLR 2010; Rogers & Gianni 2010). However, the measure does not indicate specific actions in response to such a notification.

VME Identification and Protection

Under CM22-06 CCAMLR Members are required to notify the Secretariat of any evidence of an encounter with potential VMEs during research activities (e.g. using underwater cameras or research trawls). CCAMLR scientific working groups review these notifications on an annual basis to determine an appropriate course of action. Where evidence is deemed sufficient to define the location and extent of a VME, these locations are registered under CM 22-09 and fishing within them is prohibited. Where evidence suggests the potential presence of VME taxa but is insufficient to identify a VME and define its extent, the Scientific Committee may recommend other actions on a case by case basis (CCAMLR 2012b).

Since 2005, CCAMLR has been working towards the implementation of a network of marine protected areas (MPAs). The CM91-04 (General framework for the establishment of CCAMLR Marine Protected Areas), adopted in 2011, identifies potential objectives of CCAMLR MPAs, two of which have potential relevance for protection of VMEs, i.e. 'the protection of areas vulnerable to impact by human activities, including unique, rare or highly biodiverse habitats and features' and 'the protection of representative examples of marine ecosystems, biodiversity and habitats' (CCAMLR 2012b). In 2009, an MPA was approved near the South Orkney Islands (CM91-03; CCAMLR 2012b). Subsequent proposals to establish CCAMLR MPAs in the Ross Sea region and in East Antarctica have been discussed and are currently being revised for further consideration in CCAMLR.

Atlantic RFMOs

The Northwest Atlantic Fisheries Organization (NAFO), North East Atlantic Fisheries Commission (NEAFC) and South East Atlantic Fisheries Organization (SEAFO) have all responded to the UNGA resolutions by adopting move-on protocols.

VME Identification and move-on protocols

Like Australia's high seas fishery, NEAFC, NAFO and SEAFO implement simplified bycatch protocols that rely on rapid assessments of the weight or volume of two or three key indicator taxonomic groups, typically 'corals' and 'sponges'. Initial bycatch thresholds of 60 kg live coral and 800 kg live sponge instituted by NEAFC and NAFO in 2009 were criticised for being too high, resulting in a low likelihood that the move-on rules would ever be triggered, leading to VME habitats remaining unidentified (Rogers & Gianni 2010). Based on advice from the International Council for the Exploration of the Sea (ICES), in 2012 NEAFC and NAFO lowered their move-on thresholds by 50 per cent, to 30 kg of live coral and 400 kg of sponge (NEAFC 2012; WGDEC 2012). The 2012 NAFO revision also introduced a protocol to account for cumulative impacts of encounters below threshold levels, with two encounters of 15 kg of corals in the same area[2] treated as equivalent to a 30 kg catch, triggering a move-on (WGDEC 2012). NAFO again updated its bycatch thresholds in 2013 by adding a threshold for sea pens (7 kg), further reducing the threshold of sponges to 300 kg, and increasing the threshold for other live corals back to 60 kg (NAFO 2013).

The initial bycatch thresholds of NAFO and NEAFC were based on extrapolation of 30 minute research survey trawls, a technique that has been criticised as inappropriate due to the difficulty of simple extrapolation to longer duration commercial trawls, and the possibility that VME evidence may be encountered on only part of a trawl with longer tows not necessarily catching more. Habitat-forming VME taxa such as corals and sponges often form aggregated assemblages, resulting in non-linear relationships between tow lengths or soak times, gear type and bycatch rates, making extrapolation inappropriate (PECMAS 2009; Rogers & Gianni 2010).

In addition to recording sponge and coral taxa, NEAFC and NAFO also allow for observers at sea to apply the coral-weight threshold to other VME taxa. However, without defining these taxa this provision relies on observers to recognise potential VME taxa, and it is likely that only sponge and corals will be identified and recorded (Kenchington 2011).

While the 2012 revisions have made these move-on rules more sensitive, the revised bycatch thresholds still do not distinguish between gear types and so fail to account for differences in bycatch efficiencies of bottom trawl gear, gillnets and longlines (Rogers & Gianni 2010). Each fishing gear should be separately assessed and gear-specific move-on weight thresholds developed based on the bycatch weight-frequency distributions for each gear types.

SEAFO addressed these concerns by further refining its bycatch thresholds in 2012. Bycatch thresholds in the SEAFO Convention Area now differ for different gear types and whether fishing vessels are operating in existing or exploratory fisheries (SEAFO 2012). However, the weight thresholds remain comparatively high. Trawling operations must report and move-on if 60 kg of live coral and/or 600 kg of sponge are caught in existing fishing areas. In exploratory fisheries, the threshold for sponges is 400 kg. Longline fishing operations have a threshold of 10 VME indicator units per 1200 m of line, or 1000 hooks, whichever is shorter, with one VME indicator unit being equal to 1 kg or 1 l of live coral or sponge. Operations that use pots use a similar threshold to the longline fleet: 10 VME indicator units per 1200 m of line.

VME move-on protocols

The required minimum move-on distance in the move-on rules in the NAFO and NEAFC is 2 nm. SEAFO distinguishes between trawls and tows, which require a minimum move-on of 2 nm, and longline and pot sets, which require a move-on of 1 nm. When VME taxa are detected in a trawl in NEAFC or NAFO waters, vessels are required to move a minimum of 2 nm from a single point. Vessels fishing in NAFO waters must move 2 nm from the end point of the trawl (NAFO 2013), while vessels in NEAFC waters move 2 nm from the 'position that the evidence suggests is closest to the exact encounter location' (NEAFC 2011). However, with trawls reaching 14–20 nm in linear distance, the 2 nm requirement only covers a small part of the tow and has been

[2] WGDEC (2012) does not state how trawls in the 'same area' are defined.

criticised as being insufficient, potentially leaving VMEs exposed to subsequent fishing in areas open to fishing (Rogers & Gianni 2010). SEAFO has addressed this concern by requiring vessels to move 2 nm from the entire trawl track where the VME was encountered (SEAFO 2012).

