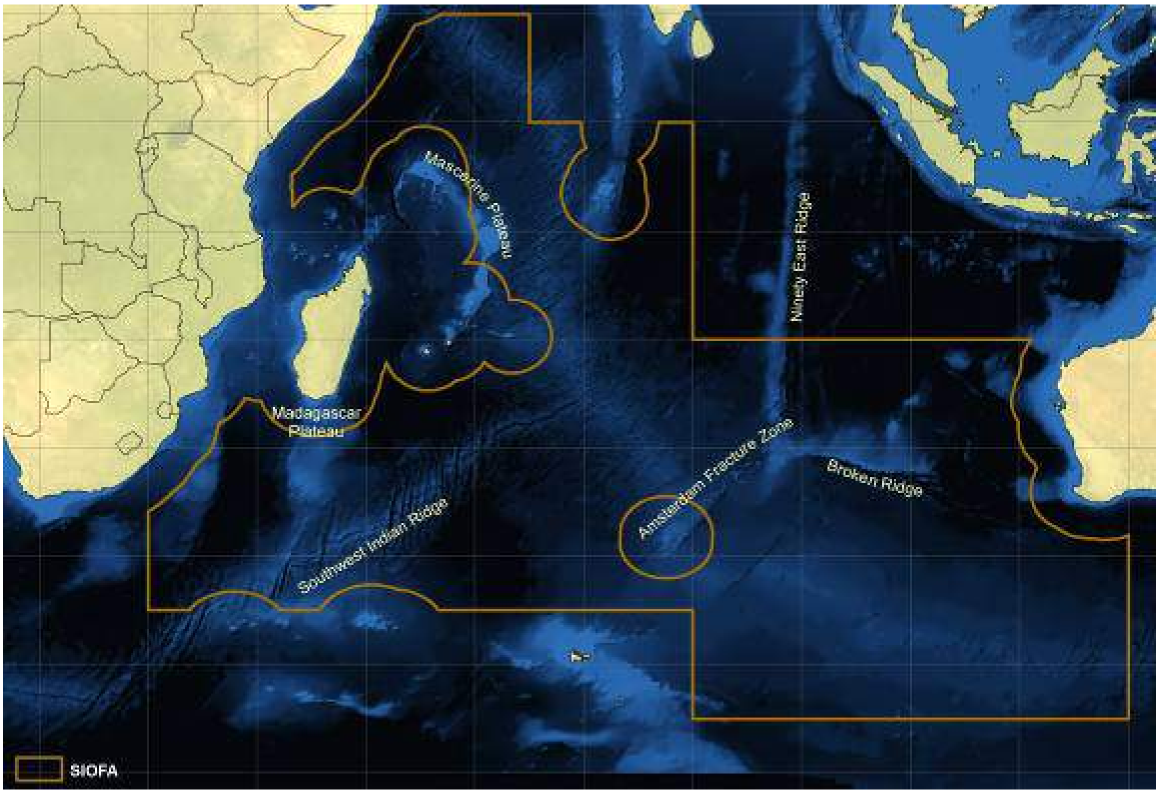
Bottom Fishery Impacts Assessment



Australian report for the Southern Indian Ocean Fisheries Agreement (SIOFA)

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List of Acronyms

AAD – Australian Antarctic Division, Department of Sustainability, Environment, Water, Population and Communities
ABARES – Australian Bureau of Agricultural and Resource Economics and Sciences
AFMA – Australian Fisheries Management Authority
BFIA – Bottom Fishery Impact Assessment
BFIAS – Bottom Fishery Impact Assessment Standard
BPA – Benthic Protection Area
CAAB – Codes for Australian Aquatic Biota
CCAMLR – Convention on the Conservation of Antarctic Marine Living Resources
CenSeam – Census of Marine life, Seamounts Program
CSIRO – Commonwealth Scientific and Industrial Research Organisation
CTD – Conductivity, Temperature, and Depth
DAFF – Department of Agriculture, Fisheries and Forestry
DFAT – Department of Foreign Affairs and Trade
DSEWPaC – Department of Sustainability, Environment, Water, Population and Communities
EEZ – Exclusive Economic Zone
EU – European Union
FAO – United Nations Food and Agriculture Organization
GEBCO – General Bathymetric Chart of the Oceans
GIS – Geographical Information System
HIMI – Heard Island and McDonald Islands
ICVMS – Integrated Computer Vessel Monitoring System
IUCN – International Union for Conservation of Nature
MFish – Ministry of Fisheries (New Zealand)
MPA – Marine Protected Area
NAFO – Northwest Atlantic Fisheries Organization
NEAFC – North East Atlantic Fisheries Commission
NIWA – National Institute of Water & Atmospheric Research (New Zealand)
NZ – New Zealand
RFMO – Regional Fisheries Management Organisation
SAI – significant adverse impact
SEAFO – South East Atlantic Fisheries Organisation
SIODFA – Southern Indian Ocean Deepwater Fishers' Association
SIOFA – Southern Indian Ocean Fisheries Agreement
SPRFMO – South Pacific Regional Fisheries Management Organisation
SWG – Science Working Group of the South Pacific Regional Fisheries Management Organisation
UN – United Nations
UNGA – United Nations General Assembly
VLIZ – a Maritime Boundaries Geodatabase
VME – Vulnerable Marine Ecosystem

Executive summary

Objective and result of the benthic fishing impact assessment

This BFIA conducted for Australian vessels fishing in the area to be managed under the SIOFA (SIOFA Area), concludes that the current overall risk of SAI on VMEs by Australian vessels fishing with bottom trawls and bottom-set auto-longlines is low. The BFIA concludes that the current overall risk of SAI on VMEs from mid-water trawling and drop-lining by Australian vessels is negligible [Section 4.3].

The BFIA forms part of Australia's response to UNGA Resolutions 61/105 and 64/72, the interim measures adopted by participants in negotiations to establish the SIOFA and the *FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas* (FAO 2008).

The BFIA considers impact, risk and existing monitoring, management and mitigation measures in assessing the potential for SAI on VMEs, and has, to the extent possible, followed the guidelines provided in the 'Revised Draft' BFIAS developed for the SPRFMO Area (SPRFMO 2009) [Section 4.2].

Description of proposed fishing activities

The assessment uses data from 1999-2009, the period for which reliable data were available when the assessment commenced. In response to UN resolutions, Australia implemented an interim fishing 'footprint' which restricts fishing by Australian vessels to its collective (all gears combined) distribution of fishing activity for the period 1999-2009 [Section 3.1.2].

There are currently four Australian high seas permits that allow bottom fishing in the SIOFA Area using one or a combination of demersal trawl, midwater trawl, longline, traps and dropline. The number of active Australian vessels has decreased from a maximum of three in 1999 and in 2005 to one since 2009. Descriptions of gear types and fishing methods are provided [Section 2].

Mapping and description of proposed fishing areas

This BFIA defines 'fishable areas' as depths of <2000 m that make up 1.7% of the ~27 million km^2 SIOFA Area. Interactions of fishing with potential VME areas occur principally in depths <1500 m that make up 0.76% of the SIOFA Area [Section 3].

In this BFIA, the fishable area is divided into five ecologically-meaningful zones (bathomes) that reflect the depth-correlated composition and structure of marine biota such as deep water corals that characterise VMEs, and which reflect the distributions of targeted commercial fish species. Bathomes act as coarse spatial scale indicators for potential VME locations against which to measure the distribution of fishing effort [Section 3]. Similarly, seamounts have also been used as indicators of VME locations because they often support VMEs and are reliably mapped at ocean basin scale [Section 4.1.4]. Major 'fishing grounds', identified from spatial concentrations of fishing activity, provide useful sub-areas for data analysis and reporting [Sections 3.1.3 and 4.2].

Impacts assessment methods

This BFIA has focussed primarily on the risk of direct impacts by bottom fishing on VMEs characterised by benthic fauna because of the potential for widespread and long-lasting effects. There is less emphasis on the status of deep water stocks because impacts assessment requires knowledge of total catch by all fleets in the SIOFA Area.

Assessing the potential for SAI on VMEs needs to consider 'impact' and 'risk' (the intensity, duration, spatial extent and cumulative effects of fishing activities), and define the dependency of these elements on spatial and temporal scales. In this BFIA, the 'overall risk' is considered as the risk remaining after monitoring, management and mitigation measures are accounted for. This BFIA used a qualitative framework because data paucity and knowledge uncertainties preclude a quantitative analysis of risk – especially of cumulative impacts. Semi-quantitative metrics are incorporated for fishing intensity, and the overlap of fishing with the predicted locations of VMEs in bathomes and on seamounts [Section 4.2].

The BFIA process commences with a scoping stage to identify the issues of relevance (concern) and to provide context [Section 4.1]. Issues considered in this BFIA include:

- Australia's management arrangements and fisher's operational measures
- the potential impacts of different fishing gears on VMEs
- the use of indicators (surrogates) to define VME distributions
- the spatial dependencies of impact/ risk assessment, including data quality issues
- the 'evidence of VME process'

Despite the potential for demersal trawling and auto-longlining to severely impact VME fauna at fine ('site') scales, and for impacts to persist and to accumulate through time, the current risk of SAI at the scale of the fishery was considered as low when the following factors are accounted for:

- low current fishing effort by Australian vessels
- few areas of high fishing intensity
- restriction of fishing to a 'footprint' area – although this permits access to 45% of deep upper slope depths (700-1000 m) and 45% of seamounts most likely to support VMEs
- limited spatial extent of Australian fishing effort: mostly low spatial overlap with the bathomes most likely to support VMEs, but medium overlap on the deep upper slope (700-1000 m depths) and on seamounts [Table 4.3.1.2]
- management arrangements to monitor and mitigate impacts and risks.

Although there is a low current risk of SAI, ongoing monitoring, management and mitigation measures are necessary because the assessment of risk also has to consider possible future impacts. There is (1) the potential for risks to increase if effort levels increase or expand within or beyond the current fishing footprint, and (2) a high degree of uncertainty about many of the key elements relevant to assessing and managing impact and risk to VMEs in the SIOFA Area. If effort levels or the spatial extent of Australian effort expands by a material amount, then monitoring, management and mitigation measures will need to be reviewed to ensure that the risk of SAI remains low. Ultimately, assessing the risk of SAI may require the context of all nations' fishing activities because persistent (long lasting) impacts are cumulative at the scale of the fishery [Section 4.3].

Status of deepwater stocks to be fished

The long-term sustainability of deep-sea stocks is assessed only on the basis of trends in historical catch and effort because quantitative methods of stock assessment (including those based on harvest strategies) require estimates of total catches in the SIOFA Area (from all Flag States and non-signatories). Historical trends of Australian catch and effort are provided for the SIOFA Area for the assessment period (1999 to 2009) [Sections 5].

Monitoring, management and mitigation measures

Australia has adopted management measures for fishing by Australian vessels in the SIOFA Area. These measures include mandatory levels of observer coverage, move-on requirements triggered by levels of evidence of VMEs (>50 kg bycatch of corals and sponges), restrictions on fishing methods and gear types, and restricting the spatial extent of fishing by Australian vessels to a 'footprint' based on its collective (all gears combined) distribution of historical fishing activity for 1999-2009 [Section 4.1.2]. This assessment explicitly acknowledges the many key sources of uncertainty that underlay the BFIA process, which serve to increase risks of SAI. This BFIA identifies several opportunities for scientists, managers, fishery observers, and the fishing industry to reduce uncertainty, both in relation to the knowledge supporting impacts assessments, and to achieving management goals [Section 6].

Bottom Fishery Impact Assessment

1. INTRODUCTION

1.1 Australia's international commitments

The UNGA, in considering the implementation of the United Nations Convention on the Law of the Sea, adopted Resolution 61/105 in 2006 and Resolution 64/72 in 2009 (UNGA Resolutions). Those resolutions call on States to take action immediately, individually and through regional fisheries management organisations and arrangements, to adopt conservation and management measures to ensure the long-term sustainability of deep sea fish stocks and to prevent SAI to VMEs. Paragraph 83(a) of resolution 61/105 and paragraph 119(a) of resolution 64/72 call on States to assess, on the basis of the best scientific information available, whether individual bottom fishing activities would have SAI on VMEs, and to ensure that if it is assessed that those activities would have a SAI, they are managed to prevent such impacts or not authorised to proceed.

In addition to the UNGA Resolutions, the SIOFA, which is expected to enter into force shortly, will specify management measures for the SIOFA area of competence (SIOFA Area). Before the Convention enters into force, Australia has taken unilateral precautionary management measures in the SIOFA Area. These measures include:

- not expanding bottom fishing activities into new regions of the SIOFA Area
- assessing whether individual bottom fishing activities would have SAI on VMEs and closing such areas to bottom fishing or implementing measures to prevent such impacts, and
- prohibiting the use of deepwater gillnets

In response to the UNGA Resolutions and as part of Australia's temporary measures for the SIOFA Area, Australia has adopted a variety of management measures for the SIOFA Area (Section 4.1.2).

This BFIA is part of Australia's overall commitment to the UNGA resolutions 61/105 and 64/72, and to the FAO *International Guidelines for the Management of Deep-sea fisheries in the High Seas.* A similar and separate BFIA has been prepared for the *Convention on the Conservation and Management of High seas Fishery Resources in the South Pacific* (Williams et al. 2011a).

1.2 Process to assess impact of Australian vessels

This BFIA documents the bottom fishing effort in the SIOFA Area from 1999 to 2009, the quantity and composition of the retained catch, and the mapped distribution of fishing effort at a fine scale resolution, and assesses whether individual bottom fishing activities of Australian vessels have SAI on VMEs in the SIOFA Area. This requires several steps including (1) defining VMEs; (2) determining the distributions of VMEs – noting that these are not explicitly mapped and that 'indicators' (surrogates) must be relied upon in the absence of actual evidence of VMEs; and (3) estimating the nature, extent and persistence of impacts from different fishing gears – that vary with fishing intensity, and between gears and VMEs, (4) assessing how the current management arrangements reduce the impact or risk of significant adverse impact on VMEs.

The assessment methods follow, to the extent possible, the guidelines provided in the revised draft BFIAS developed for the area of competence governed by SPRFMO (SPRFMO 2009). That draft standard has been developed using a range of currently available information in response to UNGA Resolution 61/105, particularly the *FAO International Guidelines for the Management of Deep-Sea Fisheries in the High Seas* (FAO 2008).

The high seas region covered by the SIOFA occupies the region between the eastern Africa and western Australia; it has a complex boundary determined by the EEZ boundaries of many nations and latitudinal components between 10 degrees North and 55 degrees South (Figure 1.2.1). Its total area is 26,812,047 km^2. All data summaries reported here are restricted to spatial data that falls within the SIOFA Area boundaries, as defined by the GIS shapefile from the FAO (FAO 2010).

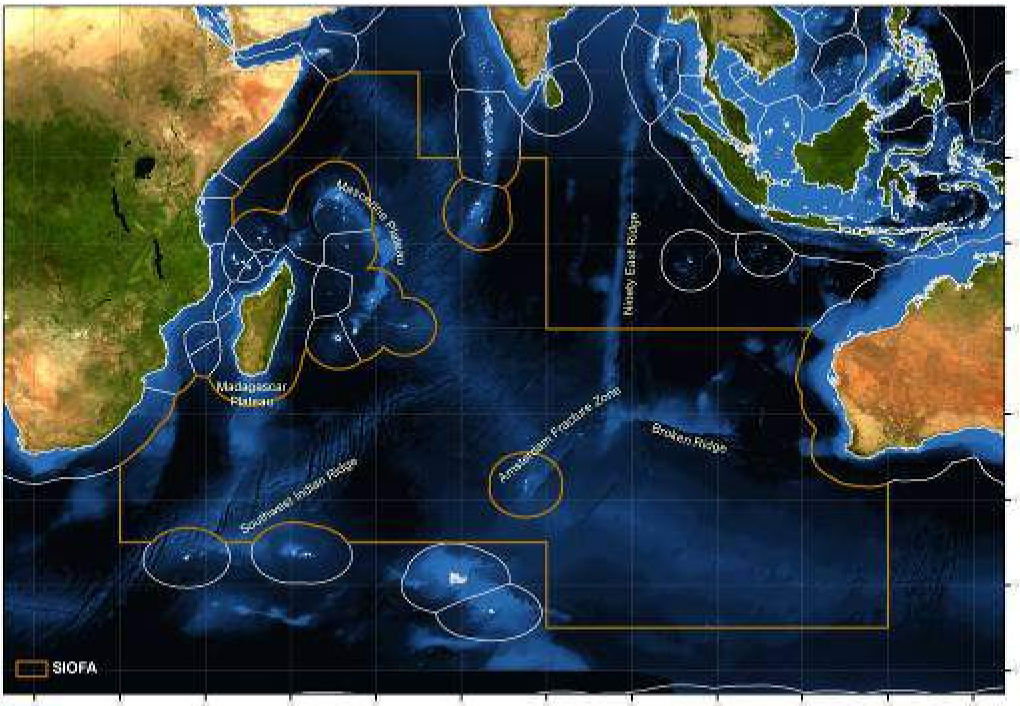

Figure 1.2.1 Map of the SIOFA Area (FAO 2010) bounded by the global EEZ (VLIZ 2010) with world topography underlay (NASA Blue Marble – Stockli et al. 2005). The major ridges are labelled, with the exception of the deep mid Indian Ocean Ridge running from NW to SE through the entire region.

Identification and assessment of risks of significant adverse impacts to VMEs in the SIOFA Area requires clear and specific operational definitions of VMEs and of SAI (SPRFMO 2009). Guidelines provided by the FAO (FAO 2008) have improved and expanded definitions relevant to UNGA Resolutions 61/105 and 64/72, and are incorporated in the template used in this assessment (SPRFMO 2009). These include definitions for vulnerability and risk, VMEs, biologically important factors, SAI, and a hierarchy of bottom fishing impacts. Details of these definitions are provided in Section 4.1.1 (and see Appendices 1-3).

It is important to recognise that evaluating the likelihood and extent of potential interactions of fishing with VMEs is constrained by the lack of data on distributions of seabed biodiversity, and hence the mappable distributions of VMEs. Assessing impact by the Australian fleet in the SIOFA Area relies on using seabed topographical features, especially seamounts, as 'surrogates' or 'indicators' for VME distributions – as has been the case for bottom fishery impact assessments in other fisheries, e.g. by New Zealand and Australia for the SPRFMO Area (MFish 2008; Williams et al. 2011a, repectively). But because the suitability of individual topographic features as habitats for VMEs is highly variable, e.g. the great majority of SIOFA seamounts may be too deep to support high abundances of coldwater corals, assessment is also reliant on analysis of habitat suitability. Such analyses are becoming available for high seas areas including the SIOFA Area (e.g. Tittensor et al. 2009; Clark and Tittensor, 2010) and are reviewed by Penney (2009). Indicators for potential VME locations used in this assessment are 'bathomes' (ecologically meaningful depth ranges within fishable depths), and seamounts. We have not considered biogeographic zones due to the absence of a single established mapping for the deep Indian Ocean, and have not included proximity/ connectivity measures due to the considerable additional complexity of including such measures in the structure of an impact assessment.

'Footprint' in this BFIA for the SIOFA Area defines an area determined by the collective (all gears combined) distribution of historical fishing activity for 1999-2009 in 20 minute grid squares. This analysis of impacts considers fishing distribution within the footprint, and at a finer 6 minute (0.1º) grid square resolution for individual gear types which we refer to as 'effort distribution'.

1.3 Data preparation and summary

1.3.1 Logbook and observer data

This assessment used fisheries data from the AFMA logbook database. Principal data used were position, date, time, fishing method, effort as reported for the different gears (hours fished, hooks set, or number of standard sets) and catch weight per species for each fishing operation (trawl shot or line set).

Observer data is collected by AFMA and managed separately from logbook data. The observer database was obtained from AFMA and summarised for the relevant years (see Section 4.1.5).

1.3.2 GIS Data Sources

This BFIA relied on the best data sets available at the time of the commencement of this assessment to assess, describe and map the distribution of potential VME indicators and distributions of Australian fishing activities.

Spatial analysis of the fishing logbook database relied on a variety of other mapping data for the SIOFA Area; the most recent and fine-scale information sources were used:

- SIOFA Area boundary — obtained from the FAO as shapefiles (FAO 2010)
- Global EEZ — VLIZ Maritime Boundaries Geodatabase (VLIZ 2010)
- GEBCO Bathymetry — The GEBCO_08 Grid a global 30 arc-second grid (GEBCO 2008)
- World topography — NASA Blue Marble (Stockli *et al*. 2005)
- Global distribution of seamounts (point data) — CenSeam 2010 (unpublished data)
- Global distribution of seamounts (polygon data) — Yesson et al. (2011)

1.3.3 Spatial processing

Operations for the SIOFA Area were selected from general high seas logbook data if the spatial location of the start coordinates of fishing operations occurred within the SIOFA Area boundary as defined by its GIS shape file (FAO 2010). Operations represent the unit of logbook recording which is equal to one trawl shot or one longline/dropline set. Gridded analysis for two spatial scales, 20' x 20' (the standard SPRFMO footprint grid cell) and 0.1° x 0.1° (6 minutes – approaching the limit of logbook resolution of 1 minute) was generated in Oracle using Oracle spatial intersect functions SDO_RELATE.

To map fishing footprint and effort distribution, fishing operations reported in AFMA logbooks from 1999-2009 were assigned to grid cells based on their start position only if no end point was reported. Where an end point was reported, and the length of a straight line between start and end points was ≤6 km, all grid cells (of either scale) touching any segment of the straight line were retained as part of the footprint and the fishing effort distribution; where the distance to the end point was >6 km only the start position was used. Six kilometres is used in domestic Australian deepsea fisheries as a limit for filtering tow lengths as part of data quality assurance; it was assumed to be a realistic limit for high seas data. Fishing effort distribution will be underestimated by logbook records that lack an end position. For the creation of the 20'x20' permit footprint these records were mapped and examined individually. Four blocks were added by AFMA because the reported start position was within close vicinity (within a margin of reporting error) of the block boundary and related trawl tracks and seabed features were such that it was more than likely that the added block had been fished within the relevant period. An additional block was added by AFMA to ensure the footprint is able to be implemented in permit conditions. Furthermore, any part of the 20' grid-cells overlying national EEZs or the BPAs (voluntary closed areas, see section 3.1.4) were excluded from the permit footprint.

Overlap analyses between the 0.1° mapped fishing distribution and depth zones (at 30 arc seconds, 0.2 n.m. resolution) were performed in ArcGIS using the Intersect analysis function. Areas for calculating the proportion overlap between fished grid cells and depth zones were calculated using a Lambert Azimuthal Aqual Area projection centred on the SPRFMO Area (PROJECTION: Lambert Azimuthal Equal Area, DATUM: WGS84, SPHEROID: WGS84, Central_Meridian: 75.0, Latitude_Of_Origin: -20.0). Where grid cells containing fishing effort crossed the SIOFA boundary they were clipped to the boundary extent. It should be noted that the depths reported here refer to the centroid depths of the grid-cells, derived from the bathymetry grid, not the reported operation depth. The form of the analytical result is therefore limited by the resolution of the underlying data (also see Section 4.1.4). For area and overlap analyses of seamount features, the Yesson et al. (2011) seamounts and knoll polygons were combined into one flat (planar) polygon area classified as 'area under seamounts', this polygon was subdivided into the bathomes and intersected with the 1° mapped fishing distribution.

1.3.4 Queries and Filters

Fishing operations were allocated to a sub-fishery based on their spatial location (occurring within the SIOFA Area) and gear code. Gear flagged as trawl were allocated to either demersal or midwater trawl based on 'trawl type' (stratum) recorded in logbook entries. For operations in pre 2003 where logbook entries did not specify the type of trawl (provision for entering trawl type was implemented in logbooks after 2003), shots were allocated to midwater trawl based on the catch ratio of orange roughy (CAAB code: 37255009, FAO code: ORY, *Hoplostethus atlanticus*) to alfonsino (CAAB code: 37258002, FAO code: BYS, *Beryx splendens*) being <3. This ratio ensured that the main target species for midwater trawls, alfonsino, was identified. The ratio also corresponded well with ratios observed where the stratum was recorded. Shots not identified using this method as midwater trawl were allocated to demersal trawl. Line methods were selected based on spatial occurrence within the SIOFA Area, and gear types: AL: Auto-longline, BL: Bottom line and DL: Dropline.

2. DESCRIPTION OF PROPOSED FISHING ACTIVITIES

There are currently four Australian high seas permits allowed to conduct bottom fishing in the SIOFA Area, although there is only one actively fishing in 2011. Fishing methods have been specified on Australian high seas permits since 2008 and include midwater trawl, demersal trawl, auto-longline, dropline and traps. Gillnetting was allowed prior to 2008, but we do not have any records of gillnet operations by Australian operators in the SIOFA Area from 1999 onward.

Few Australian vessels have been active in the SIOFA since 1999, with a total of six vessels reporting catches from the area. The operators of the licensed vessels have indicated to AFMA that they intend to use demersal trawl, midwater trawl, traps and demersal line (auto-longline and dropline) methods in the current fishing year (defined as the period of 1 January to 31 December in any given year).

2.1 Vessels and gears

2.1.1 Trawl

A total of five Australian vessels operated in the SIOFA Area between 1999 and 2009 using both demersal and midwater trawl gear (Table 2.1.1.1); a maximum of three vessels was actively fishing in any given year (Figure 2.1.1.1). There was no demersal trawling reported in 2007 and 2008.

Details of gears used currently were obtained by direct communication with the relevant companies. A critical aspect of understanding gear types in the context of benthic impacts was the distinction between midwater and demersal trawls. We confirmed the component of fishery operations recorded in the logbook as ‘midwater’ uses a net with large meshes (i.e. 20 metre diagonal meshes in the wings of the net), i.e. it is a pelagic net designed for off-bottom fishing. However, these nets do have a sacrificial footrope in case the net touches the bottom, suggesting that the midwater net is fished close to the bottom, and can touch down at least occasionally.

Most demersal trawling is done with a standard “Heard Island/Champion” net with a minimum bobbin size of 400 mm, but simple two seam ‘cut away’ demersal trawls with 80 metre sweeps and 40 m bridles have been used for orange roughy fishing. The headline length is 38 metres and the 30 metre footrope has 300 mm rubber bobbins. Two-ton Super-V otter boards are generally used. Polyvalent doors may also be employed for midwater trawling but preference is to not to frequently or routinely change doors around at sea. The vessels typically have several net drums to accommodate multiple trawl nets facilitating a relatively easy change from one net to another taking ~ 1 hour.