The NAFO and SEAFO rules state that when a move-on is triggered, the vessel must move at least 2 nm in a 'direction least likely to result in further encounters' (SEAFO 2012; NAFO 2013). This wording remains open to interpretation, and is based on the skipper's 'best judgement' (SEAFO 2012; NAFO 2013). Formally, SEAFO required subsequent 'tows or sets to be parallel to tow/set when encounter was made' (SEAFO CM 12/08, see Kenchington 2011), but this requirement is no longer in place.

The Atlantic RFMO move-on rules make a distinction between existing fishing areas and previously unfished areas. When a move-on is triggered in historical fishing locations, the vessels must cease fishing and move the appropriate distance from the encounter location. SEAFO CMM 24/12 states that any further trawl or tow set must be set at a distance 2 nm from the entire trawl/tow track where the VME encounter was made (SEAFO 2012). Single or multiple VME encounter in discrete areas[3] are then reported by the Executive Secretary to the relevant Scientific Committees, who in turn provide advice on a case-by-case basis to the Commission about the possible occurrence of VMEs (NEAFC 2011; SEAFO 2012; NAFO 2013).

When a move-on is triggered in previously unfished areas an interim closure is implemented immediately and remains in place until the data can be reviewed by the relevant Scientific Council. Should the Scientific Council advise that the area contains VMEs, the closures may be maintained until appropriate conservation and management measures have been adopted by the Fisheries Commission (NEAFC 2011; SEAFO 2012; NAFO 2013).

Protection of VMEs

SEAFO has instituted some permanent spatial closures in known seamount areas, because of evidence that these areas contain VMEs. Since 2007, NEAFC has established several permanent spatial closures in areas where cold-water coral reefs, sponge communities and coral gardens have been identified. However, some areas in which there is strong evidence for the presence of VMEs remain open to fishing (Rogers & Gianni 2010).

NAFO has taken a systematic approach to the identification of VMEs. Research trawls and predictive habitat modelling have identified the likely locations of coral and sponge communities (Durán Muñoz et al. 2008; WGEAFM 2008). This work identified 11 areas with high likelihood of containing VMEs that were closed to fishing in 2009, bringing the total number of closed areas in the NAFO Convention Area to 18 (Rogers & Gianni 2010).

As a result of concerns related to gear loss and ongoing ghost-fishing, gillnetting has also been banned in NEAFC and SEAFO jurisdictional waters, providing further protection to habitats and biodiversity in the region.

General Fisheries Commission for the Mediterranean

In contrast to the measures implemented by other RFMOs, the General Fisheries Commission for the Mediterranean (GFCM) has done little in response to UNGA Resolution 61/105. The GFCM has not completed impact assessments of bottom trawl fisheries, and there are few data on VMEs or their distributions in the Mediterranean Sea (Rogers & Gianni 2010). While the GFCM

[3] There is no indication of how a 'discrete area' is defined.

has outlined criteria upon which it will assess potential VMEs, and has identified the need for the identification and preservation of VMEs, it has not outlined a systematic approach for undertaking this work (Rogers & Gianni 2010; GFCM 2013).

The GFCM relies largely on spatial restrictions on fishing effort to moderate potential impacts to VMEs. In 2005, the GFCM prohibited all bottom trawling below 1000 m, and in 2006 they closed three areas where VMEs are thought to occur.

Discussion

Key principles of VME identification

Ideally, areas containing VMEs should be identified using research surveys and non-destructive methods. However, such survey work is prohibitively expensive and the current protocols implemented by RFMOs have to be based on data collected during fishing operations. Reponses are therefore almost entirely reactive, with management responses triggered after VME indicator species are encountered by commercial fishing operations. This reliance on identification of VMEs in the bycatch of commercial fishing operations is flawed, as commercial gears have been shown to be inefficient samplers of epibenthic assemblages (Kaiser et al. 2006; Rogers et al. 2008; Kenchington 2011; Williams et al. 2011). However, in the absence of prohibitions on bottom contact gear or properly planned spatial closures, move-on rules are one of the few measures available to avoid areas showing evidence of VMEs. Combinations of predictive habitat modelling using presence data collected by these commercial fishing operations, combined with some limited ground-truthing using surveys, video recording on the headropes of trawls or acoustic detection of VMEs can then be used to integrate all available information to inform an evidence-based spatial closure planning process (Kenchington 2011). NAFO has systematically identified VMEs through the use of predictive modelling and mapping and has already implemented closures in areas with a high likelihood of supporting VMEs. Alternatively, the introduction of net acoustics may enable some fishing gears, targeting certain species to be kept just above the seabed, thereby avoiding contact with the bottom entirely (Auster et al. 2010).

In order to ensure that VME identification processes are appropriate for different regions, RFMOs and flag states should develop tailored lists of VME indicator taxa that may occur as bycatch in commercial fisheries in each region. The list of VME indicator taxa should be identified based on agreed VME criteria, and adjusted for regional, fishery and gear differences. Indicator taxa should be specified at an appropriate taxonomic level that ensures they reliably indicate the presence of VMEs, but still facilitate the rapid and accurate identification of these taxa by scientific observers at sea. In order to do this, RFMOs have approached the identification of VME indicator species in two different ways: the Atlantic RFMOs and Australia rely on rapid assessment of only two or three key very broad taxonomic groups (corals and sponges, with sea pens recently added to the NAFO protocols), while CCAMLR and New Zealand (in their SPRFMO trawl fishery) identify a more detailed list of VME indicator taxa.

Australia's move-on rules use broad taxonomic groupings (corals and sponges) as evidence of VMEs. The protocols implemented by the Atlantic RFMOs have attracted criticism for their reliance on such broad taxonomic groups which, coupled with high weight thresholds, can result in very insensitive rules that are seldom triggered, limiting the protective benefit of the measures (Rogers & Gianni 2010; Kenchington 2011). Ineffective move-on protocols allow continued impact on VMEs by allowing the continuation of fishing in areas that have shown some evidence of VMEs, but not triggered the thresholds. On the other hand, broad taxonomic groups might result in a move-on rule being triggered when, in fact, a VME has not been encountered.