Table 2.1.1.1 Active trawl vessels in the SIOFA Area between 1999 and 2009 showing the target stratum and the number of operations (trawl shots).

Vessel	Stratum	Total no. Operations	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total no.	demersal	5	3	2	1	2	2	2	2	1	0	0	1
vessels	midwater	5	3	2	1	2	2	2	3	2	1	1	1
1	demersal	978	356			173	203	246					
	midwater	283	10			82	5	147	39				
2	demersal	1736	21	197	265	341	149	386	142	18			217
	midwater	1469	8	148	28	288	211	291	125	66	159	80	65
3	demersal	11	11										
	midwater	21	21										
4	demersal	208							208				
	midwater	54							23	31			
5	demersal	48		48									
	midwater	2		2									

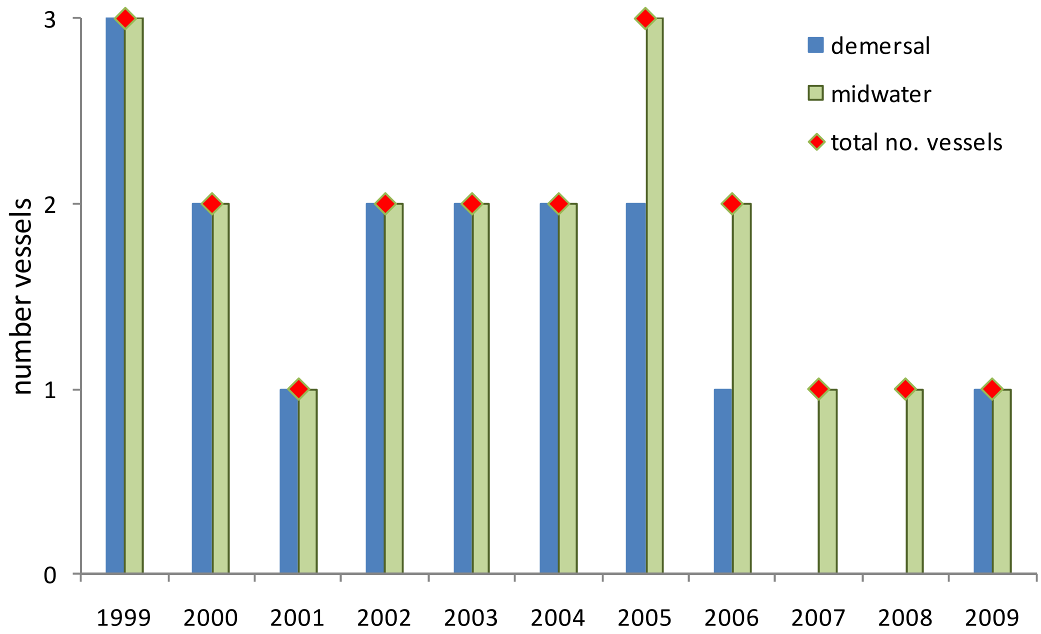

Figure 2.1.1.1 The number of trawl vessels operating in the SIOFA Area by year (red diamond), overlaid with the gear types employed. Note a single vessel can pursue more than one trawling method

2.1.2 Demersal lines

A minor component of Australian fishing in the SIOFA Area between 1999 and 2009 was by demersal line. In fact, only one vessel using longlines (autoline and dropline) operated in the SIOFA Area in the 1999-2009 period of interest, conducting 11 shots in 2008.

Auto-longline equipped vessels utilize technology that enables semi-automated setting of large numbers of baited hooks in a short time. Part of this gear is an auto-baiter that can bait ~2 hooks per second whilst the mainline is shot from the stern of the vessel. Gear specifications differ between "fresher boats" and "processing vessels". The former have a bottom set mainline that is 9-11 mm and can be weighted. Snoods of ~ 300 mm length with a 12/0 to 14/0 hook are spaced between 1 to 1.4 meters apart along the mainline. The longline is set with a 75 kg weight at each end and, depending on the target species, either floated up off the seabed using midwater floats that are clipped onto the line during deployment, or allowed to settle onto the seabed, sometimes with a weight midway along to prevent dragging. Droplines are lines set vertically with a single weight (~ 40kg) at the bottom and a large float at the surface with around 100-200 hooks attached at the bottom part of the vertical line. The maximum depth fished by “fresher boats” is reported as being ~1,500 meters.

Auto-longline gear deployed by “processing vessels”, i.e. Australian flagged vessels processing at sea, has a line ‘backbone’ with a diameter of 11.5 or 12.0 mm, weighted (50 gm/m) to mitigate interactions with seabirds. Nylon cord snoods of 42 cm are spaced at 1.4 m; each with a 20 Gauge, size 15/0 hook. Each magazine of backbone usually consists of 900 hooks giving a total magazine length of 1260 m; generally 6 magazines (range 4-8) are set per line. Attached to either end of the deployed magazines is a length of nylon free-line (anchor line) measuring 100-200m. This free-line is attached to one or two 40 kg grapnel anchors with a 20 kg chain also attached to ensure the line does not drag along the seabed. A nylon downline is used to connect the anchor line on the seafloor to the windy buoys and GPS buoy on the surface (Figure 2.1.2.1). Lines are shot from the stern of the vessel, and retrieved through the hauling station located on the starboard side. The depth fishable by “processing vessels” is reported elsewhere as being up to 2,400 meters, however, typically, auto-longline fishing does not exceed 2000 m depth.

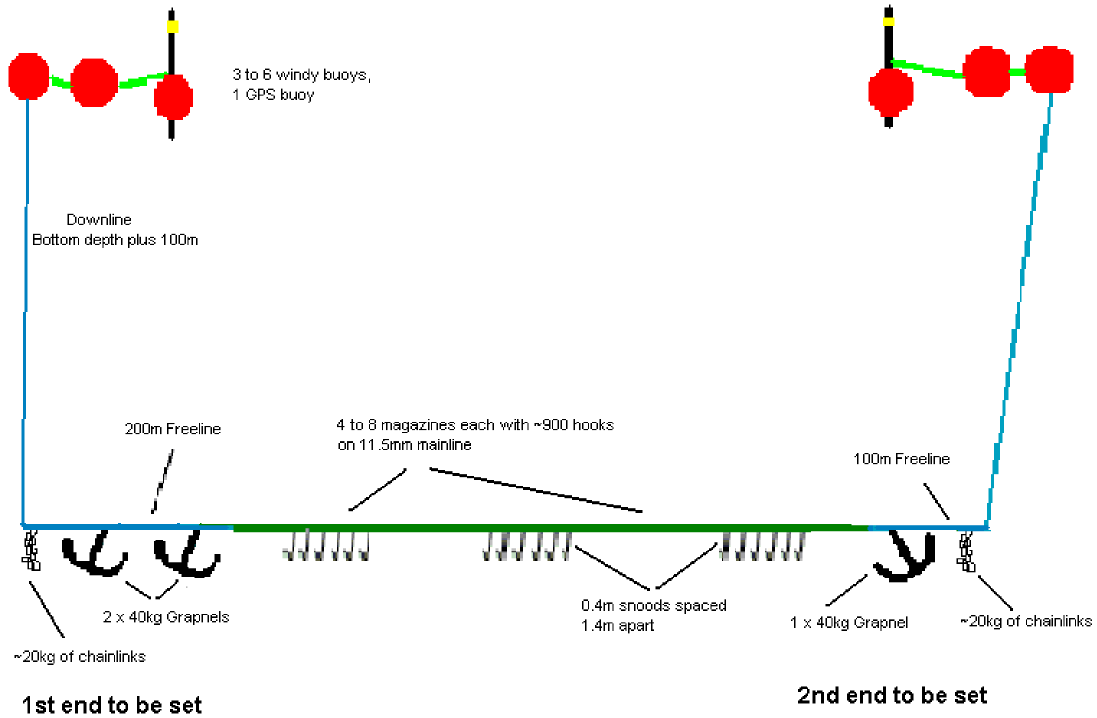

Figure 2.1.2.1 Diagrammatic representation of the set-up of auto-longlines as used by ‘processing vessels’.

3. MAPPING AND DESCRIPTION OF PROPOSED FISHING AREAS

3.1 Definition of fishing areas

3.1.1 Fishable areas

The first step towards defining the fishing interaction with, and impact on, VMEs is to define the fishable area. In this assessment, the potential fishable area was defined as depths <2000 m (Figure 3.1.1.1).

The fishable depth range can be usefully subdivided into five primary divisions (bathomes) that reflect the depth-correlated composition and structure of marine biota (Last et al. 2010; Table 3.1.1.1). In the context of benthic impacts of fishing, bathomes are relevant to the distributions of targeted commercial fish species and therefore the distribution of fishing effort, and to the distributions of faunal components such as deep water corals that characterise VMEs. For example, *Solenosmilia variabilis*, a matrix-forming stony coral that is common on southern Australian and New Zealand seamounts and has been shown to be vulnerable to bottom trawling, only occurs on the deep upper continental slope and shallow mid-slope depths (Althaus et al. 2009). It is important to appreciate that each of these bathomes makes less than 1% of the total SIOFA Area; combined fishable depths (<2000 m) make up <2% of the total SIOFA Area (Table 3.1.1.1).

Table 3.1.1.1 The area of the SIOFA Area divided into five ecologically meaningful bathomes (*sensu* Last et al. 2010)

Bathome	Name	Area (km^2)*	Percentage of total SIOFA Area
0 – 200 m	Continental shelf	37,402	0.14
201 – 700 m	Shallow upper continental slope	32,101	0.12
701 – 1000 m	Deep upper continental slope	25,133	0.09
1001 – 1500 m	Shallow mid-continental slope	110,781	0.41
1501-2000 m	Deep mid-continental slope	260,633	0.97
> 2000 m		26,414,597	98.27
TOTAL		26,880,647	100.00

* all areas given are ‘plan areas’ i.e. do not account for underlying topography.

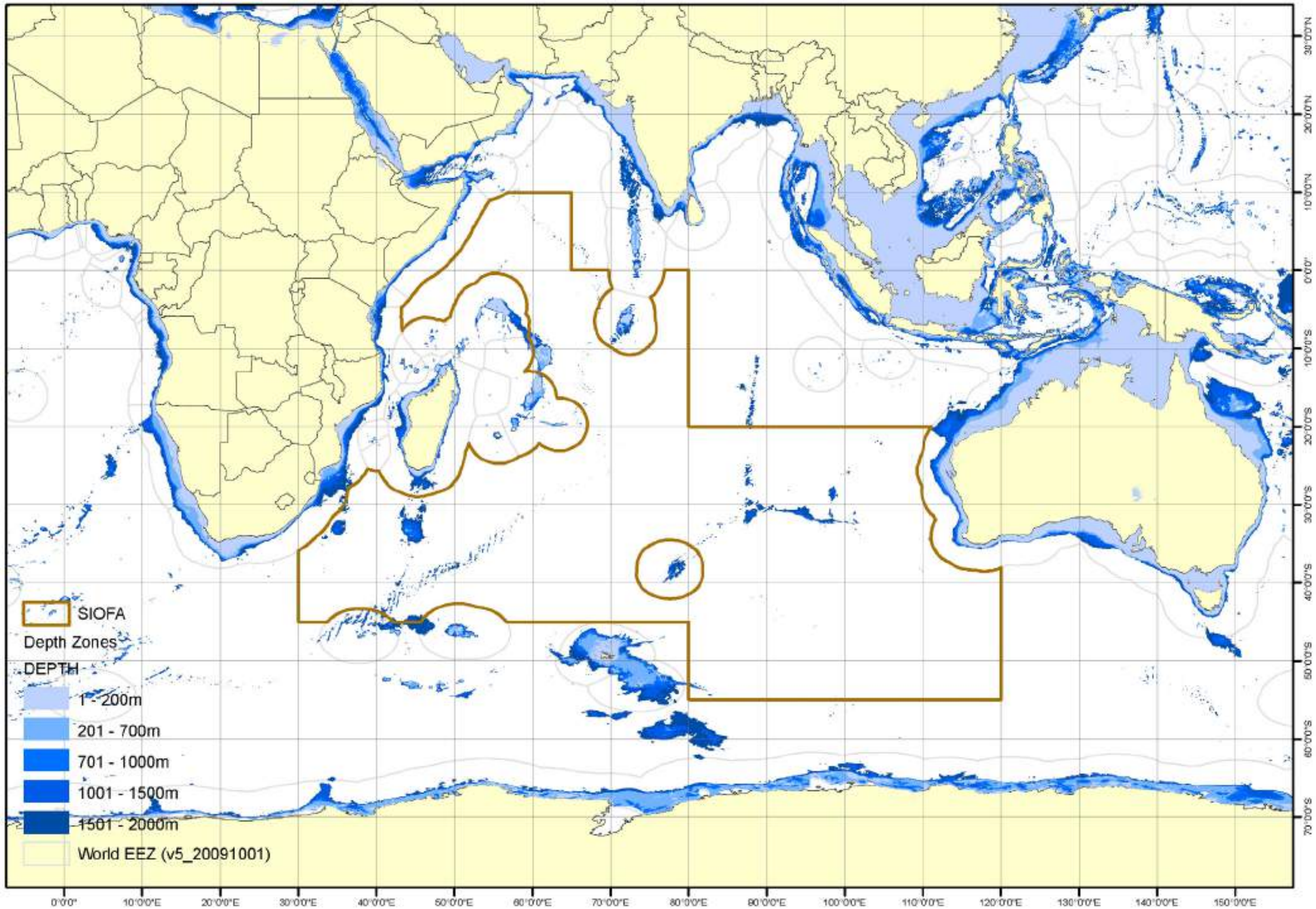

Figure 3.1.1.1 Map of the SIOFA Area (FAO 2010) bounded by the global EEZ (VLIZ 2010) with bathymetry contour polygons of the fishable depths (< 2000 m) defined based on GEBCO Bathymetry (GEBCO 2008) and divided into ecologically meaningful bathomes (*sensu* Last et al 2010). Depths beyond 2000 m are left white.

3.1.2 Footprint

The value of a measure of historical fishing effort for high seas fisheries management has been demonstrated in SPRFMO Area. There, an index of the total number of trawls in each grid cell ('block') enabled different approaches to management and mitigation measures to be tailored to the level of past impact, the likelihood of encounters with VMEs and the importance of different areas to the fishery for the New Zealand fleet (MFish, 2008). A spatial resolution of 20' (~20 n.m.) to map consolidated effort was adopted at the Fourth International Meeting on the Establishment of the proposed SPRFMO in 2007. The same spatial resolution was adopted by AFMA for management of Australia's activities in the SIOFA area. In order to satisfy the precautionary management measure of not expanding bottom fishing activities into new regions of the SIOFA Area, the Australian fishing footprint was defined for permit conditions as the consolidated historical fishing distribution over the period of 1999-2009 at a resolution of 20' blocks (Figure 3.1.2.1), excluding areas of these blocks that overlie national EEZs or the Benthic Protection Areas (see section 3.1.4). Note, however, that in this Australian BFIA, the distribution of fishing effort is also mapped at fine resolution (0.1° or 6' grid cells) over the period 1999 to 2009 and classified into six bathomes (five covering fishable areas ≤2000 m) for individual gear types (see Section 1.3.3) to ensure that impact is assessed at the finest possible resolution (see Section 4.1.4).

The footprint covers 0.84% of the SIOFA Area, but overlays up to 45% of the area of individual fishable bathomes (Table 3.1.2.1). The historical Australian fishing effort has been focussed on two distinct and separate regions: (1) the southern Madagascar Plateau and the Southwest Indian Ridge; (2) the intersection of Ninety East Ridge and Amsterdam Fracture Zone. Fishing distribution has been mapped separately for nine 'fishing grounds' within these two fishing regions (see section 4.2.3).

Table 3.1.2.1 The overlap of the Australian footprint (20 min grid, 1999-2009) in the SIOFA Area with the five ecologically meaningful bathomes (*sensu* Last et al. 2010) and their size in relation to the areas in each bathome for the SIOFA Area

Bathome	**Name**	**Footprint area (km^2)***	**SIOFA Area (km^2)***	**Overlap of footprint with total bathome in SIOFA Area (%)**
All depths		225,899	26,880,647	0.84
0 – 200 m	Continental shelf	272	37,402	0.73
201 – 700 m	Shallow upper continental slope	2,773	32,101	8.64
701 – 1000 m	Deep upper continental slope	11,307	25,133	44.99
1001 – 1500 m	Shallow mid-continental slope	26,677	110,781	24.08
1501-2000 m	Deep mid-continental slope	33,795	260,633	12.97
> 2000 m	[Unfished depths**]	151,074	26,414,597	0.57

* all areas given are 'plan areas' i.e. they do not account for underlying topography

**coarse resolution (20' grid) mapping results in the footprint overlapping some areas of unfishable depths

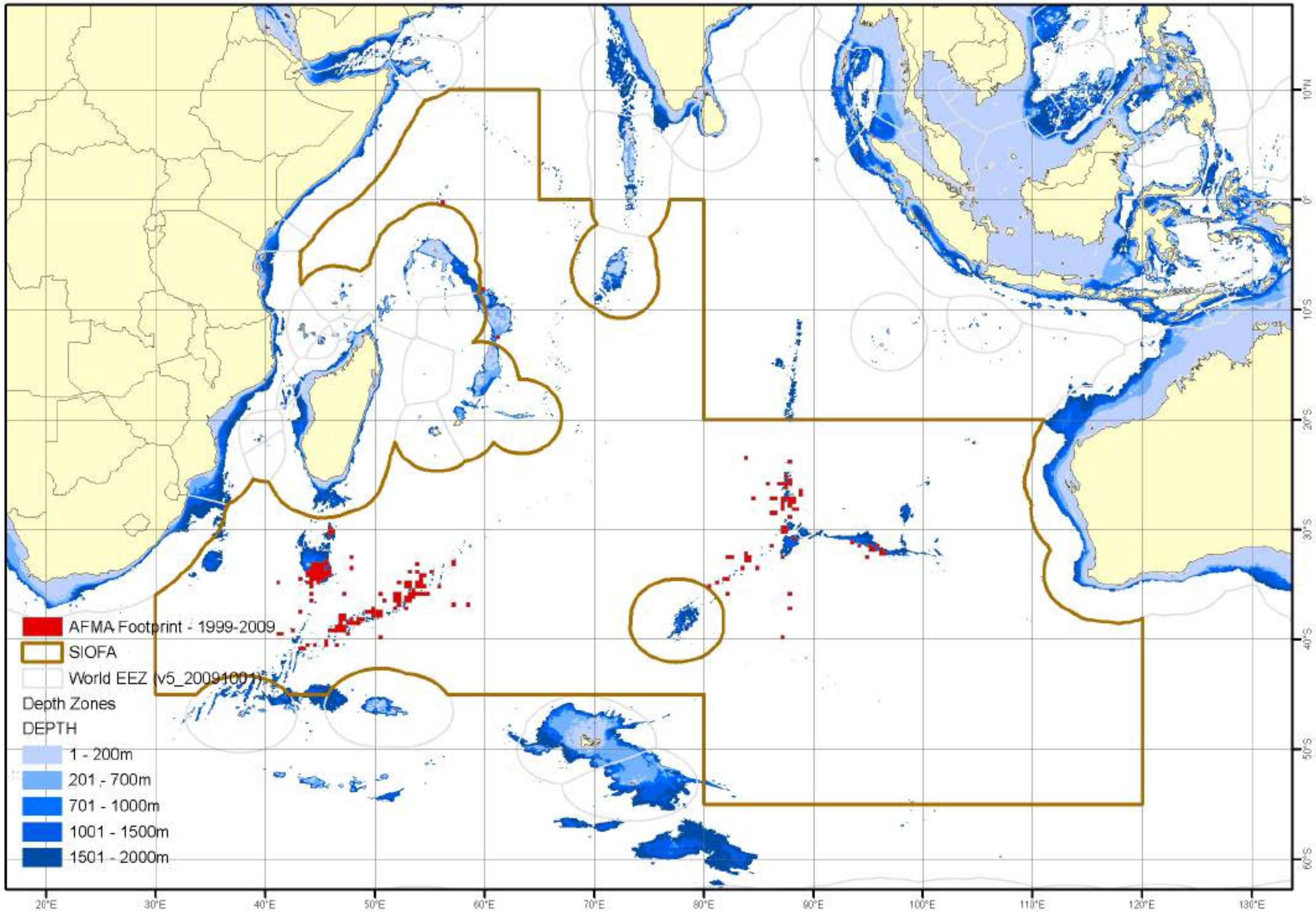

Figure 3.1.2.1 Footprint where Australian fishing operations were reported (1999-2009) for all gears combined, at the resolution of the standard 20 minute blocks. Effort is based on data from SIOFA Area only, although some individual grid-cells may partially overlap EEZs.

3.1.3 Fishing grounds

Past Australian fishing activities have been focussed on two distinct fishing regions within the SIOFA Area. Finer scale data summaries are provided by mapping fishing effort within sub-areas or 'fishing grounds'(Figure 3.1.3.1). For ease of definition and mapping, the fishing grounds are defined as rectangular boxes; some of these overlay adjacent EEZs but areas and analyses only consider the region within the SIOFA Area (Figure 3.1.3.1). The nine fishing grounds, as defined here, encompass the Australian footprint and are focussed on ridges and a plateau in the SIOFA Area where the seafloor rises to <2000 m. In fact, 77% of the total fishable area (depth ≤2000 m) are within these fishing ground — between 68% and 99% of individual fishable bathomes. Five of these fishing grounds contain BPAs, voluntary closures implemented by the SIODFA – see Section 3.1.4. These closures occupy between 0.5% and 6% of the respective fishing grounds. The details of total areas and areas within BPAs for each fishing ground are given in Table 3.1.3.1.

Table 3.1.3.1 The areas of 'fishing grounds' identified in the SIOFA Area based on the Australian footprint (combined trawl and line fisheries effort distribution 1999-2009), by ecologically meaningful bathomes (*sensu* .Last et al 2010). Also shown is the area of voluntary BPAs within fishing grounds the percentage they make up. Areal values are planar areas from SIOFA Area.

Fishing ground	**Shelf** 1 - 200m	**Shallow upper slope** 201 - 700m	**Deep upper slope** 701 - 1000m	**Shallow mid-slope** 1001 - 1500m	**Deep mid-slope** 1501 - 2000m	> 2000m	**Total Area**	**Area in BPA**	
Ninety East Ridge	48	167	303	6,295	21,836	451,543	480,191		
Broken Ridge		440	1,614	16,893	37,849	416,149	472,945	26,142	5.53%
Amsterdam Fracture Zone		370	833	9,688	14,901	716,379	742,171		
Madagascar Plateau - North		20	38	126	316	6,888	7,388		
Madagascar Plateau - East	36,643	27,937	5,828	11,666	15,314	105,613	203,000		
Madagascar Plateau - South	169	1,775	13,410	32,668	51,977	600,430	700,429	3,470	0.50%
Southwest Indian Ridge - East	39	334	511	2,140	7,834	419,699	430,556	10,847	2.52%
Southwest Indian Ridge - Central	6	55	291	2,722	15,419	243,451	261,944	135,345	51.67%
Southwest Indian Ridge - West	75	505	968	4,838	12,859	188,422	207,666	146	0.07%
Total	36,980	31,602	23,796	87,035	178,304	3,148,573	3,506,291		
Percent of bathome in SIOFA Area	98.87%	98.45%	94.68%	78.57%	68.41%	11.92%	13.04%		

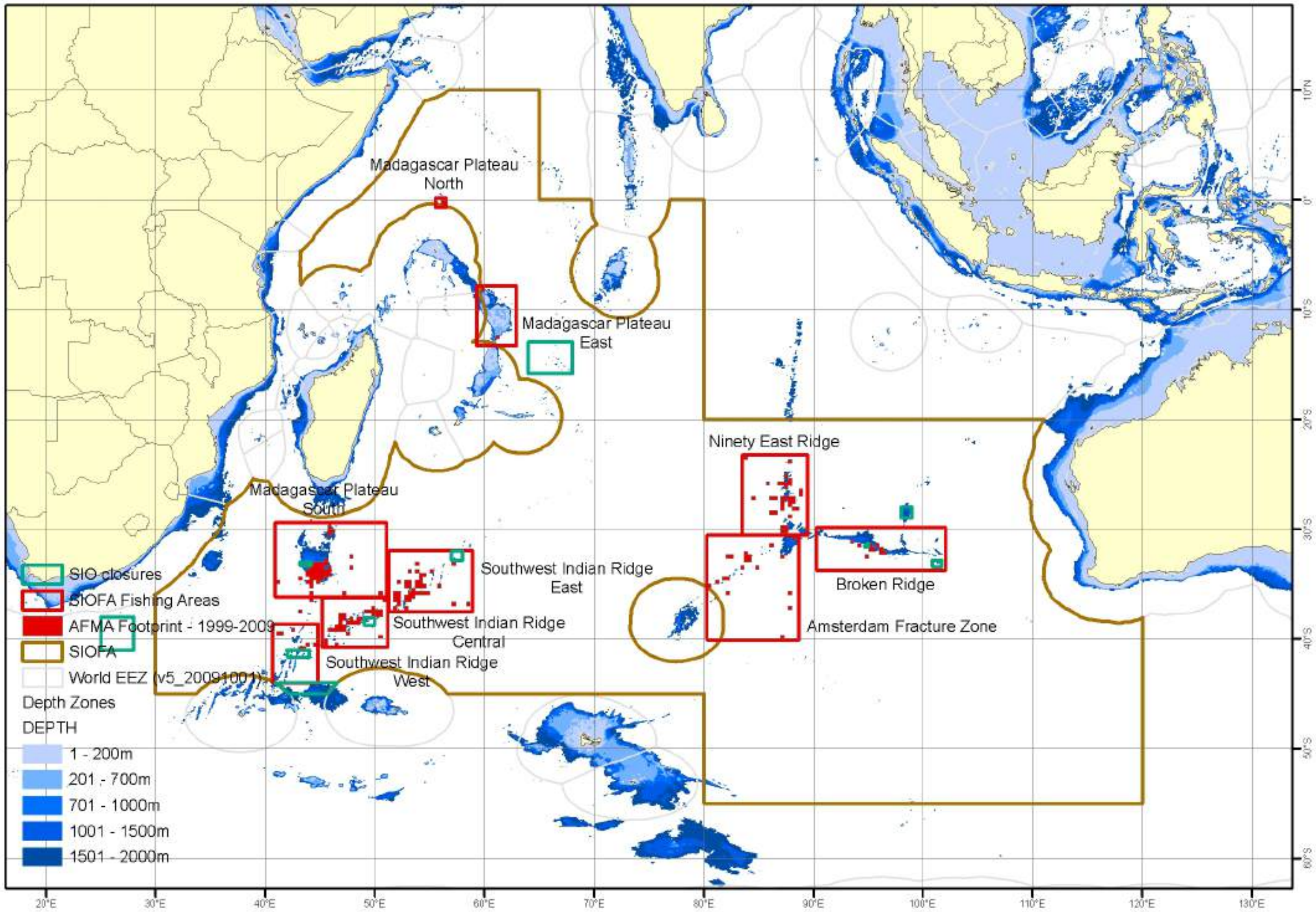

Figure 3.1.3.1 Fishing regions ("fishing grounds") within the SIOFA Area based on the Australian footprint (combined trawl and line fisheries effort distribution 1999-2009). Note: for ease of definition and mapping, the fishing grounds are defined as rectangular boxes; some of which overlay adjacent EEZs; analyses only consider fishing effort within the SIOFA Area.