Australia includes both live and dead coral as evidence of VMEs, which is more precautionary than the approach of those Atlantic RFMOs. By only considering live coral in their bycatch records the Atlantic RFMOs are disregarding the importance of dead coral structures. For many deepwater coral species, most of the supporting coral matrix is dead, with the live coral being limited to the tips of the organism. However, the supporting matrix is essential to survival of the growing tips. The structure and habitat provided by dead coral is also particularly important habitat for other species (as settlement substrata or refugia), such that damage to dead corals should also be considered to be impact on VMEs (Auster et al. 2010).

Preliminary analysis of scientific observer data provided by New Zealand (2002–12) indicates that nearly 40 per cent of trawls in the SPRFMO area encounter benthic taxa, while 4-8 per cent of all New Zealand trawls (2003–08) trigger a move-on rule (Parker et al. 2009b). By indentifying a wider variety of VME indicator taxa, CCAMLR and New Zealand have been able to implement a multi-species scoring system that allow for different weight thresholds for different taxa and inherently provides some measure of biodiversity, which would not otherwise be possible. This approach does require a higher degree of observer training to ensure the rapid and accurate identification of bycatch taxa at sea, but the taxa chosen by New Zealand have been chosen and grouped to facilitate easy identification. The use of historical bycatch weight data to inform weight thresholds also does not address the biological significance of different bycatch levels (Auster et al. 2010).

Given the continual improvement of the science that supports the development of VME move-on protocols, indicator taxa lists, taxa specific weight thresholds and gear specific thresholds should be periodically reassessed and adjusted. In particular, conservation groups criticised the high bycatch weight thresholds originally implemented by the Atlantic RFMOs (Rogers & Gianni 2010), resulting in these being revised a number of times. CCAMLR considers its list of VME indicator species to be a living document that requires continual reassessment and adjustment (CCAMLR 2009). Similarly, the SPRFMO Bottom Fishing Impact Assessment Standard (2012) explicitly states that, as the understanding on fisheries and their impacts is improved, so the standard should be updated.

Despite improving understanding of the characteristics and predicted distribution of VMEs and the impact of fishing gears, there remain high levels of uncertainty regarding the actual distribution and abundance of VMEs. Recognising this, Auster et al. (2010) suggest that moving to presence–absence based thresholds would be a more appropriate response to the expectations of UNGA Resolution 61/105, at least until these imperfect move-on protocols can be replaced by evidence-based spatial closures designed to protect known and highly diverse VME areas.

Attributes of effective move-on protocols

From the above evaluation of the various international move-on rules in effect, and from the other reviews and criticism previously published, key principles characterising an effective and responsible move-on rule can be identified. In doing so, an important question to be addressed is whether the move-on rule meet the UNGA requirement to prevent significant adverse impacts to areas known or likely to contain VMEs?

Identification and listing of regionally-specific VME taxa

In providing guidance on characteristics of VMEs, and an initial list of taxa that might contribute to forming VMEs, the FAO deep-sea guidelines (FAO 2009) recognise that both the characteristics of VME species and resulting lists of VME taxa should be regionally tailored, to ensure that the taxa used to trigger move-on rules really are those that form VMEs in each region. In some of the earlier move-on rules, particularly those originally adopted by RFMOs in the Atlantic Ocean, little attention was given to this requirement, with resulting move-on rules simply referring to ‘corals’ and ‘sponges’, the two broad groups identified in the UNGA resolutions and FAO deep-sea guidelines. Such approaches do not allow for different encounter thresholds to be tailored to the different bycatch weights and vulnerabilities of different taxa, and also do not facilitate incorporation of any biodiversity index.

The New Zealand list of SPRFMO VME taxa and the adopted CCAMLR list of VME taxa offer good examples of species lists that have been based on improved and expanded criteria for designating VME species, and which contain taxa that are known to contribute to VMEs in those regions, and are also captured by fishing gear. The CCAMLR list of VME taxa is probably the best international example of a list that has been based on a rigorous and workshopped process, evaluating all available information. However, having developed such a comprehensive and useful list of taxa, CCAMLR then does not take advantage of this in developing separate encounter thresholds for the different taxa, and does not incorporate a biodiversity index. The New Zealand VME Evidence Protocol for the SPRFMO area therefore offers the best example of a VME taxa list that has been used to develop different encounter thresholds based on the likelihood/typical weight of VME species likely to be retained in trawl nets.

Determination of weight thresholds constituting 'evidence of a VME'

Having determined the most appropriate list of VME taxa for a region, the next step should be to determine appropriate and individual encounter thresholds for different taxa. Under the Atlantic Ocean RFMOs, this has been done by adopting different trigger weights for the two groups of organisms used in those move-on rules: sponges and corals. The most complex example of adopting different trigger weights for different taxa is provided by the New Zealand move-on rule in the SPRFMO area, which uses six different threshold weights, ranging from 50 kg for mixed sponges to 1 kg each for Antipatharia (black corals), Alcyonacea (soft corals) and Gorgonacea (gorgonians; Parker et al. 2009b).

An essential consideration arising from this principle is that encounter weight thresholds will need to be different for different gear types. Trawl nets have been shown to be able to capture far higher weights of many taxa than longlines. This has been reflected, to some extent, in the different threshold weights used for these two gear types in some regions. However, further consideration needs to be given to the analyses required to ensure that these thresholds are not just different for different gear types, but are based on analyses of bycatch weights by these gears in the regions concerned.

All fishing gears designed to capture fish are highly inefficient at capturing benthic organisms, particularly if these are flexible or fragile, and retained weights of these species can be very low, even in areas known to contain substantial coral and sponge communities. Setting threshold weights near the maximum weight of these taxa retained in nets or on lines will result in a move-on rule essentially designed to be triggered very seldom, despite repeated captures of VME taxa. Ministry of Fisheries (2008) and Parker et al. (2009b) provide one of the few examples of an analysis of cumulative weight-frequency distribution of catches of different VME tax in trawl nets. Such analyses can be used to set encounter weight thresholds at appropriate levels of sensitivity, specifically designing rules to trigger a move-on for a pre-determined percentage of the tows that actually capture VME species. For example, Parker et al. (2009b) derived the different weight thresholds for the different taxa in the New Zealand SPFMO VME Evidence Protocol from the 50th percentiles of the cumulative weight-frequency distributions of these taxa in historical trawl catch records.

In many cases (such as for Antipatharia, Alcyonacea and Gorgonacea in the New Zealand move-on rule), the weight thresholds are likely to be low. Given the difficulty of weighing bycatch at sea, this will probably result in the need to adopt some arbitrary minimum weight, such as 1 kg, for species whose capture weights are typically less than that. This is the case for almost all species caught on longlines. Under these circumstances, move-on rules could rather be considered to be based on presence-absence, with capture of any quantity of a designated taxon contributing to the evaluation of evidence of a VME. However, if presence-absence is to be used, then consideration must be given to how presence of different taxa might contribute to a VME score. Requiring a move-on in every case where presence of a single species is recorded once may be difficult to justify, with presence of a single species not necessarily indicating a VME. For such rules, presence of multiple species could be used to generate a biodiversity score (as done in the New Zealand rule), or multiple encounters within a small area could be considered to indicate a VME area (as is done by CCAMLR).

Move-on distances and closure size

Move-on distances and the size of resulting spatial closures must be appropriate to the distance typically covered by the fishing gear concerned. For lengthy trawls it is difficult to determine the exact location of a VME encounter, as the retained bycatch could have been caught at any point along the trawl or line set, or at separate points at levels that individually, would not trigger the move-on-rule. Without adequate knowledge of VME patch size, it is also difficult to be sure VMEs are appropriately protected by the resulting closure (Kenchington 2011).

Move-on distances should therefore be based on an analysis of the frequency-distribution of tow and set lengths, and set to cover some acceptable percentage of trawls (such as the maximum length covering 90 per cent of fishing effort). The SPRFMO interim measures require a minimum move-on distance of 5 nm from the location of a VME encounter, but this has been rather differently interpreted by New Zealand and Australia. The New Zealand protocol initially required their fishing vessels to move-on 5 nm only from the location at which the trawl commenced, while the Australian protocol requires vessels to move 5 nm from any point along the trawl track, to account for the uncertainty of the exact location of the VME encounter (Kenchington 2011; Williams et al. 2011; AFMA 2013).

Analysis of tow lengths (Table 3, Figure 1) shows that 5 nm seems to be an adequate move-on distance for these fisheries. However, relating this to either the start or end of a longer tow is not appropriate, and will potentially leave part of the tow out of the resulting closed area. Where move-on rules are specified around a point, they should be based on the centre of the tow or set, with the move-on distance being adequate to ensure that most tows lengths will be less than the resulting closure.

Two of the Atlantic RFMOs require their fishing vessels to move 2 nm from a single point, either the best-guess VME encounter location (NEAFC) or from the end point of the trawl (NAFO). This has been criticised as being inadequate, given that trawls are known to extend to around 20 nm. This could be addressed by either increasing the move-on distance or by adopting similar protocols to those in the Australian fisheries, and requiring vessels to move-on the predetermined distance from the entire trawl track (Rogers & Gianni 2010). Either way, ensuring compliance with numbers of these small closures becomes geo-spatially complex, and more so with closures based on lines rather than single points.

Application and temporal scale of move-on closures

The damage from fishing on VME habitats is cumulative, and repeated deployment of even low impact fishing gears on sensitive locations can result in long-term damage to vulnerable communities (Williams et al. 2011). Due to the long expected recovery time of habitat forming taxa (decades to centuries), temporary closures are unlikely to facilitate habitat recovery.

In Australian, CCAMLR and exploratory Atlantic fisheries, move-on protocols require the immediate closure of the area concerned to all fishing activities in the event VME bycatch thresholds are breached, usually followed by subsequent scientific review to determine whether the area should remain closed or can be re-opened. In the case of Australian fisheries in the SPRFMO Area, the closure is implemented for all Australian fishing vessels for the remaining duration of the annual fishing permits. High-seas permits are reissued at the end of each calendar year and so closures might therefore be for a brief period or for up to 12 months, depending on when the closure is first implemented (Williams et al. 2011). However, the Australian Fishery Management Authority (AFMA) must assess whether the area should be re-opened in subsequent fishing seasons.

New Zealand has a very different approach. Under their SPRFMO move-on protocol, closures only apply to the vessel concerned for the length of the current trip, allowing other vessels to continue fishing in that area, and for that vessel to return to the same location on a subsequent trip. This is explained as being largely due to the fact that New Zealand has about 40 per cent of the 20-minute blocks constituting their SPRFMO 2002–2006 trawl footprint, and so considers the move-on rule as a secondary measure applicable only on moderately-fished open blocks (Penney et al. 2009).

Observer coverage

Adequate levels of coverage by fishery-independent observers are an essential component of effective move-on rules. The appropriate level of observer coverage will depend on the technical complexity of the move-on rule and compliance risks related to implementing the move-on rule. More complex rules requiring expertise to identify VME taxa are best dealt with by scientifically trained observers with time to accurately identify taxa to the required level. Fishery-independent observers are also required if there is a risk that move-on rules will not be implemented or that fishers will not respond to them. High levels of observer coverage (such as the 100 per cent required for the implementation of the interim measures for bottom trawl operations in the SPRFMO Area) would be ideal. However, lower levels might be justified following risk-assessments to identify high risk areas or operations on which to focus observer coverage. This mirrors the approach to having lower observer coverage for bottom longlining, where the risks of benthic damage are considered to be lower than those of bottom trawling

Spatial management

Move-on rules have been increasingly criticised as being an ineffective way of protecting VMEs (Weaver 2011) and there continues to be debate around whether the UNGA resolutions intended move-on rules to be permanent, and applicable everywhere, or a temporary approach until properly planned spatial closures can be implemented to protect highly biodiverse VME areas. CCAMLR and the Atlantic RFMOs have recently moved towards explicit spatial closures based on evidence of VME occurrence, possibly reducing the value and need for move-on rules. However, it is essential that such closures be based on scientific evidence and analysis of the known or likely distribution of VMEs in each region. For example, Kenchington (2011) has expressed concerns about the conservation value of the New Zealand spatial closures, given that these were not actually based on analysis of VME distribution, and are open to fishing by other flag states. It is therefore necessary for RFMOs to initiate processes to develop reliable predictions and analyses of VME evidence and VME distribution, and to then design and implement permanent spatial closures applicable to all participants, to protect key VME areas.