3.1.4 Voluntary closed areas (“benthic protection areas”)

The members of the SIODFA voluntarily implemented 11 BPAs in the SIOFA Area in 2006 (Figure 3.1.4.1). Details of the implementation of these BPAs are discussed in the FAO Fisheries Circular (Shotton 2006) and elsewhere (SIODFA & IUCN 2006). Table 1 in the FAO document (reproduced here in Appendix 4) shows details of locations and information of features contained within each BPA (Shotton 2006). While some of the descriptions of the BPAs are limited to bathymetry and generalised description of the topography (e.g. East Broken Ridge, Bridle), others are more detailed, referring to benthic fauna such as dense coral stands (e.g. Rusky, Coral) or high benthic biodiversity (Walters Shoal) (Shotton 2006). Atlantis Bank has the most detailed description, as it was well studied including with submersibles; sightings of lobsters, crabs, sharks, siphonophores, sea fans, sponges and other benthic species are described (Shotton 2006).

The 10 voluntary BPAs within the SIOFA boundary comprise a total area of 223,121 km^2. The closures cover between 0.5 and 10.5% of each of the fishable bathomes, and between 0.5 and 5% of the total area of the fishing grounds (Table 3.1.3.1), despite covering less than 1% of the total SIOFA Area (Table 3.1.4.1). Aghulas Plateau, an additional BPA implemented by SIODFA, is outside the SIOFA Area boundary (Figure 3.1.4.1) and its area of 86,015 km^2 is not included in the summaries shown in Table 3.1.4.1.

The single Australian company that trawls in the SIOFA Area is the founding member of SIODFA and has abided by those voluntary closures since implementation in 2006. There were few Australian fishing operations in these areas prior to their closure: Gulden Draak (two demersal trawls), Rusky (five demersal and nine midwater trawls), and Atlantis Bank (eleven demersal and one midwater trawl).

Table 3.1.4.1 The area (km^2) covered by the voluntary BPAs implemented by the SIODFA by ecologically meaningful bathomes (*sensu* Last et al 2010). Also given is the percentage the closed areas represent of each bathome in the entire SIOFA Area.

BPA	Shelf 1 - 200m	Shallow upper slope 201 - 700m	Deep upper slope 701 - 1000m	Shallow mid-slope 1001 - 1500m	Deep mid-slope 1501 - 2000m	> 2000m	Total Area
East Broken Ridge		1	34	80	321	8,295	8,731
Gulden Draak				146	1,678	4,952	6,777
Fools Flat		62	62	519	1,912	9,847	12,402
Rusky		35	36	80	128	4,731	5,010
Mid-Indian Ridge			53	224	76	232	584
Atlantis Bank				4,294	4,784	1,770	10,847
Bridle					1,481	133,864	135,345
Coral				135	11		146
South Indian Ridge			152	5,080	14,031	20,789	40,052
Walters Shoal	169	741	848	1,050	526	136	3,470
Total	169	840	1,185	11,608	24,948	184,615	223,364
Percent of bathome in SIOFA Area	0.45%	2.62%	4.71%	10.48%	9.57%	0.70%	0.83%

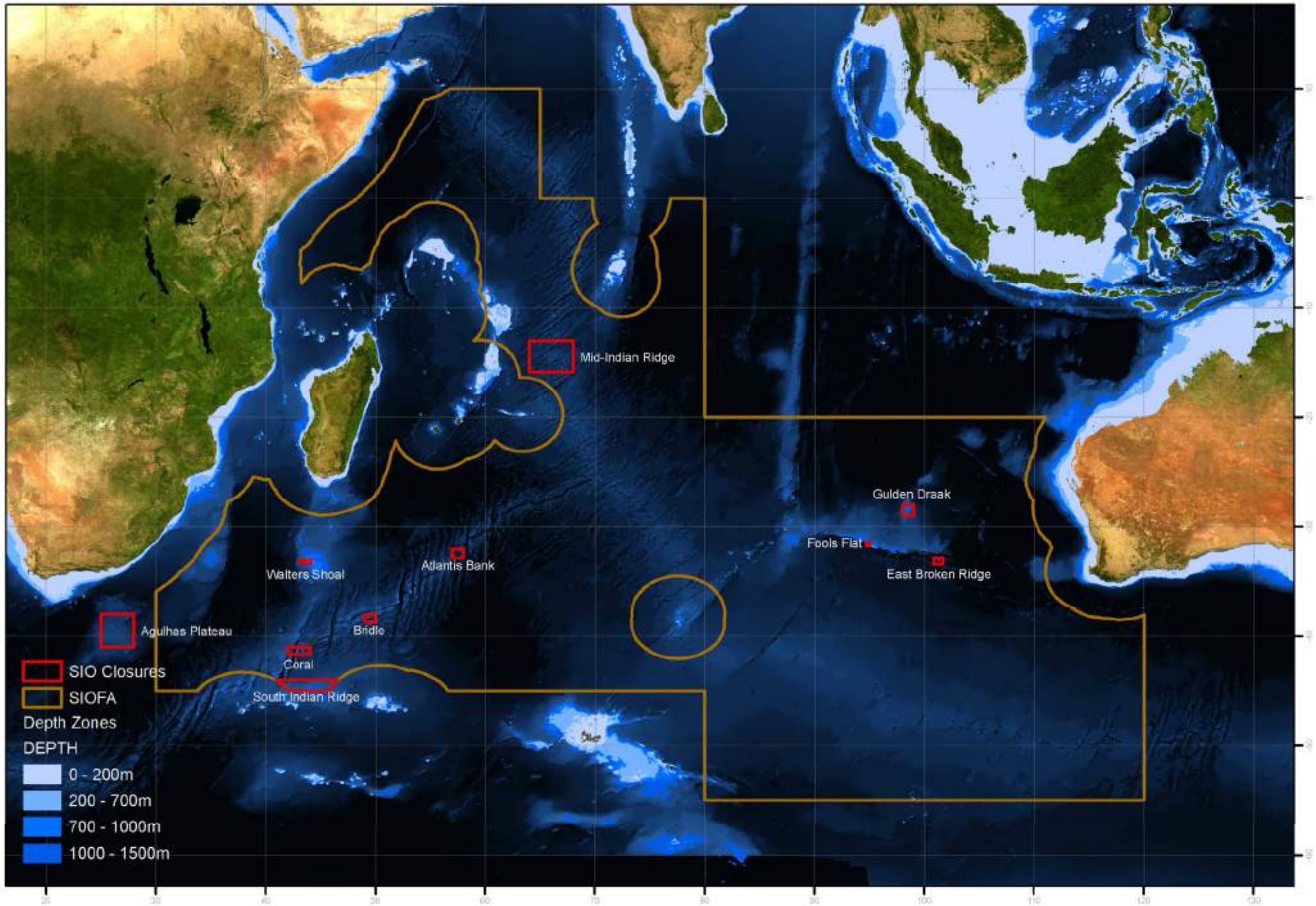

Figure 3.1.4.1 Voluntary BPAs implemented by the SIODFA. Note: 'Rusky' (not labelled) is a small area attached to 'Fools Flat'

4. IMPACTS ASSESSMENT

4.1 Scoping of issues and concerns

The aims of 'scoping' in the initial step of a fishing risk assessment are to establish context (including a description of the fishery), identify and document objectives, and identify the hazards (here, direct fishing impacts) to the assets of interest (here, VMEs) (e.g. Hobday et al. 2011). In this BFIA, the fishery description and the BFIA objectives have been provided in earlier sections; here we provide context to the assessment and identify other relevant issues by:

- defining VMEs and SAI and providing an interpretation for the assessment approach used (Section 4.1.1)
- summarising Australia's current monitoring, management and mitigation measures (as these are important for evaluating the overall risk of fishing activities) (Section 4.1.2)
- providing a rationale for the potential impacts of different fishing gears – which may vary with depth (fauna encountered), intensity, habitat type, and to some extent with the way the gear is deployed (Section 4.1.3)
- describing the opportunities and constraints to mapping VMEs and the relevance of this information to assessing impact and risk (Section 4.1.4)
- documenting the process for collecting and interpreting evidence of VMEs (Section 4.1.5)

4.1.1 Defining and identifying VMEs and SAI

Definitions of VME and SAI

In this BFIA, we provide formal definitions of VME and SAI together with an interpretation and context for VMEs in the high seas (mostly deep water) environment, and their potential vulnerability to fishing activities. The interpretation starts by examining the ecological traits of key component taxa, and the ways in which fishing may adversely impact them (this section), and is followed an explanation of how potential impacts can be evaluated as risks.

UNGA Resolution 61/105 calls upon States and regional fisheries management organisations or arrangements:

> 83 (a) To assess, on the basis of the best available scientific information, whether individual bottom fishing activities would have significant adverse impacts on vulnerable marine ecosystems, and to ensure that if it is assessed that these activities would have significant adverse impacts, they are managed to prevent such impacts, or not authorized to proceed.

However, the UN resolution does not give a formal definition of VMEs. In reference to a legal Act established in response to the UNGA 61/105 resolution ('Council Regulation (EC) No 734/2008 of 15 July 2008 on the protection of vulnerable marine ecosystems in the high seas from the adverse impacts of bottom fishing gears'), the European Union provides these definitions of the key terms (EU 2008):

> **Marine ecosystem**: a dynamic complex of plant, animal and microorganism communities and their nonliving environment interacting as a functional unit.
>
> **Vulnerable marine ecosystem**: any marine ecosystem whose integrity is threatened by significant adverse impacts resulting from physical contact with bottom gears in the normal course of fishing operations, including, inter alia, reefs, seamounts, hydrothermal vents, cold water corals or cold water sponge beds. The most vulnerable ecosystems are those that are easily disturbed and in addition are very slow to recover, or may never recover.
>
> **Significant adverse impacts**: impacts which compromise ecosystem integrity in a manner that impairs the ability of affected populations to replace themselves and that degrades the long-term natural productivity of habitats, or causes on more than a temporary basis significant loss of species richness, habitat or community types.

These definitions are reflected in the *FAO International Guidelines for the Management of Deep-Sea Fisheries in the High Seas (FAO 2008)* that determine (1) there are benthic marine ecosystems (i.e. assets) potentially vulnerable to threats (VMEs), and (2) that potential threats to VMEs exist in the form of bottom fishing activities. The FAO guidelines provide examples of the habitats and fauna that may represent VMEs (see Appendix 1). Particular classes of seabed topographic features, for example, seamounts, are explicitly identified as indicators for potential VMEs by UNGA 61/105, EU (2008) and FAO (2008). It is the component taxa of the communities likely to be supported by these features (e.g. cold water corals, see next Section) that are vulnerable to gear impacts.

Identification of VMEs and vulnerability of fauna

The FAO (2008) suggested five criteria that should be used to identify VMEs: uniqueness or rarity, functional significance of the habitat, fragility, life-history traits of component species (slow growth rates, late age of maturity, low/ unpredictable recruitment, longevity), and structural complexity (see Appendix 2). Examples of potentially vulnerable species groups, communities and habitats provided by the FAO (2008, see Appendix 1) were subsequently refined in a CCAMLR workshop on the identification of VMEs (CCAMLR 2009) into seven criteria to evaluate benthic taxa that constitute VMEs:

- habitat forming
- longevity
- slow growth
- fragility
- larval dispersal potential
- lack of adult motility
- rare or unique populations

CCAMLR (2009) also provided a ranking of 22 taxa (varying from phylum to class level) on each of those criteria (CCAMLR 2009 – Table 1 reproduced in Appendix 3). Six major taxa ranked high for four or more of the seven criteria:

- Porifera (sponges)
- Scleractinia (stony corals)
- Gorgonacea (octocorals)
- Stylasteridae (hydrocorals)
- Bryozoa (lace corals)

- stalked crinoids (sea lilies)
- chemosynthetic communities.

These taxa, with the exception of bryozoa and the chemosynthetic communities, are listed in the classification guide for potentially vulnerable taxa in the SPRFMO Area (Tracey et al. 2007; Parker et al. 2009a) that was presented at the SPRFMO 7th meeting of the SWG.

The taxa listed in Tracey et al.'s (2007) classification guide were considered in this BFIA to inform our assessment of VME evidence and the likely location of VMEs (Section 4.1.5). The presence of a single individual/ colony of a VME taxon may not indicate the presence of a VME, as many VME component taxa are not solely associated with these features and may occur in other types of ecosystems (Rogers et al. 2008). None of the definitions of VMEs or guidelines to identify VMEs identify explicit reference points for density or abundance of indicator species or communities (Auster et al. 2010). Thus, thresholds for identifying VMEs are left open for interpretation. In a recent practical application, Post et al. (2010) identified dense coral-sponge communities on the upper continental slope of the George V Land in the CCAMLR area of competence as a VME. Post et al. (2010) defined 'dense' as 'nearly continuous cover' of the seabed, as viewed by video. This measure is possible where *in situ* image data are available from e.g. scientific surveys or cameras mounted on commercial gear. In the absence of such empirical data on the presence and density of VME taxa, deciding on what level of VME taxon bycatch constitutes 'evidence of VME' depends on the taxon, the quantity in the bycatch, as well as on the gear used and the frequency of encounters (Rogers et al. 2008). These authors give practical guidelines of quantities of bycatch and frequencies of encounters that '*may be associated with the existence of VMEs*' for different gears (reproduced in Appendix 5), with the caveat that they '*will have to be tailored to regional requirements or through the application of adaptive management strategies, altered in response to new or specific data related to an area*'.

4.1.2 Australia's management arrangements

Commercial catch and effort returns

High seas fishing permits issued by the Australian Fisheries Management Authority set out specific reporting requirements for Australian vessels operating in the SIOFA Area. These include:

- the requirement to fit ICVMS
- manual position reporting in the event of the failure of the ICVMS
- pre-departure reports, including estimated time and date of departure and area of destination
- notification prior to mooring or anchoring including details of the date and estimated time that unloading will commence
- reporting of encounters with VMEs
- shot by shot logbook, trip catch disposal record and transit form reporting requirements.

Scientific observer coverage and data collection

For high seas permits that authorise trawling, an authorised observer must be carried at all times the vessel is fishing. For non-trawl fishing by high seas permit holders, there is mandatory coverage for the first trip and ongoing coverage of at least 10% annually.

Observer duties during fishing operations in the high seas fisheries include wildlife observations (including the recording of warp strikes by seabirds) during the setting and hauling of gear during daylight hours, biological data collection from fishes, including length frequencies and catch composition of target species, and bycatch monitoring. Bycatch monitoring includes observation of hauls, identification of bycatch species and catch composition reporting of weights and counts by species. When onboard, the observer is involved in the process of determining if bycatch of VME taxa exceeds the trigger limits (currently 50 kg of coral and sponges). On return from a voyage, the observer is required to present a report to AFMA and the collected data is entered into the AFMA observer data base.

Permit requirements

In response to the UNGA Resolutions, Australia has adopted the following management measures for high seas fishing activities by Australian flagged vessels in the SIOFA Area:

- mandatory 100% observer coverage for trawl operations
- mandatory coverage of the first trip and ongoing coverage of at least 10% annually for non-trawl operations
- upon encountering trigger levels of evidence of VMEs (such as corals and sponges), there is a requirement to cease fishing within a five nautical mile radius of the shot and to report the encounter. The area is then closed to all operators using that fishing method for the life of the permit. The trigger level for the SIOFA Area is 50 kg. AFMA reviews the trigger limits on an ongoing basis
- restrictions on fishing methods and gear types, including not permitting the use of deep water gillnets
- seabird bycatch reduction measures in the line fisheries, through requirements to deploy tori lines
- species catch prohibitions (e.g. Black Cod)
- ICVMS and logbook reporting requirements on a shot by shot basis
- bottom fishing effort is spatially confined within the Australian historical footprint (1999-2009) – see Section 1.1.

Closures and the move-on rule

In addition to limiting the extent of fishing via a fishing footprint, two spatial management approaches to avoid SAI on VMEs are: (1) closures that may be implemented in areas where VMEs are known or likely to occur; and (2) move-on rules enforced upon detection of evidence of VMEs (i.e. bycatch of 'trigger levels' of VME taxa during fishing operations), in areas where there may be little other information available (Parker et al. 2009a; Auster at al. 2010). Auster et al. (2010) present a decision support diagram that includes 'explicit steps regarding the identification of VMEs and decision criteria for encounters while fishing'; this diagram is a modified version of a diagram developed for FAO 2008 (Auster et al. 2010 – Figure 1, reproduced in Appendix 6).

Under the current Australian permit conditions, the use of all fishing methods (as stated in permits) is permitted in the Australian footprint, and a move-on rule is enforced where, on detection of 'evidence of a VME', a temporary closure of 5 n.m. radius surrounding the location of the trigger operation is enforced for all Australian flagged vessels using the same gear. The closure is effective for the life of the current permits and is reviewed when new permits are issued.

AFMA has excluded the voluntary BPA closures from the Australian footprint even if they contained historical Australian fishing effort. The BPA network has thus been enforced under the current Australian permits.

Detection of 'Evidence of VME'

The detection of 'evidence of VMEs' underpins move-on rules and decisions. Auster et al. (2010) acknowledge that decision-making for the protection of VMEs needs to be adaptive, because new information regarding the locations of unmapped VMEs is most likely to emerge during the course of commercial fishing operations.

Australia has adopted protocols which, similar to other RFMOs such as NEAFC, SEAFO and NAFO, use a broad definition of 'evidence of VMEs' (corals and sponges) but with lower trigger threshold of 50 kg for coral and sponge compared to the RFMOs – thresholds of coral (60 kg) and sponges (800 kg). New Zealand has adopted a protocol using a scoring system based on weight or presence of a series of VME indicator species. New Zealand's bycatch weight thresholds for individual coral taxa are lower than the 50 kg combined total specified by Australia – (30 kg for stony corals, 6 kg for hydrocorals and 1 kg for each of black, soft and fan corals) – see Parker et al. (2009a). These more closely reflect the weights Rogers et al (2008) suggest for discussion by management agencies (Appendix 5). For line fishing methods, CCAMLR has adopted different triggers of 10 kilograms or 10 litres of specified VME indicator species when recovered from a single line section. This comparison, the paucity of detailed data in observer records, and the scattered records of invertebrate bycatch (including VME taxa) in AFMA's databases, indicate a need for consideration of different thresholds for different gears and the relative priority for collecting information on VME taxa among the long list of observers' other at-sea duties. Some features of the Australian, New Zealand and CCAMLR arrangements are shown below (Table 4.1.2.1).

Table 4.1.2.1 Summary of three different arrangements for identifying and resolving VME taxa, and trigger weights and rules for 'move-on' provisions

Observer program	Identification guides	Triggers	Detail of recording
Australian high seas observer program	**VME-Taxa**: Tracey et al. (2007) – 10 Taxa **General bycatch**: some observers use Hibberd and Moore (2009)	>50 kg of sponges and/or corals collected in one operation (trawl shot or line set)	VME taxa recorded at coarse level of detail; trigger identification coarse, assessment of 50 kg volume; one trigger threshold for all gears
New Zealand high seas observer program	**VME-Taxa**: Tracey et al (2007) – 10 Taxa	Scoring system based on weights and/or presence (diversity) of a series of VME indicator species collected in one operation (see Parker et al. 2009a)	VME taxa recorded at coarse level; trigger identification moderately complex scoring system dependent on VME identifications; only for trawl gear
CCAMLR observers	**VME taxa** guide: Parker et al. (2009c) – 23 taxa **General bycatch**: Hibberd and Moore (2009) (Australian HIMI observers)	>10 kg/ 10 litres of VME indicator species collected in one operation (Parker et al 2009b; Tracey et al 2010)	VME taxa recorded in much detail; trigger identification relatively coarse but easily assessed; one trigger (trigger applies to longline operations only)

Gear specific impacts (Section 4.1.3) support the case for gear-specific and/or taxon specific trigger limits for move-on rules – especially for auto-longline, for which there is no realistic expectation of landed bycatch comparable to trawl.

The complexity and management requirements for a system such as that used by New Zealand to determine 'evidence of VMEs' in the SIOFA Area may be difficult to justify given the small size and low effort by Australian vessels in the SIOFA Area, while the intermediate complexity of the CCAMLR approach seems both appropriate, and would allow consistency across Australian fishing permits. The collection of reliable data by independent observers is essential because there is a paucity of data from high seas areas, but critically because enforcing move-on rules (as applied by Australia in the SIOFA Area) depends on defining 'evidence of VMEs' in real-time during commercial fishing operations (e.g. Parker et al. 2009a; Auster et al. 2010). Because of the need for a high level of confidence in the accuracy of taxon identifications, Parker et al. (2009b) and Tracey et al. (2010) compared VME identifications determined by observers at sea on New Zealand vessels in the CCAMLR area of competence with identifications made by taxonomists on return of the vessel. Overall they found a high level of agreement for most of the VME taxa specified (Parker et al. 2009c). These studies showed the level of confidence in identifications is directly dependent on the amount of training and experience observers have in dealing with the variety of invertebrate taxa specified in the VME identification guides (Tracey et al. 2010).

The Australian company fishing in the SIOFA Area had employed industry observers from the start of the fishery in 1999 and the data collected by these observers can be made available for future research. At this stage, the format and detail of the data recorded by these observers has not been compared to the HIMI and AFMA data reporting protocols.

Operational measures to minimise benthic impacts

Fishing operators report the following operational actions to mitigate the impacts of fishing on VMEs:

- demersal trawl operators minimise bottom contact by targeting their gear specifically at fish schools or particular seabed features, and, in general, fish with the trawl doors off bottom
- auto-longline operators minimise impact by 'peeling' the gear off the bottom in a straight line during retrieval to minimise lateral movement of the gear, and, depending on target species, will float the main line off the bottom.
- mid-water trawlers use trawl nets with weak links that break if the gear hits bottom. This frees the gear and avoids damage to benthic habitats and the loss of the gear.

4.1.3 Impacts of different fishing gears

Bottom fishing is defined as fishing with any gear type likely to come in contact with the seafloor or benthic organisms (FAO 2008). It is well established that all bottom fishing gears have the potential to impact seabed communities but have different levels of impact depending, among other factors, on the physical shape and weight of the gear and the way it is deployed (e.g. Kaiser et al. 2006; Rogers et al., 2008). The Australian fishery in the SIOFA Area has, historically, employed three gear types that contact the seabed: demersal trawl, auto-longline and dropline, and mid-water trawl with sacrificial footropes that may make bottom contact (Section 2.1.3). Current permit conditions (AFMA unpublished 2011) also allow the use of traps in the SIOFA Area. Because fishing impacts are cumulative, multiple deployments of low impact gears in the same area have the potential to damage seabed communities over time, and also negatively influence their recovery in a similar way to a lower number of deployments by high impact gears. Assessing the interactions of fishing gears with VMEs therefore needs to consider the potential impacts of all fishing gears used in high seas areas.

A semi-quantitative scheme for rating gears for benthic habitat impacts (Chuenpagdee et al. 2003) was suggested as the default for the 2009 Draft SPRFMO BFIAS (SPRFMO 2009, Table 2). However, the BFIA for the SPRFMO Area completed by Williams et al. (2011) considered that two additional considerations may be necessary in the Chuenpagdee et al. (2003) scheme. We reproduce Williams et al.'s (2011) suggested revisions and rationale here. In order of importance they are:

(1) increased rating of bottom-set auto-longline to reflect a higher likely impact on VME fauna than has been previously recognised. The rationale is the accumulating evidence for impact by bottom set (auto-) longlines on many elements of Chuenpagdee et al.'s (2003) 'biological habitat' which represent VME fauna (i.e. erect and often large and/or delicate animals typically characterised by slow growth rates and long life spans). Data sources to support this proposal include:

- Munoz et al. (2011) – documented bycatch of deepwater corals and sponges, and higher catch per unit of effort of fishes in coral areas.
- CCAMLR (2009) – acknowledged 'that simply on the basis of the characteristics of the gear, especially the potential for movement of the mainline and hooks during the soak period, there was considerable potential for differences [between types of bottom-set longlines] in the interaction of the gear with benthic organisms' and that 'a primary factor influencing the potential impact of different longline gear types was the extent of lateral movement of the mainline in contact with the sea floor during line retrieval.'

- Parker et al. (2009b) – 29% of 1522 observed longline segments in the Ross Sea caught VME indicator organisms as fishing bycatch.
- Parker and Bowden (2010) – identified 13 major benthic taxa as potentially vulnerable to auto-longline gear in the Ross Sea based on medium or high scores against factors including size, longevity, growth rate, fragility, and their presence in fishing bycatch retained by New Zealand scientific observers.
- Post et al. (2010) – identified a hydrocoral as a key VME indicator taxon, which, based on its fragility, makes it particularly vulnerable to shearing forces exerted by bottom longline gear used in East Antarctica.
- Tracey et al (2010) – 34% of 1707 observed longline segments in the Ross Sea caught VME indicator organisms as fishing bycatch.
- Sharp et al. (2009) – sources of impact from bottom longlines are from the backbone (mainline), and anchors and chains. The mechanism is lateral shearing that occurs when the gear moves on the bottom – e.g. during retrieval (citing work by the Australian Antarctic Division).