Considerations for an SPRFMO move-on rule

Although SPRFMO did not enter into force until August 2012, signatory nations to the proposed SPRFMO agreed upon interim measures to protect VMEs in 2007 (SPRFMO 2007; MFAT 2013). However, interpretation of implementation of many aspects of these measures was left to the individual flag states. As a result, different flag-state move-on protocols have been developed by Australian and New Zealand. New Zealand has published a series of papers that explain their approach to VME move-on protocols for fisheries in the South Pacific Ocean (Parker et al. 2009b; Penney et al. 2009).

It is important to note that move-on protocols cannot always be considered in isolation; they are often one component of a package that includes measures such as fishing footprints, spatial closures, impact assessments and limits on catches or fishing effort. In particular, the SPRFMO Bottom Fishing Impact Assessment Standard 'aims to ensure that areas containing VMEs and low productivity deep sea resources are protected from significant adverse impacts due to bottom fishing, by ensuring that management decisions are informed by reliable and robust impact assessments based on the best data available' (SPRFMO 2012).

The approach that New Zealand has taken in developing a VME move-on protocol also contributed to the development of CCAMLR VME move-on protocols. CCAMLR was able to further develop the New Zealand protocol, particularly in regards to the list of species acknowledged to be indicative of VMEs or vulnerable themselves. Since its implementation in 2009, the New Zealand measures have not been updated, but may provide a useful example for the development of broadly applicable VME move-on protocols by SPRFMO, noting though that the New Zealand move-on protocol was only developed for trawl fisheries and would need to be substantially revised for longline fisheries.

During 1987–2012, New Zealand fisheries observers reported 4400 records of benthic bycatch species. Since New Zealand introduced their VME Evidence Process, scientific observers have been required to complete detailed Benthic Observations Forms, greatly increasing the number of benthic species recorded from recent trawls. Under the current list of VME indicator species used by New Zealand, over 1700 of these records would not be considered to be indicative of VME taxa. Consideration should be given to reviewing the New Zealand list of VME taxa with a view to revising and expanding it to include additional VME taxa, as was done by CCAMLR. While some species observed as bycatch in bottom trawls may not be individually indicative of VME habitats, these species may still be useful for the calculation of biodiversity indexes. By introducing additional indicator species, and subdividing coarse taxonomic groups, move-on rules could be made both more sensitive and more informative regarding the distribution of taxa being regularly encountered. Analysis of scientific observer records of benthic species caught in New Zealand fishing operations could be useful in revising and improving the list of VME taxa for the SPRFMO Area. By expanding the list of indicator species it may be possible to gain higher resolution in identifying VMEs and to avoid situations in which VME encounters are not registered due to different assemblages. Note, however, that New Zealand's current list of VME indicator taxa was compiled with ease of identification as a key criterion. Any expansion of the list must be carefully considered to ensure that classification protocols do not become overly complex and impractical for rapid, at-sea assessment. Excessive extension of taxonomic lists may increase the inaccuracy of at-sea identification by observers and overwhelm on-shore management (Kenchington 2011) while providing little benefit in meeting the stated objectives.

For example, CCAMLR (2009) suggested that there may be value in finer classification of sponges because of major differences in the ecology and distribution among sponge classes.

Currently, New Zealand observers classify all sponges together at a phylum level. However, there may be merit in classifying sponges to Class level, as Hexactinellida or Demospongiae, which can still be fairly easily identified. In cases where lower level of classification is not possible, a phylum level code remains appropriate. It is unlikely to be possible to identify Hexactinellid sponges to Order, as microscopy is often required. Preliminary analysis of scientific observer data provided by Australia and New Zealand show that there is also a low rate of occurrence of Demospongiae in trawls. At the time the original list of indicator species was compiled, observer data was not at a sufficient resolution to conclude whether it was appropriate to split sponges into the separate classes. However, since that time, data collection has improved, and it may be appropriate to re-examine this classification.

Some groups of sea urchins may provide another worthwhile addition to the SPRFMO list of VME taxa. Currently, New Zealand does not include the presence of Echinoid sea urchins in their move-on rule. However, New Zealand's scientific observer data from 1987-2012 indicates that sea urchins are regularly encountered in trawls. CCAMLR considers pencil sea urchins (Order Cidaroida) as VME indicator taxa due to their longevity, slow growth and low potential for larval dispersal (CCAMLR 2009). There may be value in including sea urchins in VME taxa, classifying them as either Cidaroid urchins, or non-Cidaroid (including all other urchins, subclass Euechinoidea). Classifying non-Cidaroid urchins to lower taxonomic levels is complex due to constantly updated phylogenies, often based on molecular evidence. Further investigation into the ecology and biology of non-Cidaroid urchins may be necessary before they are added to a VME species list.

If a biodiversity index is to be included in a general SPRFMO move-on rule, the addition of species to the VME taxa list will require further consideration of the biodiversity threshold. According to New Zealand trawl data collected from May 2009 to July 2011 five trawls triggered the move-on rule (including one trawl that did not move on due to incorrect assessment). Of these, one trawl was triggered by biodiversity threshold alone (three species), while another triggered both the biodiversity and weight thresholds. Increasing the number of taxa groups identified as VME indicators, will probably require adoption of a higher biodiversity threshold, if all these species are to be counted towards a biodiversity score.

Conclusions

In the years since UNGA introduced resolutions 61/105 and 64/72, the slow progress in protecting VMEs has increasingly criticised. Recently, RFMOs have continually improved the measures that have been implemented, and substantial scientific effort has been devoted to the predictive habitat modelling and identification of VMEs. Nonetheless, the current measures of most RFMOs still rely mainly on move-on rules and resulting reactive management responses to evidence of VME. Details of many of these move-on rules have also been criticised as being insensitive, resulting in move-on rules that are seldom, if ever, triggered, and which provide few data that can be used in subsequent analysis of likely VME occurrence.

New data and analysis techniques have the potential to improve the protection of VMEs, particularly to the extent that these contribute to the objective and evidence-based planning of spatial closure to protect highly diverse areas (Durán Muñoz et al. 2008; Kenchington 2011). The analysis of new and existing data from commercial fisheries should provide a basis for RFMOs to establish spatial management approaches that balance the requirement to protect VMEs with some level of ongoing fishing in these regions. Where this is not achieved through properly planned representative and adequate spatial closures, move-on rules will need to be designed to be sensitive, with a high likelihood of detecting and protecting areas likely to contain VMEs.

There is a trade-off in the taxonomic level to which VME taxa are identified. Higher-order taxa are easier to identify, but could include less-vulnerable species, or species not considered to contribute to VMEs (Parker et al. 2009b). Identification to species would allow for VME species to be individually accounted for, but is not feasible at sea. Regionally tailored VME taxa lists need to account for this by selecting the most appropriate taxonomic grouping. By introducing more taxonomic groups, and subdividing phyla into lower order classifications, it is possible to gain a greater understanding of the taxa encountered, and to derive more appropriate thresholds for each taxon. This also facilitates the evaluation of biodiversity. However, the expansion of species lists needs to be balanced with the practicalities of at-sea identification of bycatch species by scientific observers combined with their other duties (Kenchington 2011).

There is currently little consideration of the length or duration of fishing operations in move-on protocols. Generally, the same rule is applied, irrespective of the length or duration of the tow. CCAMLR has added a refinement by applying the move-on rule to individual segments (1000 hooks or 1200 m) of a longline set (CCAMLR 2010). It may, however, be appropriate to apply the same rule, irrespective of tow length, depending on the distribution of VMEs in a region. In particular, it is possible that VME evidence may be caught at one position on a long tow. Increasing the trigger thresholds for longer tows can result in such evidence being discounted (Kenchington 2011). Conversely, however, long tows may accumulate evidence over the duration of the tow, triggering the rule only a result of the length of the tow, where a shorter tow would not have accumulated sufficient material to reach the threshold.

Move-on distances need to be adequate to cover the majority of tow or set lengths. New Zealand requires a move-on minimum distance of 5 nm, while the Atlantic RFMOs require only 2 nm. These distances are calculated from a single point along the trawl track. They may be insufficient for the small proportion of tows that extend more than 20 nm. Australia has addressed this issue by requiring its vessels to move-on 5 nm from any point along the trawl track, addressing the matter of scale, as well as the uncertainty surrounding the exact location of the VME encounter.

Trigger thresholds usually need to be set specifically for different gear types, given the different average weight of VME species that different gears are able to retain. Benthic longlines are expected to encounter much lower rates of VME taxa than trawls, and therefore require comparatively lower bycatch weight thresholds if move-on rules are applied to be effective (Rogers & Gianni 2010; Kenchington 2011). However, there are difficulties with weighing small quantities of benthic organisms at sea, suggesting that, in such circumstances, a biodiversity index based on presence data may be more appropriate. For the same reasons, CCAMLR has adopted to a volume-based 'indicator unit' to measure evidence of VMEs in longline bycatch (CCAMLR 2010).

Ultimately, however, given all of the shortcomings of move-on rules based on commercial benthic by-catch data, it is difficult to escape the conclusion that the main value of move-on rules is as an imperfect interim data collection and protection measure, until regions of highly diverse VMEs can be identified and properly protected using evidence-based and objectively planned spatial closures.

Appendix A Summary of VME move-on protocols

Table A1 Summary of VME move-on protocols adopted by RFMOs and flag states

Organisations or region	Indicator	Move-on threshold	Action	Closures implemented to protect VMEs	Comment
NEAFC 2012	Live corals and others	30 kg per set	Move 2 nm from the 'best guess' location of the VME encounter and report. If outside 'footprint', temporary 2 mile radius of closure to all vessels.	Yes >10 areas	In exploratory fisheries, closure active immediately, and reassessed at next PECMAS meeting. In existing fishing grounds, location reported and potential closure assessed at next PECMAS meeting.
	Live sponges	400 kg per set			
NAFO 2013	Live corals	60 kg per set	Move 2 nm from end of trawl/set and report. If outside 'footprint', temporary 2 mile radius of closure to all vessels.	Yes >10 areas	In exploratory fisheries, closure active immediately, and reassessed at next Scientific Council meeting. If VMEs are found to occur, temporary closure remains in place until conservation measures are instituted. If VMEs are found not to occur, closure will be lifted.
	Sea pens	7 kg per set			
	Live sponges	300 kg per set			
SEAFO existing fishing areas (trawl) 2013	Live corals and others	60 kg per set	Move 2 nm from end of trawl and report. If outside 'footprint', temporary 2 mile radius of closure to all vessels.	Yes >10 areas	2 nm move-on distance is from any point along trawl track.
	Live sponges	600 kg per set			
SEAFO exploratory fishing areas (trawl) 2013	Live corals and others	60 kg per set	Move 2 nm from end of trawl and report. If outside 'footprint', temporary 2 mile radius of closure to all vessels.	As above	2 nm move-on distance is from any point along trawl track.
	Live sponges	400 kg per set			