(2) a sub-division of the mid-water trawl category to recognise that some gear designs used by Australian vessels and possibly other Flag states, enable a minimal level of bottom contact by nets that are primarily fished off the bottom when certain benthopelagic species are targeted. The rationale and supporting evidence is provided in Table 4.1.3.1.

Table 4.1.3.1 Ratings of benthic habitat impact for gear types used by Australian vessels in the SPRFMO Area on a scale from 1 (very low) to 5 (very high) as defined by Chuenpagdee et al. (2003) but showing proposed considerations.

	Benthic habitat		
Gear class	**Physical**	**Biological**	**Suggested consideration**
Demersal trawl	5	5	None proposed
Midwater trawl	1	1	Mid-water trawls for certain benthopelagic species are designed to withstand some bottom contact
Trap	3	2	None proposed
Demersal auto-longline	2	2	Rating should be increased to reflect a higher likely impact on biological habitat that has been previously recognised.
Hook and line (Dropline)	1	1	None proposed

4.1.4 Mapping indicators to infer spatial distributions of VMEs

The FAO guidelines for VME mapping (FAO 2008) note that 'where site-specific information is lacking, other information that is relevant to inferring the likely presence of vulnerable populations, communities and habitats should be used' (SPRFMO 2009). There are two physical topographical seabed indicators presently available at ocean basin scale that can be used for this purpose and both are evaluated here in Section 4.1.4: (1) ecologically meaningful depth ranges (bathomes) and (2) seamounts. Maps of other topographical or hydrophysical features that potentially support VMEs (submarine canyons and trenches, hydrothermal and cold seeps) are incomplete at ocean basin scale and/or their surrogate potential has not been validated. The accuracy of GIS data-overlays and resultant summaries are highly dependent on the spatial scales of the data that is used to map VME indicators and fishing effort, as discussed below.

Spatial dependencies for VME and effort mapping

Because assessing the impact of bottom contact fishing on VMEs depends in part on estimating the areal overlap of impact with VME distribution, it is necessary to examine the sensitivity of the overlap metric to the spatial resolution of the underlying data sets, and to understand the real scale at which VMEs may exist. Spatial scale dependencies can be illustrated with an example of a well-studied cluster of small seamounts south of Tasmania which was mapped in detail in 2006 using multi-beam acoustics (Appendix 6). This cluster of volcanic cones was intensively, but selectively, trawled for orange roughy, and trawling effort mapped at 1 km grid cell resolution. Analysis showed that all the shallow peaks (<1000 m depth) – which included the largest seamounts – were heavily impacted (Koslow et al. 2001), while a series of smaller features in close proximity remained very lightly fished or unfished (Appendix 6). Scientific surveys using both epibenthic samplers and imaging technology have confirmed the presence of VME taxa and communities in structural refuges on the larger, impacted seamounts (Althaus et al. 2009) and intact VME communities on adjacent features (Williams et al. 2010). In summary, this example shows that the distributions of VME indicators (bathomes and seamounts) and targeted fishing effort can, and frequently does, exist at finer scale than the standard 20' blocks.

The dependencies of scale are shown by the grid cell examples ranging from 1° x 1° to 1 km x 1 km grid cells. The grid cells presented in Appendix 6 correspond to the resolution of various data sets used directly or indirectly in this BFIA:

- 1º — global scale predictive models such as the suitability of seamounts for stony corals (Tittensor et al. 2009); the model resolution is limited to this scale by the 1° resolution of the underlying physical data sets such as global salinity, temperature and oxygen.

- 20'— the standard cell-size for footprint reporting in the SPRFMO Area confirmed by the 9th SWG meeting.

- 0.1° — the limit of resolution for gridding AFMA logbook data in the high seas fisheries for data collected at 1 minute, ~0.02º, resolution; the scale of fishing effort distribution used for spatial overlays in this BFIA.

- 1 km — the scale of fishing effort mapping typical in Australian domestic fisheries, the scale reported by Australian scientific observers in CCAMLR, and the scale of some predictive environmental modelling (e.g. Davies and Guinotte, 2011).

The finest scale (1 km grid) permits an understanding of the direct impacts of fishing on individual indicator features – including to determine whether fishing and VME overlap is finely concentrated in space, resulting in high cumulative impact on, for example, a single seamount (a VME indicator). On the other hand, the finest scale may also show potentially unimpacted refuge areas, e.g. on a partially fished seamount or on adjacent features (Appendix 6). The potential relevance of increasing the spatial resolution from the standard 20' block used for reporting purposes in the SPRFMO Area was discussed in the 8th and 9th meetings of the SWG, but in the 9th SWG meeting '*it was agreed that there would be no suggested change to the current standard 20 x 20 minutes, at this time.'* Our example serves to illustrate some of the potential insights gained from finer resolution mapping.

Thus, in this BFIA we use two scales for mapping fishing effort: 20'(20 n.m., the standard SPRFMO footprint block) and 0.1º (6'or 6 n.m. – the limit of logbook resolution). Here we examine the effect of resolving fishing effort distribution at either of these scales, together with two methods of defining seamount VME indicators (point definition of seamount peak, and polygon definition of seamount boundary). Comparing the two seamount definitions serves to contrast the relative utility of the best available data sets, including their content (i.e. numbers and locations of seamounts): Yesson et al. (2011) and the unpublished Census of Marine Life Seamounts on Line database collated by CenSeam (and kindly provided by M. Clark of NIWA).

As noted above (Section 1.3.3) depths reported for area calculations in this BFIA refer to the centroid depths of the 0.1ºgrid-cells, derived from the bathymetry grid, not the reported operation depth. This resulted in a skewing towards deeper distribution of effort (see Figure 4.1.4.1a) compared to the distribution of the reported tow depths (e.g. see Table 4.1.4.3), which stems from the limitations of the bathymetry data and the scales at which fishing effort can be gridded.

The effect of a coarser spatial scale (20' blocks) of effort mapping was predictably to increase estimates of overlap with respect to bathomes and seamounts. Finer scale mapping provides a better resolution of where fishing occurs (Figure 4.1.4.1) within bathomes and on individual seamounts, and also shows where un-impacted areas may remain on fished seamounts – especially where individual trawl tracks can be interpreted from recorded start and end positions. Effort data recorded by sea-going observers at even finer scale (increased recording accuracy from degrees and minutes to decimal degrees to at least three places of decimal), would further improve the resolution of mapping and provide consistency with data collected in the CCAMLR area of competence. Uncertainties in impact assessment could be reduced by recording fishing start and end location more accurately, including as 'gear on-bottom' positions, and is recommended for future data collection. For all our summaries and descriptions of spatial overlays of effort we used the fine-scale 0.1º fishing effort distribution.

An overall comparison of the content of the CenSeam (unpublished) and the Yesson et al. (2011) data sets (Figure 4.1.4.2) revealed several relevant characteristics in the context of impact assessments. First, there is good correspondence of the data for many seamounts, but not a one-to-one match in either the numbers of seamounts or their locations; there are also some inconsistencies between seamount depths and the GEBCO 2008 bathymetry dataset. This is to be expected given the different sources of data and mapping methods used to compile each seamount data set. The Yesson et al. (2011) data tended to overestimate the number of seamounts and knolls, especially where the topography is complex, e.g. along ridges. There are many locations where multiple seamounts are defined in close proximity which leads to overlapping polygons. In contrast, some seamounts appear to remain undetected, for example in the CenSeam point data on the Amsterdam Fracture Zone and on the Southwest Indian Ridge (Figure 4.1.4.2b & c). In many instances, however, the accuracy of the bathymetry data may be unknown precluding any validation of one or other data set. As well, the CenSeam data may underestimate the number of shallow seamounts relevant to this study because summit depth data was not recorded for 7.5% of the seamounts in the SIOFA Area. It is likely that both data sets underestimate the number of smaller features, irrespective of whether they explicitly distinguish knolls from seamounts. The CenSeam data set principally includes smaller features from survey data sets (e.g. those off southern Tasmania mapped by CSIRO) where they have been provided directly to the CenSeam database. Detection of small features in the Yesson et al. (2011) data is dependent on the quality of the bathymetry data.

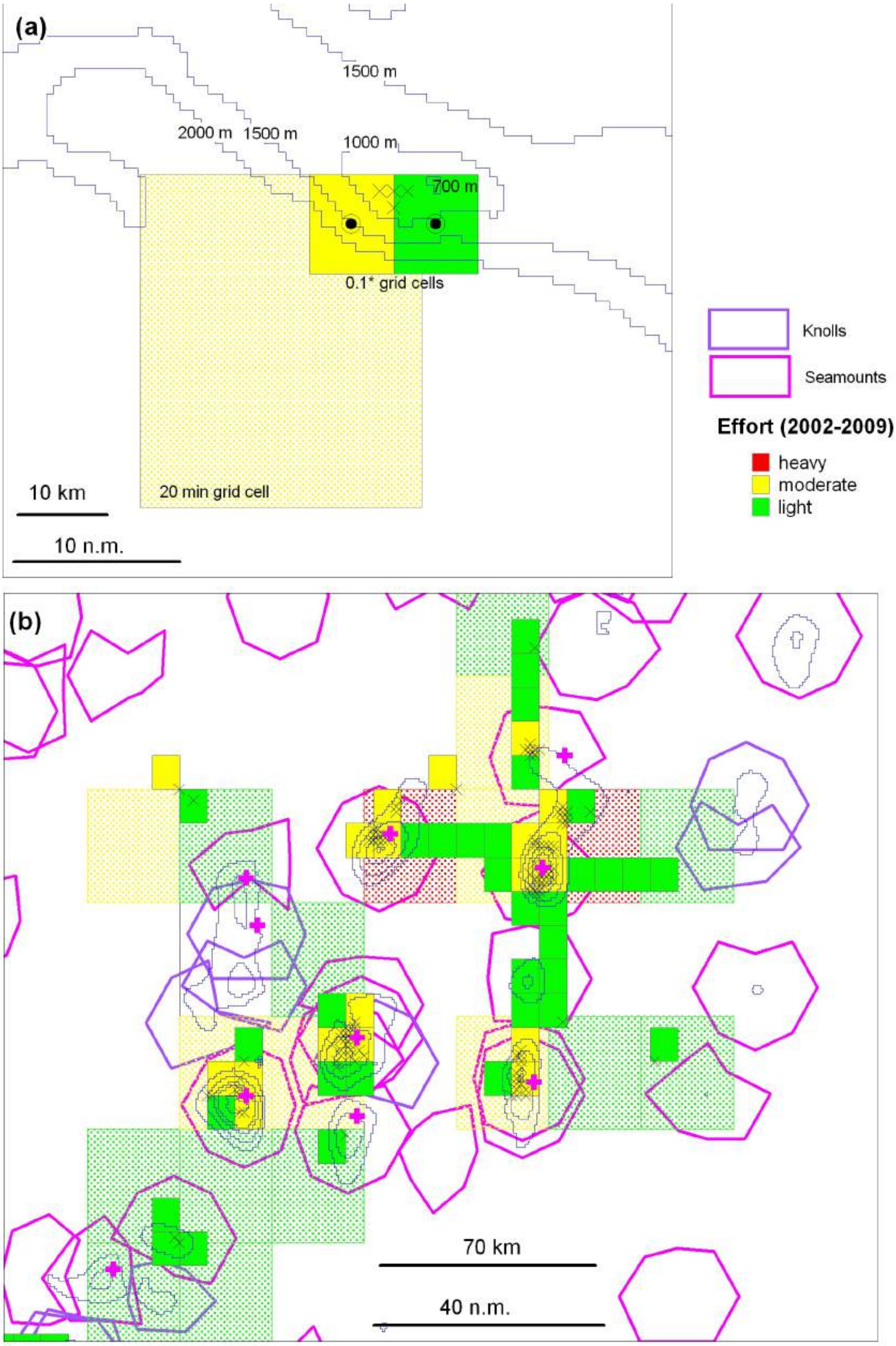

Figure 4.1.4.1 Illustration of the dependencies of overlap estimates on spatial scale of fishing effort grids and the type of data describing seamounts (point vs. polygon) using undisclosed example areas; (a) close-up of a ridge (target symbols: centroids of the 0.1° grid cells used for assigning depth; crosses: tow start positions) with 20' (hashed) and 0.1° (filled) grid cells graded by demersal trawl effort), and (b) scattered peaks (contours 200, 700, 1000, 1500, 2000 m depth) overlaid with Global seamounts data – pink crosses: CenSeam unpublished, outlines: seamounts and knolls Yesson et al (2011), 20' (hashed) and 0.1° grid cells (filled) graded by demersal trawl effort and tow start positions (x) are overlaid.

Seamounts were assigned to grid cells (20’ or 0.1º) either containing a seamount peak (CenSeam data) or where a polygon(s) extended into a cell (Yesson et al. 2011 data). Where an effort grid cell contained overlapping seamount polygons, each seamount was flagged as having fishing effort, but each seamount polygon was counted only once in summations of potentially impacted features.

Even at the 20’ grid scale, many of the seamount peaks identified in the CenSeam point data lay just outside of the effort grid cell, while the polygons of Yesson et al. (2011) features were more likely to be identified under the footprint because of their larger extent. On balance, we used the Yesson et al. (2011) polygon data for spatial overlays of fishing effort on seamounts in the SPRFMO Area, and in fishing ground subareas, because polygons are a better spatial representation of seamount extent. Use of polygons vs. peak locations also reduces the uncertainty about fishing effort distribution stemming from missing operation end positions.

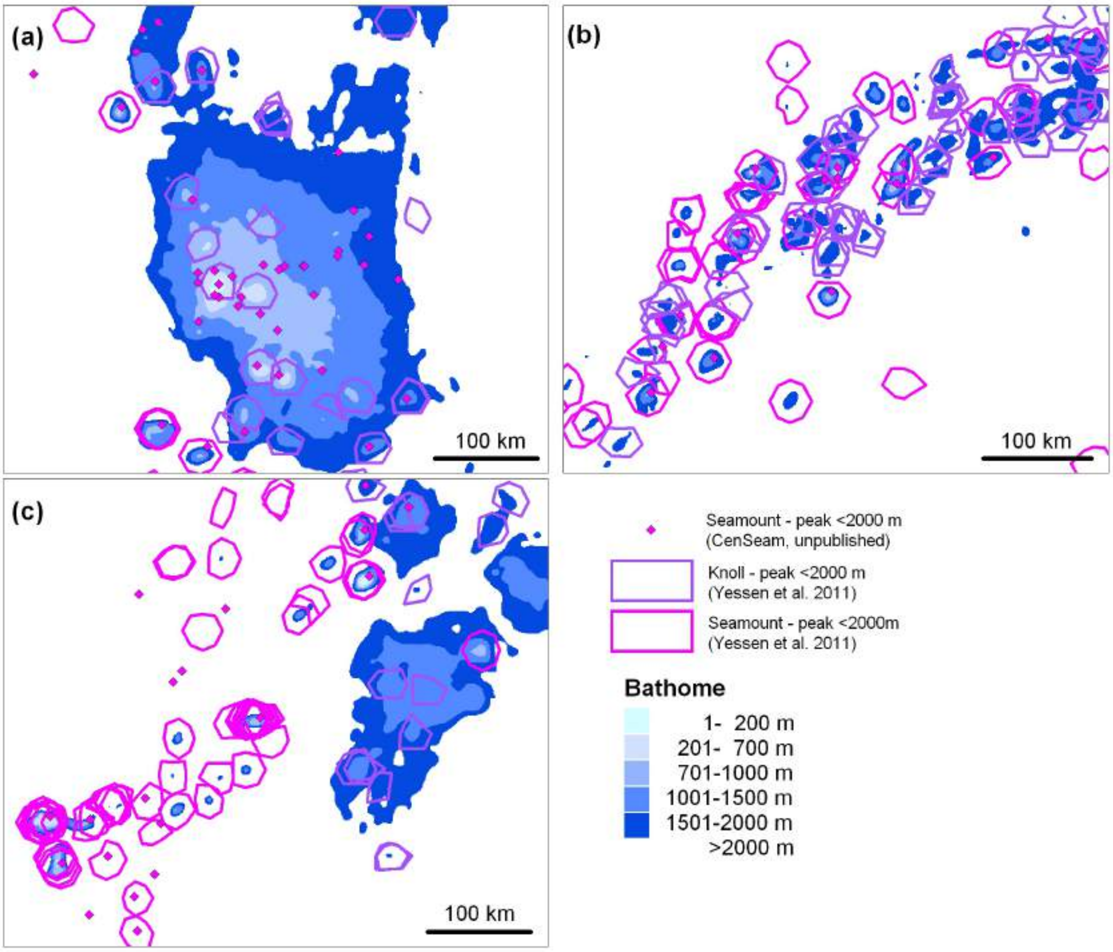

Figure 4.1.4.2 Comparison between global seamounts data sets overlain on global bathymetry coloursed by ecologically meaningful bathomes: CenSeam (unpublished) compilation of seamount peak locations from nine data sources; Yessen et al (2011) algorithm-based analysis of 30-arch bathymetry outlining seamount and knoll polygons. Only features with peak depths <2000 m are mapped. Locations: (a) Madagascar Plateau, (b) Southwest Indian Ridge, (c) Amsterdam Fracture Zone.

VME indicator mapping

Depth

In the absence of maps of VMEs, depth is a suitable coarse-scale indicator for mapping at ocean basin scale because it is the strongest environmental correlate of community structure in deep marine environments (e.g. Ponder et al., 2002; Carney et al. 2005; Last et al., 2005; Clark et al. 2010). The factors governing evolution of biota are temporally evolving, depth-related processes (e.g., depth-layering of water masses), contemporaneous physiological constraints on species depth distributions, and depth-related differentiation in habitat distribution defined by geophysical constraints (Last et al. 2010). Thus, many taxa characterising VMEs are restricted to particular depth zones (bathomes), with large invertebrate benthic fauna typically most diverse and most abundant within a ‘zone of importance’ in depths <1500 m (Williams et al. 2009), including on seamounts and in submarine canyons. For example, demosponges exist in depths <1000 m (Williams et al. 2010), while the dominant mesh building stony coral (*Solenosmilia variabilis*) exists in depths <1400 m (Clark et al. 2010). A circum-global band between 20º-50º S of very high habitat suitability (>50%) for seamount stony corals at depths between 0-750 m and moderate suitability (~30%) at depths <1500 m was predicted by Tittensor et al. (2009) this was confirmed by recently by more fine-scale analyses of Davies and Guinotte (2011).

Mapping of bathomes (Figure 3.1.1.1) showed that only 0.8% of the SIOFA Area overlies the band of high habitat suitability for VME fauna (depths <1500 m) (Table 3.1.1.1). Thus, depth-related surrogacy for VME fauna is better captured by our bathomes (0-200 m, 200-700 m, 700-1000 m, 1000-1500 m, 1500-2000 m and >2000 m) compared to those recommended by Clark (2008; SPRFMO 2009) (0-200 m, 200-800 m, 800-2000 m, >2000 m) because they more precisely represent ecological structure.

Seamounts

At a finer spatial scale than bathomes, maps of topographical or hydrophysical features have high potential to define VME distributions. However, it is important to understand that data sets of geomorphic features for the vast expanses of high seas areas and the deep ocean have been collated only recently and that they are still evolving. At this point in time there is only broad-scale mapping for seamounts. Other features identified by FAO (FAO 2008) as potentially supporting VMEs (submarine canyons and trenches, hydrothermal and cold seeps) are incompletely mapped at ocean basin scale and/or their surrogate potential has not been validated.

The first freely available, detailed global map and dataset for seamounts (defined by elevation of ≥1000 m) was produced in 2004 by Kitchingman and Lai (2004) under the *Sea Around Us* Project (http://www.seaaroundus.org). Subsequent compilations that added lists of unpublished/ grey literature data sets, and/or applied finer scale bathymetry data were those of Hillier and Watts (2007) and Allain et al. (2008). In 2010, the Census of Marine Life Seamounts Program (CenSeam) completed a compilation of a global dataset of seamount point locations with summit depths and other ancillary data from nine datasets (Kitchingman and Lai 2004; Hillier and Watts 2007; Rowden et al. 2008; Allain et al. 2008; CSIRO, Hobart - unpublished 2009; SeamountCatalog http://earthref.org; Seamounts Online http://seamount.sdsc.edu, as cited in CenSeam 2010 unpublished). Parallel to this work, Yesson et al. (2011) produced and published a new data set of ‘seamounts’ using global bathymetry at 30 arc-sec resolution. A brief comparison of these two contemporary datasets (provided above) indicated the Yesson et al. (2011) dataset is better suited to an overlap analysis of fishing effort for the reasons outlined in the 'Spatial dependencies' section above.

Yesson et al. (2011) used a geological definition to separately recognise large seamounts (with elevation ≥1000 m) and small knolls. There is no difference between large seamounts and smaller knolls in their potential suitability to support VMEs – the critical element is the depth range they occupy, not total elevation (Williams et al. 2009). For this reason we combine both feature types under the term 'seamount' in later sections of this report unless otherwise specified.

We estimated a total 13,529 seamounts lie within the SIOFA Area (Table 4.1.4.1). Using geological definitions, 2,262 are large seamounts (>1000 m elevation) and 11,267 are smaller knolls (Yesson et al. 2011). Virtually all knolls (97%) and 78% of the seamounts peak below 2000 m. By combining all seamount and knoll polygons identified by Yesson e al. (2011) into one flat (planar) polygon area, we estimated the total fraction of the SIOFA Area that is occupied by seamounts at over six million square-kilometres – 22% of the SIOFA Area.

Only 372 seamounts (3% of total) have reported summit depths in the key bathomes for VME fauna – the zone of importance (<1500 m; Table 4.1.4.1); these contribute ~1% to the total planar area of seamounts. In total, 13% of bathomes in <1500 m in the SIOFA Area are classified as part of seamounts. In this report we refer to these shallow seamounts as 'potential VME seamounts' to differentiate them from the vast majority of seamounts peaking in depths >1500 m, and beyond the depths at which fishing, and therefore fishing impact, may occur (>2000 m; Table 4.1.4.1).

Within the fishable depth range (<2000 m) a total of 830 (6%) seamounts are identified; these contribute ~6% to the total planar area of seamounts, but more than half (458, 55%) peak below the zone of importance. In total, 32% of bathomes in <2000 m in the SIOFA Area are classified as part of seamounts. The key sub-areas used for fishing ('fishing grounds', see Section 3.1.3) encompass a disproportionally higher number of potential VME seamounts – 259, 70% of the total number and 81% of the planar area in the SIOFA Area (Table 4.1.4.1); 14 of these are contained within BPAs (see Section 3.1.4). In total, 21 (6%) of the potential VME seamounts (7% by area) are in the BPAs in the SIOFA Area (Table 4.1.4.1).

Table 4.1.4.1 Planar areas and (in km^2) and number of seamount features (seamounts + knolls) reported by Yesson et al. (2011) in the key bathomes for VME fauna (<1500 m), in fishable depths (<2000 m), and in ecologically meaningful bathomes (*sensu* Last et al. 2010) over the SIOFA Area fishing grounds and BPAs. Bathomes were assigned to areas by intersecting the combined Yesson et al. (2001) polygons with the GEBCO bathymetry; for counts Yesson et al.'s (2001) summit depth was used.

	Potential VME 1-1500m		Fishable depth 1-2000m		Shelf 1-200m		Shallow upper 201-700m		Deep upper 701-1000m		Shallow mid-1001-1500m		Deep mid-slope 1501-2000m		>2000m	
	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.
Total in SIOFA Area	59,045	372	147,386	830	1,023	30	5,744	65	10,833	76	41,444	201	88,341	458	5,878,361	12699
Total in fishing grounds	47,683	259	108,626	444	601	20	5,245	43	9,656	57	32,180	139	60,942	185	752,441	951
Total in Benthic Protection Areas	4,212	21	11,647	65	169	1	762	4	570	4	2,710	12	7,435	44	95,594	150
Overlay by fishing grounds																
Ninety East Ridge	3,616	22	11,346	41	48	3	167	0	303	6	3,098	13	7,730	19	94,577	115
Broken Ridge	6,222	32	14,038	50	-	0	437	5	1,301	9	4,484	18	7,817	18	82,282	99
Amsterdam Fracture Zone	5,574	41	9,866	51	-	0	370	13	833	11	4,371	17	4,291	10	107,362	136
Madagascar Plateau - North	184	4	500	6	-	0	20	0	38	1	126	3	316	2	3,842	3
Madagascar Plateau - East	8,188	20	11,416	22	264	10	1,821	6	1,592	3	4,510	1	3,228	2	15,456	18
Madagascar Plateau - South	12,193	27	20,263	36	169	1	1,536	7	3,866	10	6,622	9	8,070	9	85,553	114
Southwest Indian Ridge - East	3,024	35	10,340	85	39	3	334	5	511	4	2,140	23	7,316	50	183,260	263
Southwest Indian Ridge - Central	3,008	43	15,859	84	6	1	55	1	291	6	2,655	35	12,852	41	118,312	153
Southwest Indian Ridge - West	5,676	35	14,997	69	75	2	505	6	922	7	4,175	20	9,322	34	61,795	50
Overlay by BPA*																
East Broken Ridge	151	2	279	2	-	0	35	1	36	0	80	1	128	0	2,897	5
Gulden Draak	1,075	4	2,649	4	-	0	-	0	-	1	1,075	3	1,574	0	382	0
Fools Flat	188	1	256	1	-	0	-	1	53	0	135	0	68	0	196	0
Rusky	2	0	3	0	-	0	-	0	-	0	2	0	1	0	-	0
Mid-Indian Ridge	-	0	1,481	23	-	0	-	0	-	0	-	0	1,481	23	75,601	129
Atlantis Bank	115	4	436	7	-	0	1	1	34	1	80	2	321	3	6,308	11
Bridle	146	2	1,366	6	-	0	-	0	-	0	146	2	1,219	4	2,252	1
Coral	478	4	1,965	15	-	0	62	1	62	0	355	3	1,487	11	5,977	3
South Indian Ridge	989	3	2,144	6	-	0	-	0	152	2	837	1	1,155	3	1,981	1
Walters Shoal	1,066	1	1,066	1	169	1	664	0	233	0	-	0	-	0	-	0

* Aghula's Plateau is not within the SIOFA Area boundary

Map and overlay of fishing effort on VME distribution

In overview, Australian fishing effort (combined for all gears) in the SIOFA Area from 1999-2009 overlays 5% of the total fishable area (<2000 m) when mapped at fine-scale (0.1º) (Table 4.1.4.2a). Fishing effort on the upper continental slope (shallow and deep) and mid-continental slope (200-1500 m) translated into areal overlaps of >6% and up to 15% of the bathome (Table 4.1.4.2a). At the 20' resolution of the Australian footprint, fishing by Australian vessels is permitted in 16% of the total fishable area (<2000 m), including 45% of the deep upper slope bathome (Table 4.1.4.2a).