Organisations or region	Indicator	Move-on threshold	Action	Closures implemented to protect VMEs	Comment
SEAFO longline and pot operations 2013	Live coral or sponge	10 indicator units per line section	Move 1 nm from the midpoint of the line section where the VME encounter was made	As above	Line section is 1000 hook section of line or 1200 m section of line, whichever is shorter.
CCAMLR CCM 22-07	Taxa in CCAMLR Benthic Invertebrate Classification Guide	5 indicator units per line segment	Report	Yes	Exploratory active bottom trawling not active in Convention Area. Some areas have special management plans involving bottom trawling.
		10 indicator units per line segment	Temporary 1 nm radius closure to all vessels.		
Australian, south Pacific Ocean (trawl)	Live and dead corals and sponges	50 kg per set	Move 5 nm from shot and remain away for duration of permit. Area closed to all Australian flagged vessels of same gear type.	No	5 nm move-on distance is from any point along trawl track.
Australian, south Pacific Ocean (longline)	Live coral or sponge	10 kg per line section			Line section is 1000 hook section of line or 1200 m section of line, whichever is shorter.
New Zealand, south Pacific Ocean	Live and dead sponges	50 kg per set	Move 5 nm from start point of trawl and remain away for duration of trip. Area remains open to other vessels.	Yes. 20 areas closed as part of representative area programme.	Move-on protocol only applies to areas previously identified as 'moderately fished'.
	Live and dead scleractinian corals	30 kg per set			
	Live and dead gorgonian corals	1 kg per set			
	Live and dead antipatharian corals	1 kg per set			
	Live and dead alcyonacean soft corals	1 kg per set			
	Live and dead hydrozoans	1 kg per set			
	11 named taxa, live or dead	Presence of any 3 taxa in catch from one set			
Spanish, South Pacific	Live and dead corals	100 kg per set	Move 2 nm from end of set and report encounter to the Secretariat.	No	
	Live and dead sponges	1000 kg per set			

Source: Adapted from Kenchington (2011), and updated with current figures.

References

AFMA 2013, *High Seas General Condition*, Australian Fisheries Management Authority, Canberra, Australia.

Auster, P.J., Gjerde, K., Heupel, E., Watling, L., Grehan, A. & Rogers, A.D. 2010, 'Definition and detection of vulnerable marine ecosystems on the high seas: problems with the "move-on" rule', *ICES Journal of Marine Science*.

CCAMLR 2009, *Report of the workshop on vulnerable marine ecosystems*, SC-CAMLR-XXVIII/10, Commission for the Conservation of Antarctic Marine Living Resources, La Jolla, USA.

—— 2010, *Conservation Measure 22-07 (2010) - Interim measure for bottom fishing activities subject to Conservation Measure 22-06 encountering potential vulnerable marine ecosystems in the Convention Area*, CCAMLR, Hobart, Australia, available at http://www.ccamlr.org/en/measure-22-07-2010.

—— 2012a, *Report on Bottom Fisheries and Vulnerable Marine Ecosystems*, SC-CCAMLR-XXXI/Appendix F, Commission for the Conservation of Antarctic Marine Living Resources.

—— 2012b, *Schedule of conservation measures in force 2012/13 season*, Commission for the Conservation of Antarctic Marine Living Resources, Hobart, Australia.

Dunn, A., Parker, S.J. & Mormede, S. 2010, *Development of methods for evaluating the management of benthic impacts from longline fishing using spatially explicit production models, including model validation*, WG-FSA-10/29, Commission for the Conservation of Antarctic Marine Living Resources, 19 June 2009, Wellington, New Zealand.

Durán Muñoz, P., Murillo, F.J., Serrano, A., Sayago-Gil, M., Parra, S., Díaz del Río, V., Sacau, M., Patrocinio, T. & Cristobo, J. 2008, *A case study of available methodology for the identification of Vulnerable Ecosystems/Habitats in bottom deep-sea fisheries: Possibilities to apply this method in the NAFO Regulatory Area in order to select Marine Protected Areas*, Ser. No. N5491 NAFO SCR Doc. 08/6, NAFO, May 2008, Dartmouth, Canada.

FAO 1995, *Code of Conduct for Responsible Fisheries*, FAO, Rome, Italy.

—— 2009, *International guidelines for the management of deep-sea fisheries in the high seas*, FAO, Rome, Italy.

—— 2010, *Report of the FAO workshop on the implementation of the FAO international guidelines for the management of deep-sea fisheries in the high seas - Challenges and ways forward*, FIPI/R948 (En), Food and Agriculture Organization of the United Nation, Busan, Korea.

GFCM 2013, *First GFCM Framework Programme (2013-2018) in support of Task Force Activities (FWP)*, General Fisheries Commission for the Mediterranean, Rome, Italy.

Kaiser, M.J., Clarke, K.R., Hinz, H., Austen, M.C.V., Somerfield, P.J. & Karakassis, I. 2006, 'Global analysis of response and recovery of benthic biota to fishing', *Marine Ecology Progress Series*, vol. 311, pp. 1-14.

Kenchington, T.J. 2011, *Encounter protocols for avoidance of harm to Vulnerable Marine Ecosystems: A global review of experience to 2010*, Department of Fisheries and Oceans Canadian Science Advisory Secretariat, Nova Scotia. Research Document 2011/009

MFAT 2013, *Treaties and International Law - Convention on the Conservation and Management of High Seas Fishery Resources in the South Pacific Ocean (SPRFMO)*, New Zealand Ministry of Foreign Affairs and Trade, viewed 26 June 2013, available at http://www.mfat.govt.nz/Treaties-and-International-Law/01-Treaties-for-which-NZ-is-Depositary/0-sprfmo-convention.php.

Ministry of Fisheries 2008, *Bottom fishery impact assessment: Bottom fishing activities by New Zealand vessels fishing in the high seas in the SPRFMO area during 2008 and 2009*, NIWA and Ministry of Fisheries, Wellington, New Zealand.

NAFO 2013, *Northwest Atlantic Fisheries Organization Conservation and Enforcement Measures*, Serial No. N6131 NAFO/FC Doc. 13/1, NAFO, Dartmouth, Canada.

NEAFC 2011, *Consolidated text of all NEAFC recommendations on regulating bottom fishing*, North East Atlantic Fisheries Commission, 20 February 2011 (Amended 2013), London, UK.

—— 2012, *31st Annual Meeting of the North-East Atlantic Fisheries Commission*, North-East Atlantic Fisheries Commission, London, UK.