In total, 129 (35%) of the 372 potential VME seamounts (Table 4.1.4.2c) which contribute 18% to the total area of seamounts in depths <1500 m, lay under the fine-scale (0.1º) Australian effort distribution (combined for all gears) from 1999-2009 (Table 4.1.4.2b). The Australian 20' footprint overlays 167 (45%) of the 'potential VME seamounts' (Table 4.1.4.2c) which contribute 34% to the total area of seamounts in depths <1500 m (Table 4.1.4.2b).

Table 4.1.4.2 Overlap of the Australian footprint and fishing effort distribution (total areas in km^2) for all gears combined in the SIOFA Area between 1999 and 2009 in relation to VME indicators – (a) the total area of ecologically meaningful bathomes and (b) areas classified as seamount and (c) the number of individual seamounts. Overlap is calculated at the indicated grid resolution for areas and at operation resolution for counts of seamount. Percentages in each row relate to the respective total in the SIOFA Area given in the first column.

Bathome	Bathome name	Total in SIOFA Area	Australian footprint (20' resolution)		Australian effort distribution (0.1° resolution	
a) Total areas		**Area**	**Area**	**%**	**Area**	**%**
1-2000m	Fishable depth	466,049	74,824	16	24,184	5
1-200m	Shelf	37,402	272	1	213	1
201-700m	Shallow upper slope	32,101	2,773	9	1,803	6
701-1000m	Deep upper slope	25,133	11,307	45	3,876	15
1001-1500m	Shallow mid-slope	110,781	26,677	24	10,485	9
1501-2000m	Deep mid-slope	260,633	33,795	13	7,807	3
>2000m		26,414,597	151,074	1	12,219	<0.1
b) Areas classified as seamounts		**Area**	**Area**	**%**	**Area**	**%**
1-1500m	Potential VME seamounts	59,045	19,917	34	10,585	18
1-200m	Shelf	1,023	154	15	109	11
201-700m	Shallow upper slope	5,744	2,158	38	1,389	24
701-1000m	Deep upper slope	10,833	5,028	46	2,506	23
1001-1500m	Shallow mid-slope	41,444	12,577	30	6,581	16
1501-2000m	Deep mid-slope	88,341	16,446	19	4,876	6
>2000m		5,878,361	58,295	1	6,699	<0.1
c) Number of seamounts		**Count**	**Count**	**%**	**Count**	**%**
1-1500m	Potential VME seamounts	372	167	45	129	35
1-200m	Shelf	30	9	30	8	27
201-700m	Shallow upper slope	65	36	55	36	55
701-1000m	Deep upper slope	76	42	55	35	46
1001-1500m	Shallow mid-slope	201	80	40	50	25
1501-2000m	Deep mid-slope	458	73	16	15	3
>2000m		12699	130	1	17	<0.1

At a higher level of resolution, the distribution of Australian fishing effort was thematically mapped, graded by the fishing effort intensity (all gears combined) per 20' block into three categories: light (<3 operations), moderate (3-50 operations) and heavy (>50 operations), following the New Zealand and Australian BIFAs for the SPRFMO Area (MFish 2008; Williams et al. 2011) (Figure 4.1.4.3). However, note that Australia's mapping groups all gears and uses different (longer) time frames. We also mapped the effort distribution at 0.1° grids for each gear separately to provide a more detailed analysis of fishing effort distribution over the ecologically meaningful bathomes (*sensu* Last et al. 2010) identified in Section 3.1, as well as in relation to the seamounts (Yesson et al. 2011) described in Section 4.2.2.

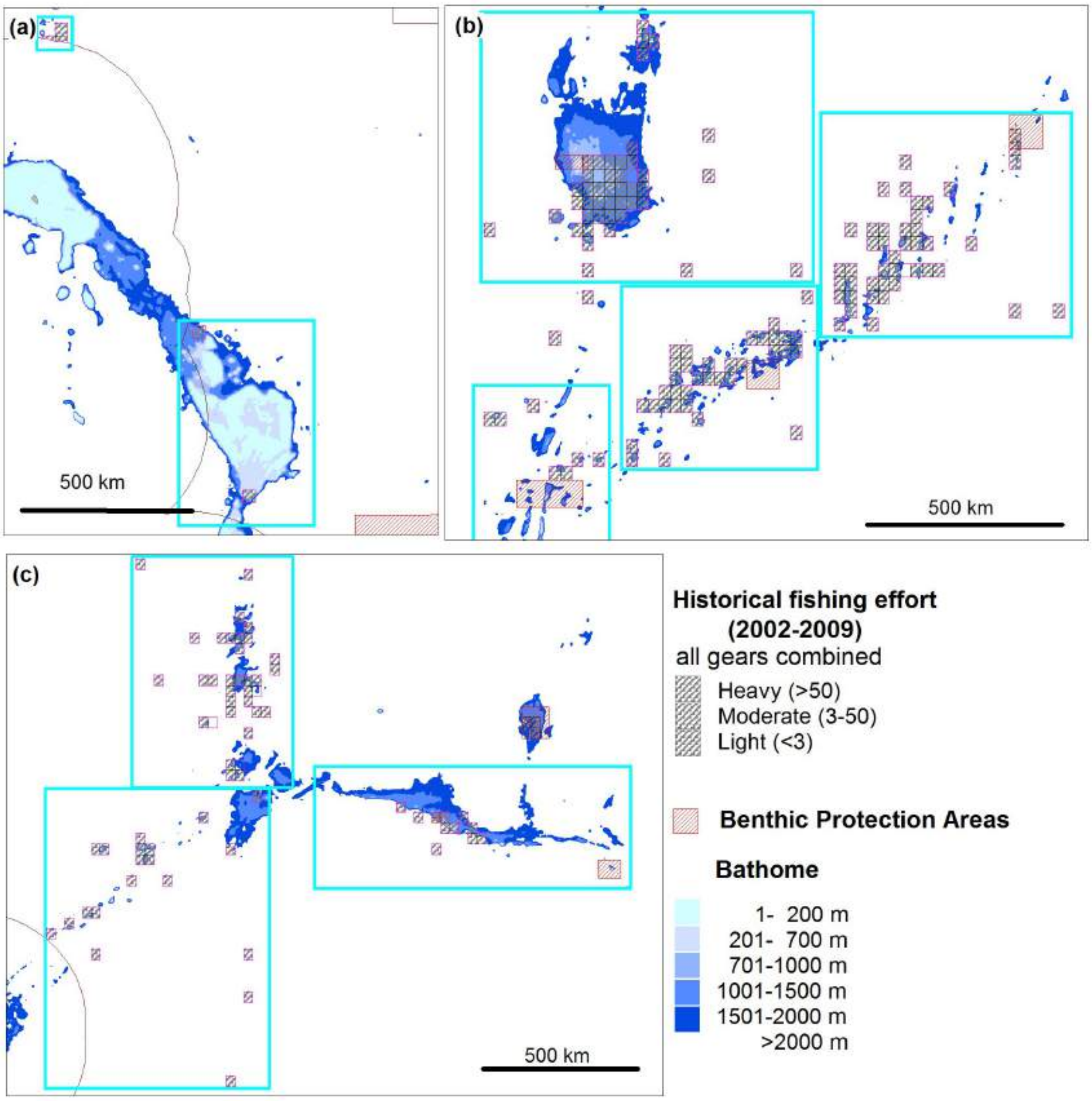

Figure 4.1.4.3 Australian fishing effort distribution and intensity (number of operations) in 20' blocks (masked due to commercial in-confidence rules). (a) Northeast of Madagascar, (b) Madagascar Plateau and Southwest Indian Ridge, (c) Broken Ridge region. SIOFA Area boundary: brown line; Australian footprint: pink outlines; fishing grounds: light blue rectangles.

Demersal trawl

Between 1999 and 2009, a total of 2981 demersal trawl operations was reported in the SIOFA Area by Australian operators. The total historical demersal trawl effort distribution (0.1º grid cells) was ~31,200 km^2, but as proportions of each bathome, all overlaps were <15%. Demersal trawling was negligible on the continental shelf (Table 4.1.4.3) but relatively high on the upper continental slope (shallow and deep) and mid-continental slope (200-1500m) where there were areal overlaps of 4.8%, 14.1% and 8.2% respectively. The overlaps were low in deeper bathomes, although the footprint in depths >2000 m appeared to be relatively large. The trawl effort in depths >2000 m is an artefact of the spatial resolution of the data (Table 4.1.4.3) because demersal trawling does not take place at these depths.

The area overlap of demersal trawl effort with seamounts was between 11 and 21% in the shallowest four bathomes <1500 m. Of the 372 potential VME seamounts in the SIOFA Area, 121 (33%) were fished at least once by Australian demersal trawls from 1999-2009 (Table 4.1.4.3). Another fourteen seamounts with peaks in fishable depths (<2000 m) and nine deeper ones are reported under Australian demersal trawl operations. Seamounts peaking in the upper slope were relatively heavily targeted – 51% and 43% of those peaking in shallow and deep upper slope depths respectively).

Table 4.1.4.3 Distribution and overlap of the Australian demersal trawl effort (number of reported operations and total areas in km^2) in the SIOFA Area between 1999 and 2009 in relation to VME indicators (ecologically meaningful bathomes and seamounts). Depth distribution of operations uses the reported fishing depth; overlap is calculated at 0.1º resolution for areas and at operation resolution for seamount counts and shown as % of total areas of bathomes and total areas and numbers of seamounts by bathome in the SIOFA Area.

			distribution (0.1º resolution)		Australian effort distribution on Seamounts (0.1º resolution)		(by operation)	
Bathome	**Name**	**No. ops. Reported**	**Area**	**%**	**Area**	**%**	**No.**	**%**
No depth reported		33						
0-200 m	Shelf	12	213	0.6	109	10.6	8	26.7
200-700 m	Shallow upper slope	317	1,519	4.7	1,105	19.2	33	50.8
700-1000 m	Deep upper slope	1646	3,528	14.0	2,264	20.9	33	43.4
1000-1500 m	Shallow mid-slope	970	9,123	8.2	5,734	13.8	47	23.4
1500-2000 m	Deep mid-slope	3	6,872	2.6	4,471	5.1	14	3.1
>2000 m			7,756	0.0	4,865	0.1	9	0.1
TOTAL in SIOFA Area		2981	29,011	0.1	18,547	0.3	144	1.1

Demersal trawling was concentrated on seamount peaks in selected areas; the effort between 1999-2009 in the 201 20'blocks of the permit area was heavy (>50 tows) in 17 blocks, moderate in 69 blocks and light in 70 blocks; no demersal trawling was reported in 45 of the 20' blocks. Before the BPAs were established, 18 demersal trawl operations were reported in subsequently closed areas; these operations were spread over four lightly fished blocks which are excluded from the Australian permit footprint (three in Gulden Draak, one in Atlantis Bank) and part of one moderately fished block (Rusky) (Figure 4.1.4.3).

Midwater trawl

Between 1999 and 2009, 1829 midwater trawl operations were reported in the SIOFA Area. The total historical midwater trawl effort distribution was ~19,700 km^2 but, as proportions of each bathome, all overlaps were <9%. Midwater trawling was negligible on the continental shelf (Table 4.1.4.4). On the upper continental slope (shallow and deep) and shallow mid-continental slope (200-1500 m), midwater trawl effort was larger, translating into areal overlaps between

3.3 and 8.8. The overlaps were low in deeper bathomes, although the footprint in depths >2000 m appeared to be relatively large. The midwater trawl effort in depths >2000 m is an artefact of the spatial resolution of the data rather than targeted fishing in these depths (Table 4.1.4.4). In addition, the reported depths may be gear depth rather than bottom depth.

Area overlap of midwater trawl effort with seamounts was between two and 17% in the shallowest four bathomes <1500 m. Of the 372 potential VME seamounts in the SIOFA Area, 98 (26%) were fished at least once by Australian midwater trawls from 1999-2009 (Table 4.1.4.4). Another eight seamounts each, with peaks in fishable depths (<2000 m) and seven beyond 2000 m, are reported under the Australian midwater trawl operations. Seamounts peaking in the upper slope were particularly targeted (45% and 43% for the shallow and deep upper slope respectively).

Table 4.1.4.4 Distribution and overlap of the Australian midwater trawl effort (number of reported operations and total areas) in the SIOFA Area between 1999 and 2009 in relation to VME indicators (ecologically meaningful bathomes and seamounts). Depth distribution of operations uses the reported fishing depth; overlap is calculated at 0.1° resolution for areas and at operation resolution for seamount counts and shown as % of total areas of bathomes and total areas and numbers of seamounts by bathome in the SIOFA Area.

			distribution		Australian effort distribution on Seamounts			
		No. ops.	(0.1° resolution)		(0.1° resolution)		(by operation)	
Bathome	**Name**	**Reported**	**Area**	**%**	**Area**	**%**	**No.**	**%**
No depth reported		17						
0-200 m	Shelf	40	41	0.1	29	2.9	6	20.0
200-700 m	Shallow upper slope	859	1,065	3.3	957	16.7	29	44.6
700-1000 m	Deep upper slope	903	2,212	8.8	1,356	12.5	33	43.4
1000-1500 m	Shallow mid-slope	10	5,270	4.8	3,752	9.1	30	14.9
1500-2000 m	Deep mid-slope		3,241	1.2	2,456	2.8	8	1.7
>2000 m			6,451	0.0	3,484	0.1	7	0.1
TOTAL in SIOFA Area		1829	18,281	0.1	12,034	0.2	113	0.8

The overall distribution of midwater trawl effort within the SIOFA Area was similar to demersal trawl, although the high effort was directed at only 9 of the 20’ blocks (4 of which also had high demersal trawl effort, the remaining 5 had moderate demersal trawl effort). Moderate midwater trawl effort in 1999-2009 was reported from 45 20’ blocks, light from 53 and no midwater trawling was reported in 94. Before the BPAs were established, ten midwater trawl operations were reported in subsequently closed areas; these operations were spread over one lightly fished block in (Atlantis Bank) and part of one moderately fished block (Rusky)) (Figure 4.1.4.3).

Line Methods

Demersal line methods were infrequently used in the SIOFA Area between 1999 and 2009; 11 demersal line operations were reported. The total historical line effort distribution was ~800 km^2 and the proportions of overlap were $\leq$0.5% in each bathome, mainly on the upper slope (Table 4.1.4.5). The demersal line effort in depths >2000 m is an artefact of the spatial resolution of the data rather than targeted fishing in these depths (Table 4.1.4.5).

Area overlap of demersal trawl effort with seamounts was less than three percent in each of the shallowest four bathomes <1500 m. Of the 372 potential VME seamounts in the SIOFA Area, eight (2%) were fished at least once by Australian demersal lines from 1999-2009 (Table 4.1.4.5). Only potential VME seamounts were fished with this method, with particular focus on seamounts peaking in shelf depths (13%).

Table 4.1.4.5 Distribution and overlap of the Australian demersal line effort (number of reported operations and total areas) in the SIOFA Area between 1999 and 2009 in relation to VME indicators (ecologically meaningful bathomes and seamounts). Depth distribution of operations uses the reported fishing depth; overlap is calculated at 0.1° resolution for areas and at operation resolution for seamount counts and shown as % of total areas of bathomes and total areas and numbers of seamounts by bahome in the SIOFA Area.

			distribution (0.1° resolution)		Australian effort distribution (0.1° resolution)		on Seamounts (by operation)	
Bathome	Name	No. ops. Reported	Area	%	Area	%	No.	%
No depth reported		1						
0-200 m	Shelf		25	0.1	25	2.4	4	13.3
200-700 m	Shallow upper slope	9	161	0.5	161	2.8	1	1.5
700-1000 m	Deep upper slope	1	92	0.4	92	0.8	1	1.3
1000-1500 m	Shallow mid-slope		141	0.1	141	0.3	2	1.0
1500-2000 m	Deep mid-slope		132	0.1	132	0.1		
>2000 m			146	<0.01	146	<0.01		
TOTAL in SIOFA Area		11	697	<0.01	697	0.0	8	0.1

Demersal line operations targeted a total of three of the 20’ blocks in one of the fishing grounds; the number of operations did not exceed 50 in any of these blocks. No demersal line operations were reported from the BPAs.

4.1.5 Evidence of VMEs

Scientific survey results

The southern Indian Ocean is one of the least sampled regions of the global ocean (Rogers et al. 2007) and there is a commensurately scarce knowledge of its biodiversity and ecosystems. This knowledge gap has reduced to some extent in recent years. For example, we are aware of scientific surveys collecting data from the SIOFA Area as recently as 2010 (e.g. Rogers, Lambshead and Hughes proposed a scientific survey of the “benthic biodiversity of seamounts in the southwest Indian Ocean” in 2010 – document obtained from the internet through Google). It is outside the scope of this report to review the latest data. Some of the scientific data collected in the SIOFA prior to 2006, is summarised by Shotton (2006) in relation to the BPAs.

Summary of observer data

Compulsory observer coverage of 100% of trawl operations and ~10% of line operations (and all other gears) came into effect with permits issued in 2008. However, vessels often fished in the SIOFA Area on transit to the Australian HIMI Fishery. The observer program in HIMI was commenced before the implementation of the HIMI Management plan in 2002. Thus, AFMA observers who were trained by the AAD for data collection in HIMI Fisheries, were often onboard ships fishing in the high seas within the SIOFA Area, collecting data in the AAD developed ‘Fishlog’ observer database using the HIMI observer protocols and identification guides (Hibberd and Moore 2009; Parker et al. 2009c). Detailed observer data from 20 trips of 2 vessels (1762 trawl hauls) between 1999 and 2010 were available electronically; for the time period of 1999-2009 a total of 1458 (30%) of the 4810 trawl hauls recorded in logbooks were observed and bycatch was recorded in ‘Fishlog’ databases. In addition, the Australian fishing company fishing in SIOFA voluntarily carried independent observers from the beginning of fishing in the Indian Ocean; data from that work are available from the fishing company for additional future analyses, but were not included in this BFIA.

All observed trawl hauls from the Fishlog data bases were assigned to the trawl strata based on the reported target species: 983 demersal trawls targeting orange roughey, oreos boarfish and blue-eye trevalla, and 779 midwater trawls targeting alfonsino or black cardinal fish (Table 4.1.5.1). Benthic invertebrate bycatch, including sponges, corals, anemones, crustaceans, molluscs, echinoderms and tunicates, was reported for 50% of the demersal trawls and for only 3% of midwater trawls. Between 1999 and 2010, 21 (2%) of the observed demersal trawl hauls and none of the midwater trawls caught more than 50 kg combined weight of sponges and corals (Table 4.1.5.1). Using the ‘evidence of VMEs’ scoring system which includes a diversity trigger (Parker et al. 2009a – *hereafter referred to as the New Zealand scoring system*), as implemented by New Zealand in the SPRFMO Area, 38 (4%) demersal trawl hauls reached a score of ≥3, which is considered ‘evidence of VME’ in the New Zealand scoring system. An additional 177 (18%) demersal trawl catches scored 2 or 1 in this system (Table 4.1.5.1). The highest score reached by midwater trawls was 1 (Table 4.1.5.1).

Table 4.1.5.1 Summary of the available data collected by AFMA observers aboard two vessels fishing in the SIOFA between 1999 and 2010, using HIMI protocols. The number of hauls with and without benthic invertebrate bycatch is given. Hauls with benthic invertebrate bycatch were classified using a value of 50 kg combined coral and sponge catch, as well as using the New Zealand scoring system for ‘evidence of VME’ (Parker et al. 2009a).

Year	Total observed hauls	% of hauls in logbook	No benthic invertebrate bycatch	Benthic invertebrate bycatch recorded	> 50kg coral and/or sponge bycatch	NZ evidence of VME scoring system						
						Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7
Demersal Trawl												
1999	118	30	63	55	3	7			3			
2000	133	54	55	78		30	12	1	1	1	1	
2001		0										
2002	1	0	1									
2003	178	51	107	71	2	10			2	2		
2004	192	30	70	122	13	33	7	3	14	1		1
2005	141	40	47	94	1	48	9	1	3			
2006		0										
2007												
2008	5		5									
2009	10	5	5	5	1	2			2		1	
2010	205	103	142	63	1	17	2		1			
Grand Total	983	31	495	488	21	147	30	5	26	4	2	1
Midwater Trawl												
1999		0										
2000	60	40	56	4		2						
2001		0										
2002	20	5	20									
2003	78	36	78									
2004	216	49	216									
2005	90	48	90									
2006	67	69	66	1								
2007	89	56	88	1								
2008	34	43	34									
2009	26	40	21	5		1						
2010	99	150	85	14		4						
Grand Total	779	41	754	25	0	7	0	0	0	0	0	0

In 2009 observers reported catches of benthos in excess of 50 kg for eight operations, however, the trigger for move-on action was 100 kg in that year (Table 4.1.5.2). These data were not included in the above table because they were all from fishing trips where the ’Fishlog’ database was not available and thus the data was not easily converted into the same electronic format. In total, 153 trawl operations were completed – 64 midwater and 89 demersal trawls. On two of the 8 occasions the benthos was mostly volcanic rocks (and 0.001 kg of gold coral in one of the two operations); on the other 6 occasions, stony corals and glass sponges made up a large proportion of the benthos (Table 4.1.5.2).

Table 4.1.5.2 Records for 8 operations where the observer reported substantial catches of epibenthos, giving details of observed taxa and weights (kg)

volcanic rock	limestone rock	soft coral (gorgonian)	black coral	stony coral	sponge	TOTAL VME taxa	Location of trigger action
	70			450		450.0	"904"
	15	1.42		209	2.24	212.7	Blob
		1	199			200.0	Austral Alp
				>177		177.0	no action
			0.8	50	21	71.8	no action
		0.5	0.5	25	25	51.0	no action
>100		0.001				<0.1	no action
>100						0.0	no action

'Evidence of VMEs' (both using >50 kg corals and/or sponges (current Australian permits), and the New Zealand scoring system) was proportionally greater on the seamounts of the Southwest Indian Ridge than on the Madagascar Plateau (Table 4.1.5.3). On the Ninety East Ridge and Amsterdam Fracture Zone, most of the observed operations used midwater trawling which did not yield any evidence of VMEs (Table 4.1.5.3).

Table 4.1.5.3 Distribution of the observed trawl operations by fishing grounds of the SIOFA Area. The total number of hauls and the number of operations with benthic invertebrate bycatch is given. Hauls with benthic invertebrate bycatch were > 50 kg of coral and sponges, as well as the NZ scoring system for 'evidence of VME' (Parker et al. 2009a).

Fishing ground	Total observed operations	Demersal trawls	Benthic invertebrate by-catch	> 50kg coral and/or sponge bycatch	NZ evidence of VME scoring system	
					score 1 or 2	score ≥3
Madagascar Plateau - North	0	0				
Madagascar Plateau - East	0	0				
Madagascar Plateau - South	382	328	115	0	58	2
Southwest Indian Ridge - East	366	265	178	11	57	16
Southwest Indian Ridge - Central	352	337	207	10	67	19
Southwest Indian Ridge - West	3	3	0			
Ninety East Ridge	521	5	4	0	0	0
Amsterdam Fracture Zone	134	35	9	0	2	1
Broken Ridge	4	0	0			

History of trigger actions

Three occurrences of move-on action were recorded in the SIOFA Area in 2009, based on >100 kg bycatch of sponges and corals (see Table 4.1.5.2). These three occasions were all reported from the Southwest Indian Ridge (Figure 4.1.5.1) where observers had previously recorded benthic invertebrate bycatch (see Section 4.3.2 Table 4.1.5.3). In one of these move-on locations, observers recorded sponge and coral catches of >50 kg for several operations in 2004. Two of the 20' cells where triggers were reported had >50 trawl operations reported between 2002-2009, the third had 41 trawl operations reported for that time period. In addition, observer data prior to 2002, and reports by the Australian fishing industry, indicate that all three areas have been heavily fished by Australian and other vessels.

The three 5 n.m. radius move-on closures put in place during the life of the 2009 permits were reopened for fishing in 2010 and 2011 permits.

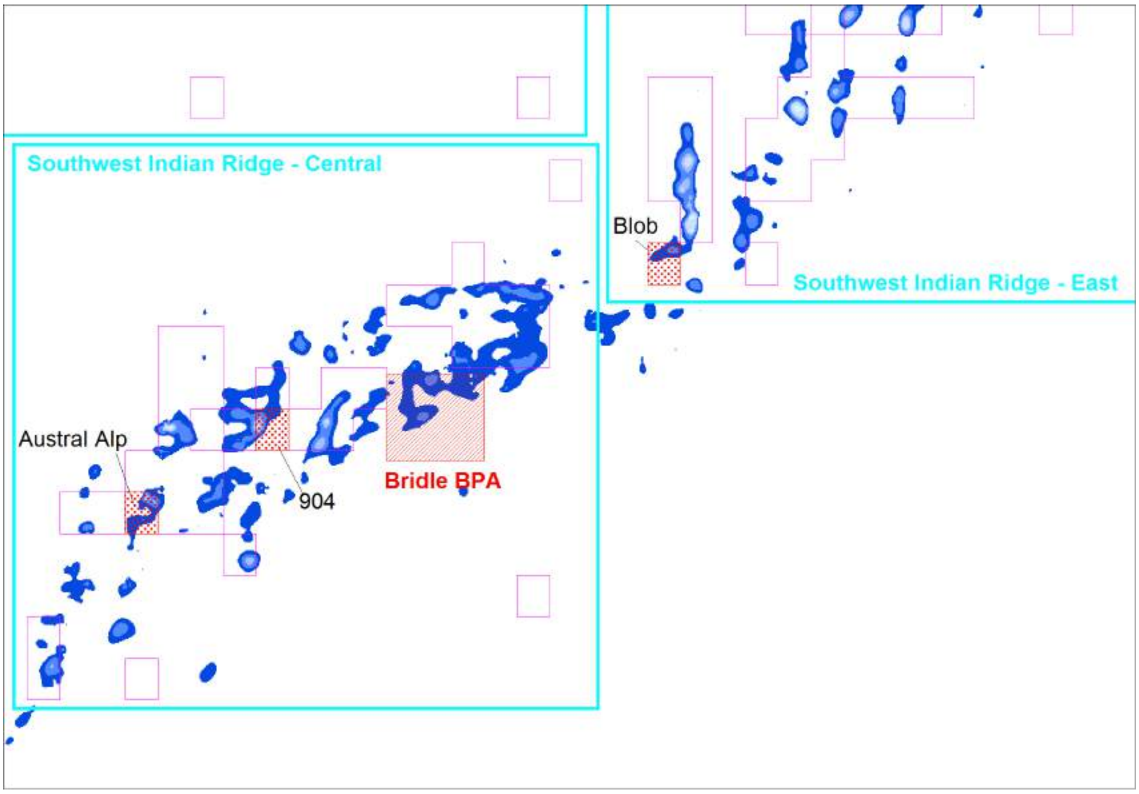

Figure 4.1.5.1 Reported locations (as 20' blocks – red dotted) of catches with VME fauna >100 kg in 2009 resulting in the implementation of the move-on rule; Australian footprint: pink outlines; fishing grounds: light blue outlines; BPA: red hashed..

Australian effort in areas with VME evidence

The southern Indian Ocean is potentially one of the most favourable habitats for cold-water corals in the world, especially to depths of around 1500 m (Tittensor et al. 2009). Many seamounts peak above this depth along the major ridges in the SIOFA Area, and the Australian fishing effort is also concentrated along those ridges (see Section 3.1.3). On the other hand, the voluntary BPAs implemented by the SIODFA are protecting some seamount features within the fishing grounds, along those same ridges (Sections 3.1.3, 3.1.4 and 4.2.2). Corals and other VME taxa were reported from Coral, Atlantis Bank, Rusky and Walters Shoal BPAs (Shotton 2006); their presence was inferred on Fools Flat (Shotton 2006) and, given the described topography and depth ranges, as well as recent fine-scale modelling results from Davies and Guinotte (2011), likely to occur in the other BPAs.

Catches of epibenthic organisms classed as VME taxa – corals, sponges and selected hydrocorals and echinoderms (Tracey et al. 2007) were reported in the Australian observer data from several locations on the central and northeastern part of Southwest Indian Ridge, few on the Madagascar Plateau (south) and only one location on the Amsterdam Fracture zone. Since the move-on rule was enforced in the Australian permit conditions, three locations, two in the Southwest Indian Ridge central and one in the Southwest Indian Ridge east fishing grounds, were identified where catches of sponges and corals exceeded 100 kg (Section 4.3.3 – Figure 4.1.5.1). Data collected by observers between 1999 and 2010 indicated that 21 demersal trawl operations yielded >50 kg of sponge and coral (Section 3.3.2 – Table 4.1.5.3), these catches were concentrated in eight locations (i.e. eight peaks) in the same two fishing grounds: the three reported trigger locations and five additional features in each ground. If the New Zealand scoring scheme had been used to identify 'evidence of VMEs' three more locations would have been identified: two on the Madagascar Plateau (south) and one on the Amsterdam Fracture Zone. However most of these locations are in 'heavily fished' blocks (>50 operations between

1999-2009), which in the spatially tiered system of closures and fishing areas of the New Zealand management approach in the SPRFMO Area would be considered 'open' and not subject to move-on rules (MFish 2008; Penney et al. 2009).

Incidental mortality of Threatened, Endangered and Protected species:

Logbook data from 1999 to 2009 and observer reports from 2007-2011 recorded no interactions with any threatened or endangered species (as defined under Australian law) or seabirds (protected under Australian law) in the SIOFA Area.

4.2 Risk assessment

4.2.1 Context to impact and risk assessment frameworks for VMEs

An assessment of risk to an asset by a potentially threatening process (or 'hazard'), e.g. the risk of a SAI by bottom fishing on VMEs, needs to take account of the potential impact of each threatening process, the asset's vulnerability, the effect of impacts on the asset, past and future exposure of the asset to the threat, and the cumulative effects of impacts through time and space (the balance between continued impact, recovery and mitigation). 'Residual risk' is the risk of effects from continuing exposure after management and mitigation measures are accounted for. Useful summaries of these concepts in the context of VMEs, and the distinctions between impact assessment and risk assessment, are provided by Sharp et al. (2009), Martin-Smith (2009) and Hobday et al. (2011).

The draft BFIAS provided by the SPRFMO SWG (SPRFMO 2009) is a template for this evaluation of Australian vessels in the SIOFA Area. Although termed an 'impact' assessment, the BFIAS specifies that elements of risk, management and mitigation are also considered.

It is not possible to consider ecological risk for VMEs of high seas areas in a quantitative way due to several key uncertainties in the data (Section 4.1.4, 'Spatial dependencies'), and the absence of key data on cumulative impacts. A full ecological risk assessment for VMEs in high seas areas, and the development of risk management frameworks, will ultimately need to account for the potential cumulative effects across different fishing gears, across Flag States, and across other threatening processes – deep sea mining, hydrocarbon extraction, pollution, ocean acidification and others (Glover and Smith 2003).

4.2.2 The BFIAS and alternative approaches

The draft BFIAS provided by the SPRFMO SWG (SPRFMO 2009) used for the BFIA of Australian vessels in the SIOFA Area identifies the risk being determined as the risk of not achieving the stated objective – that there is no SAI from bottom fishing on VMEs. In this context, no SAI on VMEs means, 'no impacts which compromise ecosystem integrity in a manner that impairs the ability of affected populations to replace themselves and that degrades the long-term natural productivity of habitats, or causes on more than a temporary basis significant loss of species richness, habitat or community types', in the SIOFA Area.

The potentially threatening process being evaluated is the direct impact of fishing gear on the seabed during fishing. Other potential impacts from fishing, e.g. anchoring, effluent discharge are not issues for impact and risk assessment of VMEs in deepwater fisheries.

The BFIAS states, 'the level of risk posed by each activity (hazard) should be assessed in a transparent, scientific manner. Determining the level of risk for each activity should be based on quantifiable criteria where possible. However, it is likely qualitative criteria will be needed due to data gaps, where this is the case, qualitative judgements should be underpinned by quantitative analyses where possible and sufficient documentation should be provided to enable the SWG to determine if the assigned risk levels are appropriate.

In determining the level of risk (low, medium, high) posed by an activity, the elements that should be specifically evaluated are:

1. Intensity – The intensity or severity of the impact at the specific site affected. This may be quantified by previous studies or an expert evaluation of the magnitude of the impact, e.g. None (no detectable impact); Low (some physical damage to some taxa/colonies); Medium (substantial damage to a small proportion of colonies/taxa, or small damage to a large number of taxa at the site, likely to modify biological and ecological processes e.g. reproduction) or High (significant damage to a significant proportion, where environmental functions and processes are significantly altered such that they temporarily or permanently cease).

2. Duration – how long the effects of the impact are likely to last.

3. Spatial extent – The spatial impact relative to the extent of the VMEs (e.g. will fishing impact 5%, 30% or 80% of the VME distribution) and whether there may be offsite impacts (e.g. will reproduction be impacted at a broader spatial scale).

4. Cumulative impact – The frequency of the impact will influence the risk, with activities occurring repeatedly at a site likely to have a greater risk. This will depend on the amount of fishing effort and should be considered in relation to the recovery of the VMEs/taxa.

BFIAS 'overall risk'

The overall risk ranking of an activity is then evaluated from the combination of the criteria used. The method for combining these criteria to assign low, medium or high risk to an activity should be detailed in the assessment report.

<u>Low</u>: Where the impact will have a negligible influence on the environment and no active management or mitigation is required. This would be allocated to impacts of low intensity and duration, but could be allocated to impacts of any intensity, if they occur at a local scale and are of temporary duration.

<u>Medium</u>: Where the impact could have an influence on the environment, which will require active modification of the management approach and / or mitigation. This would be allocated to short to medium-term impacts of moderate intensity, locally to regionally, with possibility of cumulative impact.

<u>High</u>: Where the impact could have a significant negative impact on the environment, such that the activity(ies) causing the impact should not be permitted to proceed without active management and mitigation to reduce risks and impacts to acceptable levels. This would be allocated to impacts of high intensity that are local, but last for longer than 5-20 years, and/or impacts which extend regionally and beyond, with high likelihood of cumulative impact.

The risk assessment should be based on criteria that are independent, such that they provide separate measures of risk. Criteria should also be quantifiable, preferably with the method of quantification and ranking categories determined beforehand.'

Because the BFIAS is yet to be finalised by the SPRFMO SWG, we have adopted the revised draft BFIAS (SPRFMO 2009), and have also considered the approaches used for avoiding SAI on VMEs in the CCAMLR area of competence (Constable and Holt 2007; Martin-Smith 2009; Sharp et al. 2009), the Ecological Risk Assessment for the Effects of Fishing framework used to assess risk within Australian domestic fisheries (Hobday et al. 2011), some relevant scientific literature (key elements of which are summarised in the context of benthic fauna by Parker et al. (2009a) and Williams et al. (2011b), and the BFIA for the New Zealand fisheries (MFish 2008). The key elements of these other studies relevant to this BFIA are discussed below.

The concept underlying our assessment is an exposure-effects framework (Sharp et al. 2009; Williams et al. 2011b) which is better suited to assessing risks posed by ongoing effects, such as fishing impacts on benthos, than likelihood-consequence frameworks (e.g. Martin-Smith 2009). A strength of exposure-effects frameworks is their ability to deal with the spatial and temporal dependencies of many risk elements. Exposure refers to the impact which, because it is not directly measureable, needs to be described in terms of its nature and extent. The effect refers to the ecological consequences of the impact. We note, however, that much of the underlying ecology linking impact to effect and risk remains unknown for deep ocean benthic ecosystems, and ecological responses are affected simultaneously by other environmental and biological influences interacting at a range of spatial and temporal scales (Sharp et al. 2009).

Sharp et al. (2009) provide an operational framework for BFIA in CCAMLR which provides a template to systematically assess impacts in a way that permits comparison of different fisheries and gears, and thereby offers the prospect of estimating cumulative impact. However, despite the considered and detailed calculation of the cumulative spatial extent of effort distribution in the Ross Sea for the history of the New Zealand fishery (total area seabed contacted by longlines), Sharp et al (2009) acknowledge the calculations of cumulative impact on VME organisms are subject to considerable uncertainty. This was primarily due to (1) the unknown relationship between impacted areas and the spatial distribution of VMEs, (2) no knowledge of the ecological consequences of impacts, and (3) untested assumptions about the mobility of longlines during fishing (especially when retrieved). A key problem in assessing cumulative impacts is the likely complex, non-linear relationship between impact and risk, which means that impact is unlikely to be simply additive across sources (Sharp et al. 2009).

The same key uncertainties apply to any framework developed for BFIAs of Australian fishing activities in the SIOFA Area. The poor knowledge of VME distribution at fine scales prevents accurate calculation of spatial overlap of fishing with VMEs. Estimates of overlaps with bathomes (depth zones), as calculated here and by Sharp et al. (2009), will underestimate the degree of interaction with VMEs because (1) VME taxa are not homogeneously distributed within bathomes and are likely to be spatially concentrated, and (2) fishing effort distribution is not independent of VME distribution, i.e. fishery target species are often concentrated at the same finer scale locations as VMEs – e.g. seamount peaks and the heads of submarine canyons (Lorance 2002; Genin 2004; Watson et al. 2007; Rogers et al 2008; Post 2010; Vetter et al. 2010; Section 4.1.4). Resolving the spatial scale of analysis by using seabed topography to indicate where VMEs are more likely to be located can help to reduce this 'VME distributional uncertainty'. However, datasets of topographic features and predictive methods used to infer their suitability for supporting VMEs are also prone to a range of uncertainties including data density and resolution, and scaling issues (Section 4.1.4).

The additional difficulties for this BFIA of Australian vessels in the SIOFA Area are insufficiently resolved effort distribution data to accurately map impact extent (and hence overlap with VME indicators) for the primary fishing gears (longlines and trawls) at finer scales than 0.1º. All data grids are limited to 0.1º spatial resolution and many operational end points are missing – although this resolution will more accurately define overlap than the 20’ standard for footprint analysis.

4.2.3 Framework used for Australian BFIA in the SIOFA Area

The combination of key uncertainties, untested assumptions and coarsely resolved data restricts the value of detailed calculations of bottom contact (e.g. following the method of Sharp et al. 2009) and constrains the opportunities to develop a semi-quantitative assessment framework. The mix of impact and risk elements in the SPRFMO draft BFIAS, and the need to assess both ecological and management risk, have lead us towards developing a predominantly qualitative approach to this assessment. Rankings are substantiated, to the extent possible, with quantitative estimates of particular elements (overlaps of effort and VME indicators). Estimates of our confidence in rankings are provided, and key uncertainties in underlying data are identified. We follow approaches in CCAMLR in seeking to define and quantify as clearly as possible, the nature, extent and spatial distribution of potential impacts by Australian fisheries on VMEs, but without reference to the anticipated ecological consequences to communities or populations – which are largely unknown. Our assessment deals primarily with the potential threat to VMEs from bottom trawl and auto-longline fishing because of the low impact and negligible effort for other gear types.

The term ‘overall risk’ in the BFIAS is used to define the potential risk stemming from the combination of the individual elements of impacts and risk (intensity, duration, spatial extent and cumulative impact) (see Section 4.2.1). In this BFIA we follow Australia’s ERAEF method used to assess and manage risks in its Commonwealth fisheries by also considering the extent to which overall risk is influenced by risk-reducing management measures and other factors including uncertainties. This additional process of assessing the ‘residual risk’ is incorporated within AFMA’s ecological risk management process because it more accurately represents overall risk and helps clarify if/ what further (quantitative) assessment is necessary (e.g. AFMA (2010).

4.3 Assessment of ‘overall risk’

As noted above (Section 4.2.3) overall assessment of risk is mainly qualitative, and in this BFIA accounts for risk reduction by existing management measures. Impact ratings are substantiated, to the extent possible, with semi-quantitative estimates of particular elements (e.g. overlaps of effort and VME indicators to define ‘spatial extent’) and extended as estimates of risk. Estimates of confidence and identification of key uncertainties in underlying data are provided because these also influence the assessment of overall risk (low confidence or higher uncertainty usually equates to higher risk). Key uncertainties indicate priorities for future data collection or analytical methods development.

Risk ratings extend the descriptions of impact to descriptions of exposure by providing context (the magnitude and trend of fishing effort, and whole-of-area measures). Although arbitrary thresholds are used to define risk ratings (Table 4.3.1.2), they provide a more transparent way of assessing SAI than a purely descriptive account of impact. Management, mitigation and monitoring measures also need to be accounted for when analysing risk because they influence (typically reduce) the assessment of overall risk.

While this approach to completing a BFIA does not provide a completely developed framework, it does contain components that can be emulated in BFIAs completed by other Flag States, and potentially included in a ‘whole-of-area’ assessment for the SIOFA Area.

4.3.1 Demersal trawling

The potential impacts of demersal trawling on VMEs evaluated using the four elements of the draft BFIAS are 'potentially high' for intensity, 'long' in terms of their duration, 'low' in spatial extent but with 'definite' cumulative impact (Table 4.3.1.1). The overall risk of significant adverse impact of demersal trawling by Australian vessels in the SIOFA Area, which accounts for potential impact together with the trends in exposure, and existing management, mitigation and monitoring measures, is evaluated as currently low, although with the potential to increase to medium (Table 4.3.1.1).

The low overall risk of SAI accounts for several factors that moderate the risk, particularly the management and mitigation measures applied to Australian vessels, including limits on the amount of fishable seabed available for fishing, an 'evidence of VME' process with validation and move-on provisions, and infrastructure that transparently supports monitoring and compliance. Our evaluation of low overall risk also considers the low exposure of VMEs to fishing impact from Australian vessels because there are few issued permits and only one active Australian trawler.

Low overall risk is qualified with a potential medium rating that reflects the influence of factors that may serve to increase risk if they occur. These include the potential for effort to expand within or beyond the Australian fishing footprint in the future. High levels of uncertainty regarding key aspects of exposure and effect also increases the risk of SAI. Some uncertainties are specific to impacts and risks from demersal trawling, while others are common to all fishing methods (Table 4.3.1.1). The single greatest uncertainty in assessing the risk of significant adverse impact is the lack of knowledge of the activities by other Flag States and unrecorded fishing, which contributes an unknown (but likely relatively large) cumulative impact in space and time (Table 6.1.1).

As required by the draft BFIAS, the rationale for the impact and risk ratings are described below against the identified elements of impact and risk (Table 4.3.1.1), together with a description of the type of resulting impact. Semi-quantitative measures are summarised in Table 4.3.1.2. The key sources of uncertainty influencing the BFIA are documented in Section 6 (see summary Table 6.1.1).

Impact description (What will be affected and how?)

The potential risks of fishing impacts to deepwater benthic fauna, which are adapted to stable and quiescent environmental conditions, are high relative to fauna from shallower depths (Williams et al. 2011b). The potential negative impact of demersal trawls on many VME taxa by degradation or removal of biological and physical habitat is well established (Watling and Norse 1998; Koslow et al. 2001, Hall-Spencer et al. 2002; Clark and Koslow 2007; Althaus et al. 2009; Clark and Rowden 2009). Negative effects of bottom-contact fishing on marine benthic systems have been well documented, and include reductions in biodiversity and biomass, homogenization of the substratum, and disruption of ecosystem processes (Thrush and Dayton 2002). Despite the impact being variable with depth (faunal composition) and trawl intensity (e.g. Kaiser et al. 2006), and habitat type (rocky bottom may have inaccessible refuges), and to some extent with the way the gear is rigged and the navigational and fishing monitoring equipment employed (e.g. see MFish 2008, Section 4.1.2), the nature of the potential impact of demersal trawls on VME fauna is made with high confidence.

BFIA element 1: Intensity (Magnitude of impact is 'none', low, 'medium' or high' at the specific site affected?)

The severity of demersal trawl impact on VME fauna needs to consider fishing intensity (density and distribution of effort with defined areas), but is also partly assessed by inference because there are few (if any) direct *in situ* observations of impact in the SIOFA Area. Evaluation can, however, be made with a medium to high degree of confidence because fishing effort intensity has been mapped at sub-block scale (0.1º), and because there are observational studies of trawl impact on VME taxa made elsewhere that relate directly to BFIAs for deep water fisheries (see Impact Description above).

Intensity mapping of Australia's demersal trawl effort, from 1999 to 2009 in the total Australian footprint of 201 blocks, shows effort had been distributed over eight fishing grounds in 156 of the 20' blocks but with heavy effort (>50 tows) in 17 blocks and moderate (3-50 tows) in 69 blocks. The intensity metric is conservative (total individual trawl tows in 20' blocks over ten years), and the proportion of blocks in the footprint with high effort is small (< 10%) (Table 4.3.1.2). In total, 19 (5.1%) of the 372 potential VME seamounts have high effort (>50 tows) by Australian demersal trawlers between 1999 and 2009.

The severity of the impact may depend on the intensity of trawling and on the taxa encountered. However, individual trawl tows have the potential to have severe impacts, particularly on large, erect and delicate fauna, as exemplified by long-lived 'tree-forming' corals. This is reflected in differential bycatch weight thresholds for black corals, soft corals and fan corals in New Zealand's management arrangements – see Parker et al. (2009a). Severity of impact also depends on the site-scale spatial extent of fishing, i.e. whether all parts of a site potentially representing a VME are impacted. Widespread site-scale impact has been observed, for example on some individual seamounts, although in many locations it is likely that some fauna remains unimpacted in natural refuges inaccessible to fishing gear. A key uncertainty is whether partly impacted areas remain viable as ecologically functioning communities. (Additional uncertainty is whether site-scale intensity of impact has effects at larger scales; it is quite plausible that impacts affecting reproductive function at sites which are important upstream sources of propagules will also impact downstream VMEs.)

This combination of factors, together with additional uncertainty about the extent to which landed bycatch underestimates fishing impact, results in the intensity of impact being rated as potentially high at individual site scale – with potential for ecological effects at broader scales.

BFIA element 2: Duration (How long the effects of impacts are likely to last.)

The duration of impact may be taxon dependent, but because VME taxa are typically slow growing and long-lived (e.g. Clark et al. 2010), there is a justifiably high confidence in evaluating the duration of impact (recolonisation by VME taxa) as long (decades to centuries, or longer). Whether heavily impacted VMEs will return to original ecosystem structure and function is uncertain (Williams et al. 2010).

BFIA element 3: Spatial extent (The spatial impact relative to the extent of VMEs.)

Rating the 'spatial extent' of impact is highly dependent on the spatial and temporal scales of reference (Section 4.2). This BFIA for Australian vessels uses a conservative metric (all 0.1º grid cells containing any fishing effort) to estimate overlap of trawling with the distributions of

VME indicators (bathomes and seamounts) for the total historical extent of fishing between 1999 and 2009.

The proportional overlap of demersal trawling was medium (14%) with the deep upper slope and low with other bathomes (< 9%) at the whole-of-fishery scale (Table 4.3.1.2) indicating that the historical impact had been low in terms of spatial extent. The overlap of demersal trawling on potential VME seamounts was high (32.5%) in terms of numbers and medium (15.6%) in terms of area – although heavy fishing effort was only recorded on 5% of the potential VME seamounts with moderate effort on 22% (Table 4.3.1.2), indicating that the historical impact had been medium in terms of potential VME features. However, higher proportions of each bathome and a greater number of seamounts are available to Australian vessels within the defined management footprint. The current footprint prevents fishing in 55-99% of each of the important VME bathomes (in 0-1500 m depths, Williams et al. 2009; Tittensor et al. 2009) and 55% of the potential VME seamounts, and 66% of the area of potential VME seamounts (Table 4.3.1.2). We note, however, that 45% of the deep upper continental slope, and 45% of potential VME seamounts, remain available for trawling. This shows that the spatial extent of impact has the potential to expand, and therefore the overall risk of SAI has the potential to increase. Trawling effort (vessels, hours and operations) has declined since its peak in 2004 but rose in 2009. While only a single vessel is active the future extent of impact is likely to be low, however, the impact has the potential to be wide-ranging and cumulative.

Rating the risk of SAI is also subject to several key uncertainties. Important among these are having no accurate estimates of overlap of Australian trawl effort distribution with VME distribution because neither are precisely mapped at 'site' scale. Additionally, there has been no evaluation of whether there is fine scale co-location of fishery resources with VMEs at the site or feature scale, e.g. whether both VMEs and fishing impact are concentrated in places such as seamount peaks and canyon heads. A high degree of co-located VME fauna and fishing effort has the potential to greatly increase impact and risk. Furthermore, analysis and interpretation of information at multiple spatial and temporal scales is required to understand the ecological effects of fishing impacts on ecosystem processes such as dispersal and recruitment.

This combination of factors, results in the spatial extent of impact being rated as low (‘site specific at local scale’), but with potential to increase (medium) if effort increases and expands to new areas within the footprint, or if management regulations change to permit trawling outside the current footprint.

Table 4.3.1.1 Summary of impact and risk assessment of bottom trawling and auto-longline fishing on VMEs in the SIOFA Area using elements of the SPRFMO BFIAS. Detail supporting the rationale for risk rating provided in Table 4.3.1.2.

Elements of impact/ risk assessment from the BFIAS	Impact rating for trawl and auto-longline	Analytical measures used to assess impact and risk from demersal fishing	Monitoring, management and mitigation measures that reduce uncertainty and risk	Rationale for overall risk rating of SAI by Australian vessels as 'LOW'		Events with potential to increase risk of SAI by Australian vessels
				Demersal trawl	Auto-longline	
1. Intensity Severity of impact is 'none', 'low', 'medium' or high' at the specific site detected?	High (trawl) Medium (auto-longline)	Demersal fishing intensity at 0.1º resolution mapped over VME indicators (ecologically meaningful depth zones and seamounts) to determine overlap. Measured as grid cells containing fishing effort (not refined as swept area).	The spatial extent of Australian fishing is limited by management measures to a defined footprint. Australia has implemented an 'evidence of VME' process with validation steps and move-on provisions. Australia has management infrastructure that transparently supports monitoring and compliance - including ICVMS and reporting requirements using a shot by shot logbook record, trip catch disposal record, and a transit details form. Australian vessels with high seas permits have mandatory observer coverage. Fine scale spatial analysis of Australian fishing effort distribution provides semi-quantitative measures of exposure.	The severity of demersal trawl impact on VME fauna is potentially high at individual sites, but fine scale (0.1º resolution) analysis shows there are few areas of high fishing intensity. Most sites within the Australian footprint have experienced low or medium effort, and the measure used is conservative. 5% of potential VME seamounts are in blocks fished with high effort by Australian trawlers between 1999 and 2009.	The severity of demersal longline impact on VME fauna is potentially medium at individual sites, but fine scale (0.1º resolution) analysis shows no sites within the Australian footprint fished with auto-longline have experienced heavy effort, and the measure used is conservative. There are no potential VME seamounts fished with high effort by Australian auto-longline between 1999 and 2009.	Change of management arrangements leads to effort expanding beyond the currently defined Australian fishing footprint. A material increase in the number of permits leads to effort increasing within the currently defined Australian fishing footprint. Relaxation of 'evidence of VME' reporting, e.g. increased VME taxa trigger thresholds, leads to unrecognised impacts. Decreased observer coverage leads to unrecognised impacts. Improved knowledge of the activities by other Flag States shows the 'whole-of-area' cumulative impact in space and time provides new perspective on the potential risks by individual Flag States including Australia.
2. Duration Expected duration of impact is 'short', 'medium', 'long' ?	Long (both)	Inference. [Duration (persistance) of impact is taxon dependent, but many/ most VME taxa are long-lived; some corals and sponges are among the oldest living animals. Longevity and recovery rates of VME taxa are supported by published studies.]		Persistant impacts (and cumulative impacts) are both indicators of high potential risk, but are moderated by spatial patterns of intensity (mostly low and medium) and extent (spatially regulated).	Persistant impacts (and cumulative impacts) are both indicators of high potential risk, but are moderated by spatial patterns of intensity (very low) and extent (spatially regulated).	
3. Spatial extent The spatial impact relative to the extent of VMEs	Low (both)	Demersal fishing effort distribution at 0.1º resolution mapped over VME indicators to determine overlap within ecologically meaningful depth zones (bathomes) and on seamounts. Measured as grid cells containing fishing effort (not refined as swept area).		VME taxa are potentially severely impacted at site scale, but proportional overlaps with VME indicators (bathomes and seamounts) were historically low. Effort levels have declined and effort extent is restricted to historical footprint. Majority of area/ occurence of VME indicators lie outside footprint: fishing is prevented in the majority (> 55%) of each of the important VME bathomes (in 0-1500 m depths) and on 55% of the potential VME seamounts - although overlap high in deep upper slope bathome (700-1000m).	VME taxa may be impacted at site scale, but proportional overlaps with VME indicators (bathomes and seamounts) were historically low. Effort levels are very low and effort extent is restricted to historical footprint. Majority of area/ occurence of VME indicators lie outside footprint: fishing is prevented in the majority (> 55%) of each of the important VME bathomes (in 0-1500 m depths) and on 55% of the potential VME seamounts.	
4. Cumulative impact Repeated impacts may accumulate in time and space	Definitely cumulative (both)	Spatial-temporal patterns [Recovery times (decades to centuries or longer) greatly exceed intervals between fishing (days to years) at specific sites where VME fauna exist or existed. Taxa longevity and recovery rate are supported by published studies.]		Trend of effort levels decling with 1 Australian trawler active in 2009. There is low exposure of VMEs to fishing impact from Australian demersal trawling because there are few (2) issued permits.	Effort levels very low and no vessels fishing in 2009. There is low exposure of VMEs to fishing impact from Australian auto-longlining because there are few (2) issued permits.	