Parker, S.J., Cole, R.G. & Hanchet, S.M. 2010, *Further analysis of spatial patterns of benthic invertebrate habitats from fishery by-catch in the Ross Sea region*, WG-FSA-10/30, Commission for the Conservation of Antarctic Marine Living Resources, 19 June 2009, Wellington, New Zealand.

Parker, S.J., Mormede, S., Tracey, D. & Carter, M. 2009a, *Evaluation of VME taxa monitoring by observers from five vessels in the Ross Sea region Antarctic Toothfish longline fisheries during 2008-09 Season*, Commission for the Conservation of Antarctic Marine Living Resources, 19 June 2009, Wellington, NZ. TASO-09/8

Parker, S.J., Penney, A.J. & Clark, M.R. 2009b, 'Detection criteria for managing trawl impacts on vulnerable marine ecosystems in high seas fisheries of the South Pacific Ocean', *Marine Ecology Progress Series*, vol. 397, pp. 309-317.

Parker, S.J. & Smith, M.H. 2011, 'Can toothfish catches be used to predict the presence of vulnerable benthic invertebrate taxa?', *CCAMLR Science*, no. 18, pp. 87-96.

Parker, S.J., Tracey, D., Mackay, E., Mills, S., Marriott, P., Anderson, O., Schnabel, K., Bowden, D., Kelly, M. & Lockhart, S. 2009c, *CCAMLR VME Taxa Classification Guide*, Commission for the Conservation of Antarctic Marine Living Resources, Hobart, Tasmania.

PECMAS 2009, *Permanent Committee on Management and Science of the North-East Atlantic Fisheries Commission*, North-East Atlantic Fisheries Commission, 28-29 September 2009, London, UK.

Penney, A.J., Parker, S.J. & Brown, J.H. 2009, 'Protection measures implemented by New Zealand for vulnerable marine ecosystems in the South Pacific Ocean', *Marine Ecology Progress Series*, vol. 397, pp. 341-354.

Rogers, A.D., Clark, M.R., Hall-Spencer, J.M. & Gjerde, K.M. 2008, *The Science behind the Guidelines: A Scientific Guide to the FAO Draft International Guidelines (December 2007) For the Management of Deep-Sea Fisheries in the High Seas and Examples of How the Guidelines May Be Practically Implemented*, IUCN, 2008, Switzerland.

Rogers, A.D. & Gianni, M. 2010, *The Implementation of UNGA Resolutions 61/105 and 64/72 in the Management of Deep-Sea Fisheries on the High Seas*, International Programme on the State of the Ocean, London, UK.

SEAFO 2012, *Conservation Measure 24/12: on Bottom Fishing Activities in the SEAFO Convention Area*, South East Atlantic Fisheries Organization, Swakopmund, Namibia, available at http://www.seafo.org/ConservationMeasures/2013%20CM/CM24-12.pdf.

Sharp, B.R., Parker, S.J., Pinkerton, M.H., Breen, B.B., Cummings, V., Dunn, A., Grant, S.M., Hanchet, S.M., Keys, H.J.R., Lockhart, S.J., Lyver, P.O.B., O'Driscoll, R.L., Williams, M.J.M. & Wilson, P.R. 2010, *Bioregionalisation and spatial ecosystem processes in the Ross Sea region*, WG-EMM-10/30, Commission for the Conservation of Antarctic Marine Living Resources, 19 June 2009, Wellington, New Zealand.

Sharp, B.R., Parker , S.J. & Smith, N. 2009, 'An impact assessment framework for bottom fishing methods in the CCAMLR convention area', *CCAMLR Science*, vol. 16, pp. 195-210.

SPRFMO 2007, *Third International Meeting on the Establishment of the proposed South Pacific Regional Fisheries Management Organisation*, SPRFMO, 30 April - 4 May, Reñaca, Chile.

—— 2008, *EU preliminary assessment of the risk of causing serious damage to VMEs and protocol of actions*, SP-08-SWG-DW-02, South Pacific Regional Fisheries Management Organization, Auckland, NZ.

—— 2012, *Bottom fishery impact assessment standard*, Third Session of the Preparatory Conference, Santiago, Chile.

UNCLOS 1982, *United Nations Convention on the Law of the Sea of 10 December 1982*, United Nations, New York, USA.

UNFSIA 1995, *The United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (in force as from 11 December 2001)*, United Nations, New York, USA.

UNGA 2010, *Resolution 64/72 Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments*, UNGA A/RES/64/72, United Nations General Assembly.

—— 2012, *Resolution 66/68 Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments*, UNGA A/RES/66/68, United Nations General Assembly.

Weaver, P.P.E., Benn, A., Arana, P.M., Ardron, J.A., Bailey, D.M., Baker, K., Billett, D.S.M., Clark, M.R., Davies, A.J., Durán Muñoz, P., Fuller, S.D., Gianni, M., Grehan, A.J., Guinotte, J., Kenny, A., Koslow, J.A., Morato, T., Penney, A.J., Perez, J.A.A., Priede, I.G., Rogers, A.D., Santos, R.S., Watling, L, 2011, *The impact of deep-sea fisheries and implementation of the UNGA Resolutions 61/105 and 64/72. Report of an international scientific workshop*, National Oceanography Centre, Southampton. SWG-10-INF-04

WGDEC 2012, *Report to the NAFO Scientific Council on ICES/NAFO Joint Working Group on Deep-water Ecology*, Ser. No. N6068 NAFO/SCS Doc. 12/18 Northwest Atlantic Fisheries Organization, 26-30 March, Copenhagen, Denmark.

WGEAFM 2008, *Report of the NAFO Scientific Council Working Group on Ecosystem Approach to Fisheries Management (WGEAFM)*, Ser. No. N5511 NAFO/SCS Doc 08/10, June 2008, Dartmouth, Canada.

Williams, A., Althaus, F., Fuller, M., Klaer, N. & Barker, B. 2011, *Bottom Fishery Impact Assessment - Australian Report for the South Pacific Regional Fisheries Management Organisation (SPRMO)*, CSIRO, Canberra.