Table 4.3.1.2 Summary data to assess aspects of the risk of demersal trawling and auto-longlining impacts on benthic VMEs in the SIOFA Area (noting autolongline fishing is still permitted in the BPAs). Indications of high (H), medium (M) and low (L) risk are arbitrary; all values shown are percentages

	Australian trawling			**Australian auto-longline**			**High Seas fleet (cumulative)**		
Maximum no. vessels in any year (2002-2009)		3 (1999)			1 (2008)			?	
No. vessels in 2009		1			0			?	
No. permits issued in 2011		2			2			?	
Trend in total effort		Slight decline			No trend			?	
	H (>30%)	**M (10-30%)**	**L (<10%)**	**H (>30%)**	**M (10-30%)**	**L (<10%)**	**H (>30%)**	**M (10-30%)**	**L (<10%)**
Proportion of each bathome available for fishing (footprint)									
Shelf (0 – 200 m)			0.7			0.7	99.5		
Shallow upper slope (201 – 700 m)			8.6			8.6	97.4		
Deep upper slope (701 – 1000 m)	45			45			95.3		
Shallow mid-slope 1001 – 1500 m)		24.1			24.1		89.5		
Deep mid-slope (1501 - 2000 m)		13			13		90.4		
Proportion of each bathome fished between 1999-2009 (effort distribution)									
Shelf (0 – 200 m)			0.6			0.1	?	?	?
Shallow upper slope (201 – 700 m)			4.7			0.5	?	?	?
Deep upper slope (701 – 1000 m)		14				0.4	?	?	?
Shallow mid-slope 1001 – 1500 m)			8.2			0.1	?	?	?
Deep mid-slope (1501 - 2000 m)			2.6			0.1	?	?	?
Proportion of footprint with high intensity fishing (total: 201 blocks)			8.5			0			
Proportion 'potential VME seamounts' under Australian footprint: Number (total: 372)	44.9			44.9			?	?	?
Area (total: 264,452 km^2)	33.7			33.7					
Proportion 'potential VME seamounts' fished between 1999-2009: Number (total: 372)	32.5					2.2	?	?	?
Area (total: 264,452 km^2)		15.6				0.7	?	?	?
Proportion 'potential VME seamounts' with high intensity fishing effort: Number (total 372)			5.1			0	?	?	?
Proportion 'potential VME seamounts' with moderate intensity fishing effort: Number (total 372)		21.5				1.3	?	?	?
Proportion of any bathomes protected in fishery closures									
Shelf (0 – 200 m)			0.5			0.5			0.5
Shallow upper slope (201 – 700 m)			2.6			2.6			2.6
Deep upper slope (701 – 1000 m)			4.7			4.7			4.7
Shallow mid-slope 1001 – 1500 m)		10.5			10.5			10.5	
Deep mid-slope (1501 - 2000 m)			9.6			9.6			9.6
Proportion of potential VME seamounts protected in fishery closures: Number (total 372)			5.6			5.6			5.6
Area (total: 264,452 km^2)			7.1			7.1			7.1
Proportion of any types of VMEs protected in fishery closures								?	

BFIA element 4: Cumulative impact (Repeated impacts may accumulate in time and space.) The impact of demersal trawling on VME fauna is definitely cumulative in space and time because recovery times (decades to centuries or longer) greatly exceed intervals between fishing (days to years) at specific sites where VME fauna exist or existed. Knowledge of the historical impact by Australian vessels is limited by a paucity of information on the identity and quantity of VME fauna damaged or removed, and lack of direct *in situ* observations of VMEs present. Australian management regulations have required 100% observer coverage since 2008, and improved monitoring (e.g. identification of VME bycatch) will reduce uncertainties about the realised impact of demersal trawls on VMEs in the SIOFA Area. The key uncertainty is cumulative impact; the largest challenge to effectively manage VMEs in the SIOFA Area is to estimate the cumulative effects of impacts across Flag States.

4.3.2 Demersal (auto-) longlining

The potential impacts of demersal auto-longline fishing on VMEs evaluated using the four elements of the draft BFIAS are 'potentially medium' for intensity, 'long' in terms of their duration, 'low' in spatial extent but with 'definite' cumulative impacts) (Table 4.3.1.1). The overall risk of SAI of demersal auto-longlining by Australian vessels in the SIOFA Area, which accounts for potential impact together with the trends in exposure, and existing management, mitigation and monitoring measures, is evaluated as currently low, although with the potential to increase to medium (Table 4.3.1.1).

The low overall risk of SAI accounts for several factors that moderate the risk, particularly the management and mitigation measures applied to Australian vessels, including limits on the amount of fishable seabed available for fishing, an 'evidence of VME' process with validation and move-on provisions, and infrastructure that transparently supports monitoring and compliance. Our evaluation of low overall risk also considers the low exposure of VMEs to fishing impact from Australian vessels because there are few issued permits and no active Australian demersal longline vessels.

Low overall risk is qualified with a medium rating that reflects the influence of factors that serve to increase risk. These include the potential for effort to expand within or beyond the Australian fishing footprint in the future. High levels of uncertainty regarding key aspects of exposure and effect also increases the risk of SAI. Some uncertainties are specific to impacts and risks from demersal auto-longlining, while others are common to all fishing methods (Table 4.3.1.1). The single greatest uncertainty in assessing the risk of SAI is the lack of knowledge of the activities by other Flag States and unrecorded fishing, which contributes an unknown (but likely relatively large) cumulative impact in space and time.

As required by the draft BFIAS, the rationale for the impact and risk ratings are described below against the identified elements of impact and risk (Table 4.3.1.1), together with a description of the type of impact resulting. Semi-quantitative measures are summarised in Table 4.3.1.2. The key sources of uncertainty influencing the BFIAS are documented in Section 6 (see summary Table 6.1.1).

Impact description. (What will be affected and how?)

The potential risks of fishing impacts to deepwater benthic fauna, which are adapted to stable and quiescent environmental conditions, are high relative to fauna from shallower depths (Williams et al. 2011b). There is potential for demersal longline impact on large, erect and delicate VME taxa such as sponges and tree-forming corals through degradation or removal, and a higher likely impact than previously recognised (Section 4.1.3) – and see Chuenpagdee et al. (2003, Figure 6) who rate this gear as having 'medium impact' based on its relative severity of collateral impacts compared to other fishing gears. Because the impact is expected to vary with depth (faunal composition), and habitat type (rocky or very steep bottom may have inaccessible refuges), and because there are few empirical data on the nature of the potential impact of demersal longline on VME fauna, this description is made with medium confidence.

BFIA element 1: Intensity (Magnitude of impact is 'none', low, 'medium' or high' at the specific site affected?)

The severity of demersal auto-longline impact on VME fauna needs to consider fishing intensity (density and distribution of effort with defined areas), but is also partly assessed by inference because there are no direct *in situ* observations of impact in the SPRFMO Area. Evaluation can, however, be made with a medium degree of confidence because fishing effort intensity has been mapped at sub-block scale (0.1º), and because there some observations of VME bycatch by auto-longline made elsewhere, and expert-based first principle evaluations, that relate directly to BFIAs for deep water fisheries (see Impact Description above and Section 4.1.3).

Intensity mapping of Australia's demersal auto-longline effort, from 1999 to 2009 in the total Australian footprint of 201 blocks, shows effort had been distributed over one fishing ground in three of the 20' blocks, with no heavy effort (>50 sets) and moderate effort (3-50 sets) in two blocks. The intensity metric is conservative (total individual auto-longline sets in 20' blocks over 10 years), and the proportion of blocks in the footprint with high effort is zero (Table 4.3.1.2). No potential VME seamounts are in blocks with high effort by Australian auto-longliners between 1999 and 2009.

The severity of the impact may depend on the intensity of auto-longline fishing and on the taxa encountered. However, while auto-line sets have the potential to have impacts, particularly on large, erect and delicate fauna, as exemplified by long-lived 'tree-forming' corals, there is considerable uncertainty about resultant impact (see Section 4.1.3). As well, different management regulations apply in different areas, e.g. New Zealand has no trigger thresholds for auto-longlining in the SPRFMO Area, while there are triggers in the CCAMLR area of competence. Severity of impact also depends on the site-scale spatial extent of fishing, i.e. whether impact affects all parts of a site potentially representing a VME. There are no published or widely-available records of direct observations of demersal auto-longline impact, although in many locations it is likely that fauna remains unimpacted in natural refuges inaccessible to fishing gear. A key uncertainty is whether partly impacted areas remain viable as ecologically functioning communities. (Additional uncertainty is whether site-scale intensity of impact has effects at larger scales; it quite plausible that impacts affecting reproductive function at sites which are important upstream sources of propagules will also impact downstream VMEs.)

This combination of factors, together with additional uncertainty about the extent to which landed bycatch underestimates fishing impact, results in the intensity of impact being rated as potentially medium at individual site scale – with potential for ecological effects at broader scales.

BFIA element 2: Duration (How long the effects of impacts are likely to last.)

The duration of impact may be taxon dependent, but because VME taxa are typically slow growing and long-lived (e.g. Clark et al. 2010), there is a justifiably high confidence in evaluating the duration of impact (recolonisation by VME taxa) as long (decades to centuries, or longer). Whether heavily impacted VMEs will return to original ecosystem structure and function is uncertain (Williams et al. 2010).

BFIA element 3: Spatial extent (The spatial impact relative to the extent of VMEs.)

Rating the 'spatial extent' of impact is highly dependent on the spatial and temporal scales of reference (Section 4.2). This BFIA for Australian vessels uses a conservative metric (all 0.1º grid cells containing any fishing effort) to estimate overlap of auto-longlining with the distributions of VME indicators (bathomes and seamounts) for the total historical extent of fishing between 1999 and 2009.

The proportional overlaps of auto-longline with all bathomes and with seamount area and numbers were low (≤ 0.5% and <3%, respectively) at the whole-of-fishery scale (Table 4.3.1.2) indicating that the historical impact had been low in terms of spatial extent. However, higher proportions of each bathome and a greater number of seamounts are available to Australian vessels within the defined management footprint.

The current footprint prevents fishing in 55-99% of each of the important VME bathomes (in 0-1500 m depths, Williams et al. 2009; Tittensor et al. 2009) and 55% of the potential VME seamounts, and 66% of the area of potential VME seamounts (Table 4.3.1.2). We note, however, that 45% of the deep upper continental slope, and 45% of potential VME seamounts, remain available for trawling. This shows that the spatial extent of impact has the potential to expand, and therefore the overall risk of SAI has the potential to increase. However, historical effort (vessels, hours and operations) has been negligible and there has been no activity since 2008. This indicates that the future spatial extent of impact is likely to remain low.

Rating the risk of SAI is also subject to several key uncertainties. Important among these are the considerable uncertainty about the nature of the impact of auto-longlines on VME taxa (Section 4.1.3), and having no accurate estimates of overlap of Australian auto-longline effort distribution with VME distribution because neither are precisely mapped at 'site' scale. Additionally, there has been no evaluation of whether there is fine scale co-location of fishery resources with VMEs at the site or feature scale, e.g. whether both VMEs and fishing impact are concentrated in places such as seamount peaks and canyon heads. A high degree of co-located VME fauna and fishing effort has the potential to greatly increase impact and risk. Furthermore, analysis and interpretation of information at multiple spatial and temporal scales is required to understand the ecological effects of fishing impacts on ecosystem processes such as dispersal and recruitment.

This combination of factors, results in the spatial extent of impact being rated as low ('site specific at local scale'), but with potential to increase (medium) if effort increases and expands to new areas within the footprint, or if management regulations change to permit auto-longlining outside the current footprint.

BFIA element 4: Cumulative impact (Repeated impacts may accumulate in time and space.)

The impact of demersal auto-longlining on VME fauna is definitely cumulative in space and time because recovery times (decades to centuries or longer) greatly exceed intervals between fishing (days to years) at specific sites where VME fauna exist or existed. Knowledge of the historical impact by Australian vessels is limited by a paucity of information on the identity and quantity of VME fauna damaged or removed, and lack of direct *in situ* observations of VMEs present. Australian management has had a target of 10% observer coverage since 2008, and improved monitoring (e.g. identification of VME bycatch) will reduce uncertainties about the realised impact of demersal longlining on VMEs in the SIOFA Area. The key uncertainty is cumulative impact; the largest challenge to effectively manage VMEs in the SIOFA Area is to estimate the cumulative effects of impacts across Flag States.

4.3.3 Other fishing methods

Midwater trawling and drop-lining have not been assessed as part of this BFIA due to the low rating of these gears for impacts on benthic habitats and, in the case of drop-lining, negligible levels of effort.

5. INFORMATION ON STATUS OF DEEPWATER STOCKS TO BE FISHED

Historical trends of catch and effort are provided for the SIOFA Area for the period 1999 to 2009. No stock impact assessment is provided as part of this BFIA because there have been no stock assessments for the Australian fishery in the SIOFA Area to this point in time. Some minor inconsistencies in the catch weight reporting between vessels (whole weights vs. processed weights were revealed as this BFIA was being finalised. Updated data will be used in subsequent stock assessment reporting.

5.1 Historic catch and effort trends (1999-2009)

5.1.1 Demersal Trawl

Fishing effort by demersal trawl from 1999-2009 fluctuated between about 70 hours to 220 hours with almost no effort in 2006 and no demersal trawling in 2007 and 2008 (Figure 5.1.1.1a). The changes in effort were operational and reflected fishing activities in other regions (e.g. the sub-Antarctic) by the single Australian company participating in the SIOFA Area. Over all years, effort was concentrated on the slope with ~450 hours applied in the deep upper slope (700-1000 m) and ~350 hours in the two adjacent bathomes (200-700 m and 1000-1500 m; Figure 5.1.1.1b).

Orange roughy (*Hoplostethus atlanticus*) was the main target species of demersal trawling, making up between 35% and 92% of the annual total catches for 2000-2009. The second most commonly caught species (0% to 15% annually) was spikey oreo (*Neocyttus rhomboidalis*), with the remainder comprising a mix of cardinal fish (*Epigonus* spp.), smooth oreo (*Pseudocyttus maculatus*), boarfish (family Pentacerotidae) and 36 other species (Figure 5.1.1.1a). The first year in the time series, 1999 was different in that 97% of operations had no catch data recorded in the logbooks; the recorded catches were 98% 'other' species; the percentage of presumably failed shots, i.e. operations that had no catch reported, typically fluctuated between 20% and 40% annually. Catch by depth indicates that deeper shots in the 1000-1500 m bathome caught almost entirely orange roughy (90%; Figure 5.1.1.1b). Orange roughy accounted for 55% of the catch of slope shots in the 700-1000 m bathome, with the remainder comprising a mix of spikey oreo (*Neocyttus rhomboidalis*), cardinal fish (*Epigonus* spp), smooth oreo (*Pseudocyttus maculatus*), boarfish (family Pentacerotidae) and 36 other species (Figure 5.1.1.1b). The upper slope was not heavily fished, with the greatest effort of about 45 hours in 2003 (Figure 5.1.1.1b).

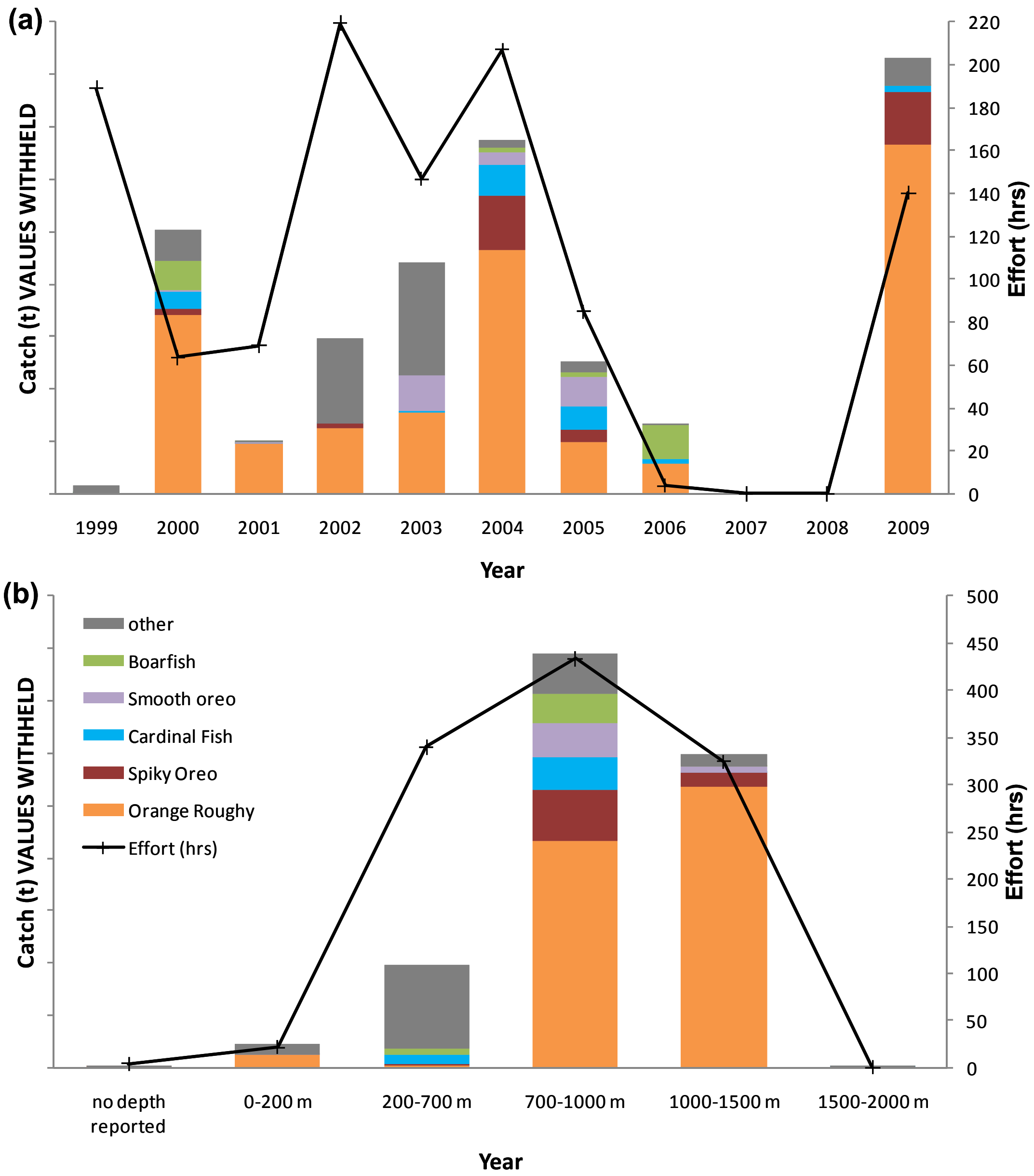

Figure 5.1.1.1 Total Demersal Trawl catch and effort in the SIOFA Area (a) by year, (b) by depth zone for the five most commonly caught species and 'other'.

5.1.2 Midwater Trawl

Fishing effort by midwater trawling has was below 30 hours for the first three years and then varied annually from about 70 hours to 320 hours from 2002 to 2009 (Figure 5.1.2.1a). As for demersal trawl, these changes in annual effort were operational and reflected fishing activities in other regions (e.g. the sub-Antarctic) and changes in the species targeted by the single Australian company participating in the SIOFA region. Over all years, midwater trawl effort was mostly applied in depths of 200-700 m, and secondarily in deeper waters from 700-1000 m (Figure 5.1.2.1b). As this method operates in the water column, albeit with the potential to be fished close to the bottom, it is not possible to make strong assumptions about the placement of this effort in relation to the upper or lower slope, except to say that the deeper effort was only physically possible in waters at or below the lower slope.

Alfonsino (*Beryx splendens*) was the main target species of midwater trawling, making up between 31% and 97% of the annual total catches for 1999-2009. The second most commonly caught species (0% to 56% annualy) was ocean blue-eye (*Schedophilus labyrinthica*), with the remainder comprising a mix of blue-eye trevalla (*Hyperoglyphe antarctica*), boarfish (family Pentacerotidae), gemfish (*Rexea solandri*) and 45 other species (Figure 5.1.2.1b). Alfonsino comprised almost all (95%) of the catch in depths from 700-1000 m and about 61% of the catch in 200-700 m (Figure 5.1.2.1b). Ocean blue-eye dominated the catches in waters shallower than 200 m where the effort was less than 100 hours (Figure 5.1.2.1b). The percentage of presumably failed shots, i.e. operations that had no catch reported, typically fluctuated between 20% and 40% from 2003 onward; it was zero for the earlier years.

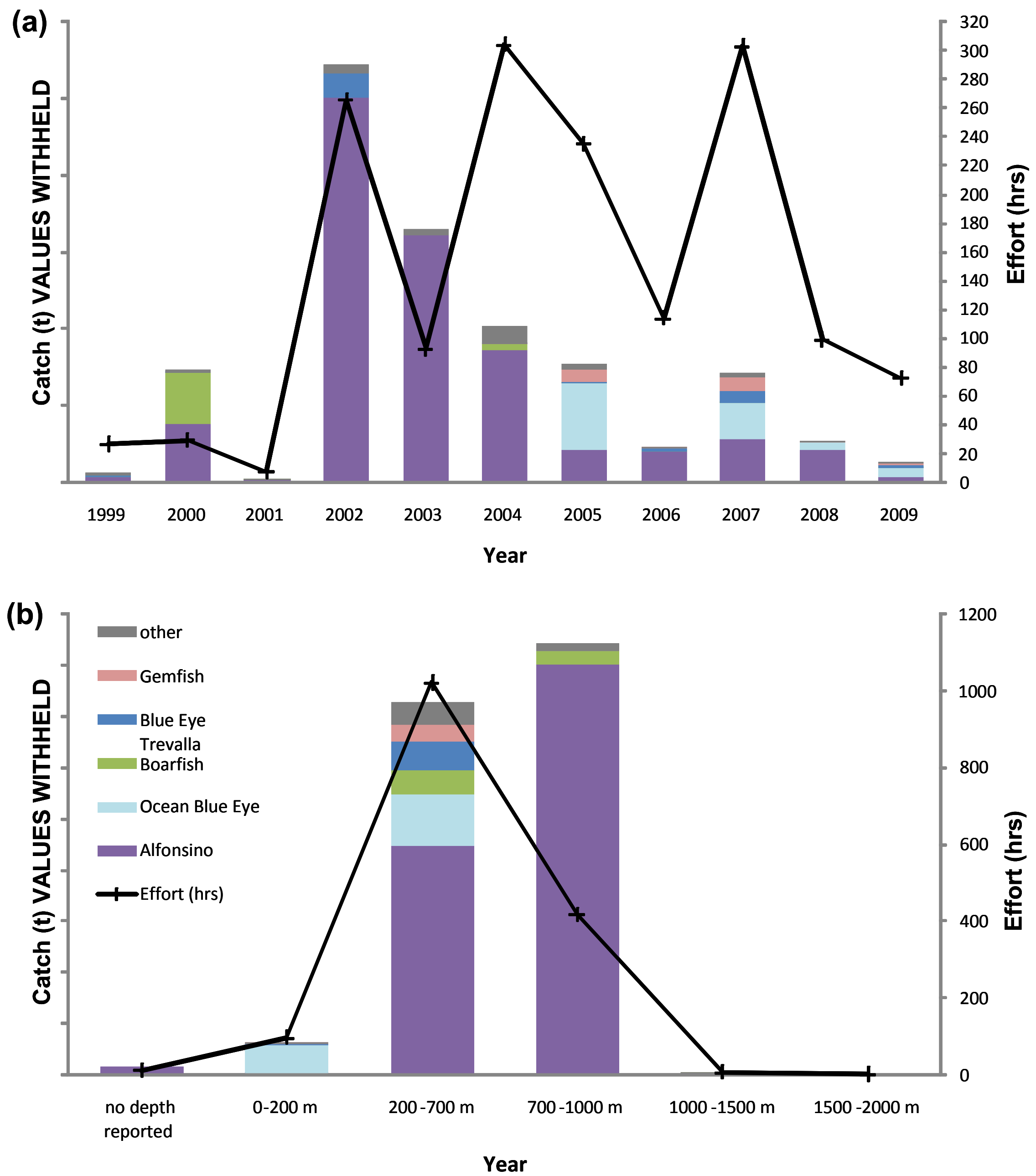

Figure 5.1.2.1 Total Midwater Trawl catch and effort in the SIOFA Area (a) by year, (b) by depth zone for the five most commonly caught species and 'other'.

5.1.3 Line Methods

Demersal line methods (mostly auto-longline) in the SIOFA Area were reported in 2008 only; the total recorded catch was 0.7 t for 54,000 hooks set on the shallow upper slope. The main target species were Hapuku (*Polyprion oxygeneios*), ocean perch (*Helicolenus percoides*), ribaldo (*Mora moro*) and seabass (*Lutjanus spp*.); Jackass morwong (*Nemadactylus marcopterus*) and 5 other species were also caught (Figure 5.1.3.1).

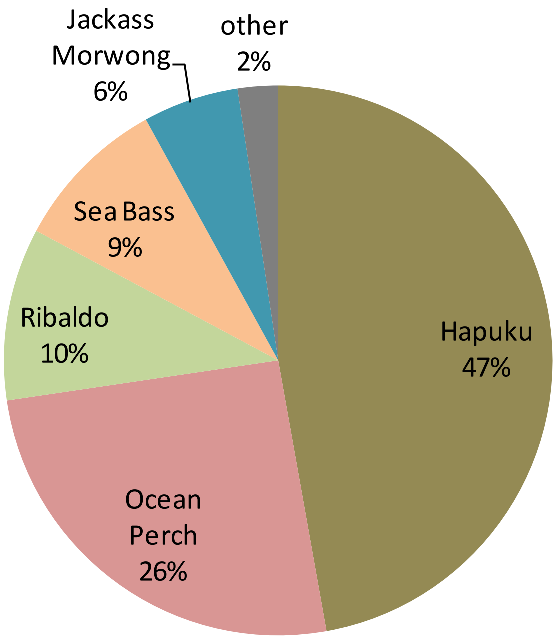

Figure 5.1.3.1 Relative distribution of species caught by demersal line methods in the SIOFA Area over the time period of 1999-2009.

6. MONITORING, MANAGEMENT AND MITIGATION MEASURES

The BFIA conducted for Australian vessels fishing in the SIOFA Area identifies that the risk of SAI on VMEs is low for the two primary demersal fishing methods used (demersal trawling and auto-longlining). It is negligible (considered, but, having regard to impact and effort, not formally assessed) for other methods (midwater trawling and droplining).

Ongoing monitoring, management and mitigation measures are necessary to address the potential impacts arising from demersal trawling (high) and demersal auto-longline fishing (medium). The risk ratings need to acknowledge the scope for risks to increase, and the high degree of uncertainty about many of the key elements relevant to assessing and managing impact and risk to VMEs in the SIOFA Area.

While Australia remains committed to implementing unilateral actions in the SIOFA Area, along with control and assessment of individual activities of Australian operations, these factors need to be considered in the context of the cumulative impact of fishing through time and by vessels from other Flag states. The lack of knowledge of the cumulative impacts of fishing across Flag states is perhaps the single greatest source of uncertainty for conducting individual BFIAs because cumulative impact provides essential context. Collating the BFIAs, and determining the activities of non-member nations, is also necessary to understand the risks associated with any future increase or expansion of fishing by individual Flag States including Australia. It will be important for Australia have input to developing the SIOFA along with other member nations, to allow for broader assessments of fishing impacts. Australia's proposed future monitoring, management and mitigation measures for the SIOFA fishery will be presented in a separate report prepared by AFMA.

6.1 Enhanced monitoring, management and mitigation

Australia's fishery logbook system records the distribution of fishing effort and levels of targeted catch, and bycatch – including of VME taxa. This provides the basis for evaluating the level of seabed impact by Australian vessels in the manner reported in this BFIA. Logbook data collection is supported by mandatory observer coverage (100% for bottom trawl, and the first trip and ongoing coverage of 10% annually for demersal longline), and satellite vessel monitoring systems and logbook reporting requirements on a shot by shot basis (see Section 4.1.2). Measures implemented by Australia to manage the risk of SAI by Australian fishing include currently restricting fishing to a 'footprint' area, and implementing an 'evidence of VME' and move-on protocol in the entire Australian fishing footprint (see Section 4.1.2). If effort levels or the spatial extent of Australian effort expands by a material amount, monitoring, management and mitigation measures will need to be reviewed to ensure that risk of SAI remains low.

There is presently scope to reduce uncertainties in knowledge underlying completion of this (and future) risk assessments, and to increase certainty about the effectiveness of management implementation, with a range of actions involving fishery managers, scientists and industry operators (Table 6.1.1). These include:

- targeted spatial management measures to protect areas where VMEs are predicted to exist – including by using industry-provided acoustic data (depth, species) to define the boundaries of key fishing areas, and potential VME areas that are presently unfished, or unfishable because of the seabed terrain
- improved logbook recording of vessel position to permit fine-scale and consistent mapping of fishing effort distribution (including higher accuracy and specified gear on-bottom recording)
- achieve a higher level of observer coverage of auto-longlining to reduce uncertainty about impacts by this method – including through use of 'e-monitoring' (see below)
- collect VME evidence using cost-effective camera-based methods to supplement existing observer coverage:
    - 'e-monitoring' with deck based cameras of sufficient resolution to cost-effectively and more comprehensively identify VME taxa in fishing bycatch
    - identify potential VME taxa/ regions with compact cameras mounted on fishing gears (ruggedized equipment suited to this application requires little additional development by the AAD and CSIRO to be used for monitoring purposes)
- support research to define VMEs and assist predictive models with ongoing data collection using other in-water sensors such as mini-CTDs to record attributes of water column structure
- improving the 'evidence of VME' protocol by

- increasing the reliability of VME taxa identification with formalised training and a dedicated logsheet
- improving compatibility of observer databases to merge information currently residing in different databases
- targeted collection of selected biological specimens – including for research that identifies regional substructure to inform VME management

Table 6.1.1 Summary of elements of impact and risk in Australia's BFIA for the SIOFA Area showing the key sources of uncertainty that affect the confidence of ratings, and the opportunities that exist to reduce uncertainty. Numbers in square brackets indicate relevance to the individual elements of impact.

<table>
<tr><th>Elements of impact/ risk assessment from the BFIAS</th><th>Confidence in LOW risk rating</th><th>Key sources of (risk increasing) uncertainty for Australian BFIA</th><th>Opportunities to reduce knowledge and implementation uncertainties in Australian BFIA</th></tr>
<tr><td>1. Intensity
Severity of impact is 'none', 'low', 'medium' or high' at the specific site detected?</td><td>Low/ medium</td><td rowspan="4">The extent to which landed bycatch underestimates fishing impact is not known, but is expected to be high. [1, 3]

Knowledge of the identity and quantity of VME fauna impacted is limited by the resolution of the bycatch data collected, and lack of direct in situ observations of VMEs present. [1, 2]

Neither fishing effort distribution nor VME distribution are precisely mapped at 'site' or any coarser scale. [1, 3]

It is not known if VMEs and fishing effort is co-located at fine spatial scales, or if there are ecological dependencies of target species on VME areas. [1, 3]

There is little information on the recovery trajectories by different and variously impacted deep ocean VME communities, and the potential for a variety of persistent stable states during recovery. [2]

There is little knowledge of regional scale (biogeographic) substructure [3]

Few empirical data link impacts to effects on ecosystem function and processes at ecologically relevant spatial, temporal and environmental scales. [1,2, 3, 4]

Cumulative impacts will occur across Flag States but are undocumented [1, 2, 3, 4]</td><td rowspan="4">Improved indentification and standard recording of VME bycatch [1, 2]

Verified reporting of VME bycatch for all operations, i.e. presence AND absence recorded [1, 2, 3]

VMEs and VME indicators mapped at ecologically relevant scales - local and site - including with cameras [1, 2, 3]

Accurately recorded on-bottom fishing positions [1, 3]

Baseline information and data established for representative VMEs within the SIOFA Area [1, 2, 3, 4]

Targeted collection of biological material to identify regional (biogeographic) sub-structure [2, 3]

Further development and validation of methods to predictively map VME distributions [3]

Re-evaluate risks when collated information on all fishing footprints is available to estimate the cumulative extent of impact, and to refine 'whole-of-area' precautionary management measures [4]</td></tr>
<tr><td>2. Duration
Expected duration of impact is 'short', 'medium', 'long' ?</td><td>High</td></tr>
<tr><td>3. Spatial extent
The spatial impact relative to the extent of VMEs</td><td>Medium</td></tr>
<tr><td>4. Cumulative impact
Repeated impacts may accumulate in time and space</td><td>High</td></tr>
</table>

6.2 Scientific research

The 'data-poor' reality for most of the SIOFA Area means that mapping VMEs may be limited to estimating their associations with seabed topography (seamounts and, potentially, other geomorphic features) and depth zones (bathomes). In data-poor cases, precautionary decisions need to be made about risks of localised impacts on habitat types with restricted distributions, and fragmentation leading to the associated loss of connectivity between types. We concur with the New Zealand BFIA (MFish 2008) that the effective protection of VMEs in the longer term is likely to require the regional implementation of a series of spatial closures that protect adequate and representative areas of VMEs. This acknowledges that some key uncertainties (e.g. ocean basin scale mapping of VMEs) will remain unknown for a long time relative to the accumulation of impacts in time and space. Identifying suitable areas for closures will be aided by identifying regional substructure (biogeographic patterns), and environmental modelling that predicts locations of VME fauna. These research areas are a focus for international scientists, including from Australia, New Zealand, the United States of America, Canada, Chile and the United Kingdom, and will benefit from data collected in the SIOFA Area.

Future risk assessment will ideally include a focus on ecological effects such as maintaining population connectivity and trophic relationships. This will require integrating many ecologically relevant data sources, and then building the concept of ecological resilience into management planning (Thrush and Dayton 2010). Maintaining the overall resilience of seamount benthic ecosystems, currently the best indicator type for the locations of VMEs, will be assisted by protecting intact habitats on shallow seamounts to mitigate against the impacts of climate change, and, over a range of depths, especially <1500 m, on clusters and isolated seamounts (Williams et al. 2010).

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9. APPENDICES

Appendix 1 – Examples of potential VMEs

Examples of potentially vulnerable species groups, communities and habitats, as well as features that potentially support them according to the FAO guidelines, Annex 1 (as quoted in the SPRFMO draft BFIAS – SPRFMO 2009):

> The following examples of species groups, communities, habitats and features often display characteristics consistent with possible VMEs. Merely detecting the presence of an element itself is not sufficient to identify a VME. That identification should be made on a case-by-case basis through application of relevant provisions of these Guidelines, particularly Sections 3.2 and 5.2.
>
> Examples of species groups, communities and habitat forming species that are documented or considered sensitive and potentially vulnerable to DSFs in the high-seas, and which many contribute to forming VMEs:
>
> i. certain coldwater corals and hydroids, e.g. reef builders and coral forest including: stony corals (Scleractinia), alcyonaceans and gorgonians (Octocorallia), black corals (Antipatharia) and hydrocorals (Stylasteridae);
>
> ii. some types of sponge dominated communities;
>
> iii. communities composed of dense emergent fauna where large sessile protozoans (xenophyophores) and invertebrates (e.g. hydroids and bryozoans) form an important structural component of habitat; and
>
> iv. seep and vent communities comprised of invertebrate and microbial species found nowhere else (i.e. endemic).
>
> Examples of topographical, hydrophysical or geological features, including fragile geological structures, that potentially support the species groups or communities, referred to above:
>
> i. submerged edges and slopes (e.g. corals and sponges);
>
> ii. summits and flanks of seamounts, guyots, banks, knolls, and hills (e.g. corals, sponges, xenophyphores);
>
> iii. canyons and trenches (e.g. burrowed clay outcrops, corals);
>
> iv. hydrothermal vents (e.g. microbial communities and endemic invertebrates); and
>
> v. cold seeps (e.g. mud volcanoes for microbes, hard substrates for sessile invertebrates).
>
> (FAO 2008)

Appendix 2 – Criteria for identification of VMEs

Characteristics which should be used as criteria in the definition of vulnerable marine ecosystems according to the FAO (2008) guidelines (as quoted in the SPRFMO draft BFIAS – SPRFMO 2009):

42. A marine ecosystem should be classified as vulnerable based on the characteristics that it possesses. The following list of characteristics should be used as criteria in the identification of VMEs.

    i. Uniqueness or rarity – an area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include:

        - habitats that contain endemic species;
        - habitats of rare, threatened or endangered species that occur only in discrete areas; or
        - nurseries or discrete feeding, breeding, or spawning areas.

    ii. Functional significance of the habitat – discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species.

    iii. Fragility – an ecosystem that is highly susceptible to degradation by anthropogenic activities.

    iv. Life-history traits of component species that make recovery difficult – ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics:

        - slow growth rates;
        - late age of maturity;
        - low or unpredictable recruitment; or
        - long-lived.

    v. Structural complexity – an ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.

(FAO 2008)

Appendix 3 – Vulnerability of benthic invertebrates to physical disturbance

Reproduction of Table 1 from CAMLR (2009)

Table 1: Intrinsic factors contributing to the vulnerability from physical disturbance of invertebrates in the Southern Ocean.

Taxon	Habitat forming	Rare or unique populations	Longevity	Slow growth	Fragility	Larval dispersion potential	Lack of adult motility
Phylum Porifera							
Hexactinellida	H	L	H	H	H	M	H
Demospongiae	H	M	H	H	H	M	H
Phylum Cnidaria							
Actiniaria	L	L	H	L	L	M	M
Scleractinia[1]	H	M	H	H	H	M	H
Antipatharia	M	L	H	H	H	L	H
Alcyonacea	M	L	M	L	M	M	H
Gorgonacea	M	L	H	H	H	M	H
Pennatulacea	L	H	H	M	H	L	M
Zoanthida	L	L			M	L	H
Hydrozoa							
Hydroidolina	L	L			L		H
Family Stylasteridae	H	L	H	M	H	H	H
Phylum Bryozoa	H	L	H	M	H	H	H
Phylum Echinodermata							
Crinoidea: Stalked crinoid orders	L	H	H		H		H
Echinoidea: Order Cidaroida	M	L	H	H	M	H	L
Ophiuroidea: Basket and snake stars	L	L			H	L	M
Phylum Chordata: Class Ascidiacea	M	L		L	L	L	H
Phylum Brachiopoda	L	H	H	L	M	M	H
Phylum Annelida: Family Serpulidae	M	L			H	L	H
Phylum Arthropoda: Infraclass Cirripedia: Bathylasmatidae	L	H	H		M	L	H
Phylum Mollusca: Pectinidae: *Adamussium colbecki*	L	H	H	M	M	L	M
Phylum Hemichordata: Pterobranchia	M	M			M	H	H
Phylum Xenophyophora	L	H			H		H
Chemosynthetic communities	H	H	H	H	H	L	H

[1] As of 2009, almost all records of Scleractinia in the CAMLR Convention Area are of cup corals (*Desmophyllum* and *Flabellum* sp.). However, records of matrix forming scleractinians (*Madrepora oculata* and *Solenosmilia variablis*) do exist in the northernmost areas, as far south as 60°S. Cup corals are typically not habitat-forming, but Scleractinia were classified as 'high' for the habitat-forming criterion to be consistent with the approach of using the precautionary attributes of the members of each taxon.

Appendix 4 – Details of the voluntary benthic protection areas implemented by SIODFA

Reproduction of Table 1 from Shotton (2006):

TABLE 1
Indian Ocean benthic protected areas – names and locations

SIODFA BENTHIC PROTECTED AREAS						
Area	Coordinates				Area (km²)	Area features
	Lat (S)	Long (E)	Lat (S)	Long (E)		
Golden Draak	28° 00'	98° 00'	29° 00'	99° 00'	10 867	A massive mid-ocean seamount in pristine biological condition.
Rusky	31° 20'	94° 55'	31° 30'	95° 00'	147	A productive knoll located on extensive ridge; extensive black coral exists with the benthos in an almost pristine state.
Fools' Flat	31° 30'	94° 40'	31° 40'	95° 00'	585	A deep-sea bank with numerous canyons incising its slopes; strong upwelling currents sustain extensive coral beds; in pristine condition, this is a previously unmapped area of the seabed.
East Broken Ridge	32° 50'	100° 50'	33° 25'	101° 40'	5 037	A seamount rising to 1 000 m, biologically pristine; its benthos and topography previously undescribed.
Mid-Indian Ridge	13° 00'	64° 00'	15° 50'	68° 00'	135 688	An area of seamounts rising to 650 m; a tropical region in pristine biological condition.
Atlantis Bank	32° 00'	57° 00'	32° 50'	58° 00'	8 694	This seamount was formed from an ancient island; extensive research has been conducted on this BPA by a number of agencies; it is the location of a productive fishery
Bridle	38° 03'	49° 00'	38° 45'	50° 00'	6 788	An area of knolls and ridges in almost pristine condition; previously unmapped and undescribed.
Walters Shoal	33° 00'	43° 10'	33° 20'	44° 10'	3 443	This area, which rises from 4 000 to within 10 m of the surface provides a habitat for a variety of whale species; the area is characterized by high biodiversity
Coral	41° 00'	42° 00'	41° 40'	44° 00'	12 376	A spreading centre with seamounts and ridges with depths from 4 500 m to 180 m. Extensive coral beds, a near pristine area.
South Indian Ridge (North/ South)	44° 00' 45° 00' S	40.878° S 42.124° E	44 00' 45° 00' S	46.544° E 45.711° E	39 358	An area of seamounts adjacent to the CCAMLR region to the south; in pristine biological condition. This area is bounded to the east and west by the EEZs of South Africa and France.
Agulhas Plateau	38° 00'	25° 00'	41° 00'	28° 00'	85 828	Region of seamounts north of the proposed South African Antarctic MPA; contiguous with the South African EEZ to the west.
Total area					309 051	

Appendix 5 – What constitutes significant bycatch of a VME?

Reproduced from Rogers et al. (2008) – pg 26 & 27:

"Practical guidelines have been drawn from observations of the quantities of by-catch that may be associated with the existence of VMEs on the seabed from different types of fishing gear[11,12] as well as the authors' own experience of how key species that comprise VMEs are distributed and their size and shape. These guidelines will have to be tailored to regional requirements or through the application of adaptive management strategies, altered in response to new or specific data related to an area. They are included here solely as an indication of the sorts of factors that should be considered when RFMOs or management agencies discuss how to define a significant encounter with a VME in their area of jurisdiction."

Corals	**Sponges or other habitat-forming epifauna**
A single haul constituting >5kg of stony coral or coral Rubble, or >2kg of black corals or octocorals or more than 2 coral colonies	A single haul constituting >5kg of sponge or other habitat-forming epifauna
Two or more consecutive hauls containing > 2kg each of live corals on the same trawl track or setting area for fishing gear or where consecutive trawling tracks or sets intersect	Two or more consecutive hauls containing >5kg sponges or other habitat-forming Epifauna on the same trawl track or setting area for fishing gear or where consecutive trawling tracks or sets intersect.
>4 encounters of corals >2kg within an area (1km^2) within one year. >4 corals per 1000 hooks in a long line fishery within one year within an area (10 km^2).	>10 encounters of >2kg sponges or other habitat forming epifauna in an area (1 km^2) within one year.
>15% of hauls of any gear within an area (10-100 km^2) containing corals.	>15% of hauls of any gear within an area (10- 100 km^2) containing sponges or other habitat-forming epifaunal taxa.

Appendix 6 – Decision-support diagram for managing VMEs

Reproduction of Figure 1 from Auster et al. (2010)

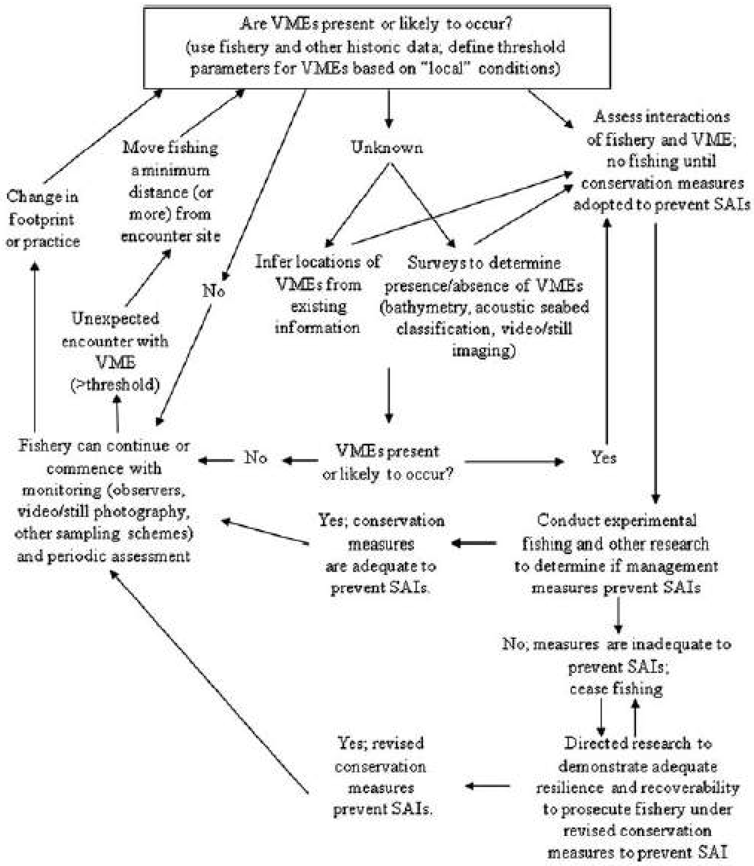
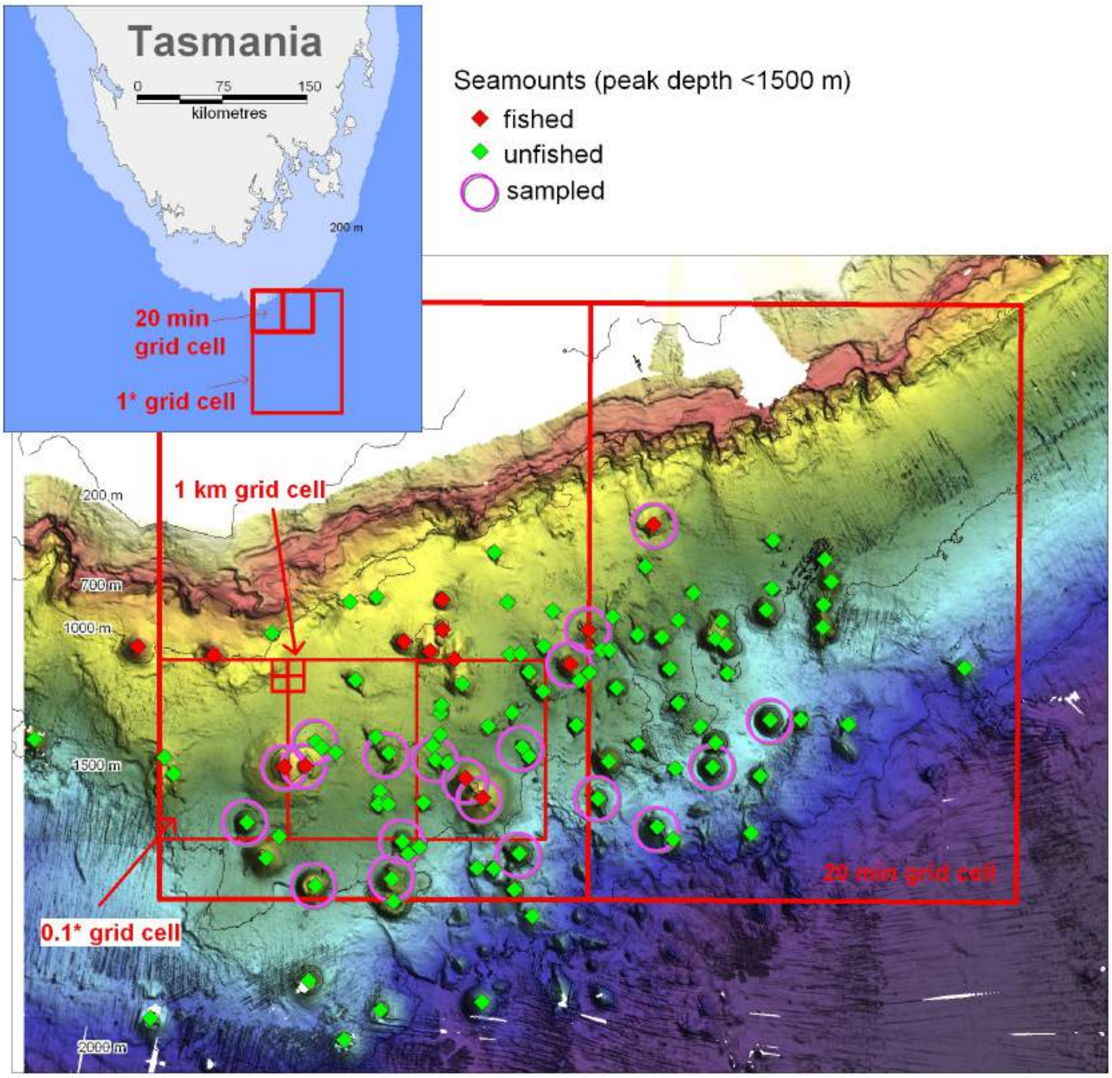


Figure 1. Decision-support diagram for managing vulnerable marine ecosystems based on FAO guidelines (modified from FAO, 2008).

Appendix 7 – Tasmanian Seamounts — illustration of spatial scales

An illustration of spatial scales relevant to BFIA using a well-studied fishery area encompassing a cluster of small conical seamounts south of Tasmania. The grid cell sizes are 1º (the finest scale at which some data layers are available at global scales); 20 minute (SPRFMO footprint standard); 0.1º (scale of fishing effort distribution mapped in this BFIA); and 1 km (the scale of fishing effort mapping typical in Australian domestic fisheries, the scale mapped by scientific observers in CCAMLR, and the scale suited to understand the fine scale impacts of fishing on individual features). Multi-beam swath image (20 m resolution) shaded by depth with main contours shown at left-hand side of image. Individual seamounts with peak depths of <1500 m flagged with fishing history and presence of scientific sampling.



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