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Cumulative Bottom Fishery Impact Assessment for Australian and New Zealand Bottom Fisheries in the SPRFMO Area, 2023

Australia / New Zealand

CUMULATIVE BOTTOM FISHERY IMPACT ASSESSMENT FOR AUSTRALIAN AND NEW ZEALAND BOTTOM FISHERIES IN THE SPRFMO CONVENTION AREA, 2023

Submitted by Australia and New Zealand, 12 July 2023

CONTENTS

1 EXECUTIVE SUMMARY

1.1 OBJECTIVE AND RESULT OF THIS ASSESSMENT

Through the adoption of United Nations General Assembly (UNGA) resolutions 61/105 in 2006, 64/72 in 2009, 66/68 in 2011 and 71/123 in 2016 on deep-sea fisheries, the management of bottom fisheries and protection of deep-sea ecosystems on the high seas has been a priority for the international community. UNGA Resolutions on Sustainable Fisheries (specifically, paragraph 83 of resolution 61/105, and paragraph 119(a) of resolution 64/72), called on States and regional fisheries management organisations to assess, based on the best available scientific information, whether bottom fishing activities would have significant adverse impacts (SAIs) on vulnerable marine ecosystems (VMEs)[1] and the long-term sustainability of fish stocks, and to ensure that these activities are managed to prevent such impacts or are not authorised to proceed. This was initially reflected in the South Pacific Regional Fisheries Management Organisation (SPRFMO) interim bottom fishing measures (SPFRMO 2007) adopted prior to the entry into force of the SPRFMO Convention and carried through to the first binding measure in 2013. The SPRFMO Commission has considered the bottom fishing measures annually since 2013, adopting the most recent changes in 2023. The UNGA Resolutions also influenced the development and adoption by the SPRFMO of a standard for impact assessment of bottom fisheries (SPRFMO 2012), compatible with the Food and Agricultural Organisation's (FAO) International Guidelines for the Management of Deep-sea Fisheries in the High Seas ('the FAO Deep-sea Guidelines') (FAO 2009). The SPRFMO bottom fishery impact assessment standard was updated in 2019 (SPRFMO 2019). The updated standard requires that impacts on marine mammals, seabirds, reptiles, and other species of concern be addressed as well as impacts on fish stocks and VMEs to deliver on the action called for in the UNGA Resolutions. This cumulative bottom fishery impact assessment has been prepared jointly by Australia and New Zealand in accordance with the relevant obligations prescribed in SPRFMO Conservation and Management Measures (CMMs) and the SPRFMO Bottom Fishing Impact Assessment Standard (BFIAS) (SPRFMO 2019), updating the 2020 BFIA (Delegations of Australia and New Zealand 2020).

The assessment concludes that:

- Risk assessments using Productivity-Susceptibility Analysis (PSA) and Sustainability Assessment for Fishing Effects (SAFE) have been used to categorise teleost fishes into a three-tiered stock assessment framework. The first and second tiers require formal stock assessment modelling or the application of data-limited methods for orange roughy (*Hoplostethus atlanticus*) and alfonsino (*Beryx* spp., predominantly *B. splendens*) (predominantly trawl fisheries), and bluenose / blue-eye trevalla (*Hyperoglyphe antarctica*), wreckfish (*Polyprion* spp.), yellowtail kingfish (*Seriola lalandi*) and tarakihi / jackass morwong (*Nemadactylus* spp., predominantly *N. macropterus*) (predominantly line fisheries).
- The only tier 1 species for which stock assessment modelling has been concluded is orange roughy. Where stock status has been estimated (Westpac Bank), the model

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[1] 'Vulnerable marine ecosystem' (VME) means a marine ecosystem that has the characteristics referred to in paragraph 42 of, and elaborated in the Annex to, the FAO (2009) Deep-sea Fisheries Guidelines.

suggests that there is a low risk that the stock is below 20% of unfished biomass. For other stocks a minimum pre-fishing biomass (B_{min}) has been estimated. Precautionary catch limits are in place. However, there is considerable uncertainty in these stock assessments and work is underway to reduce uncertainty.

- There are no formal stock assessment models for other tier 1 or tier 2 species targeted by bottom trawl, midwater (benthopelagic) trawl, or bottom line fisheries. SAFE analyses suggest the risk posed to these species by bottom and midwater trawl fishing is low. However, risk posed by bottom line fisheries is ranked as high or extreme for tarakihi / jackass morwong, bluenose / blue-eye trevalla, and one species of wreckfish (hapuku, *Polyprion oxygeneios*). Outputs from the PSA and SAFE analyses should be considered as relative rankings rather than absolute estimates of risk. Catch limits aggregated across species are in place and priority species for additional work have been identified.
- Most species of teleost and chondrichthyan fishes are caught only as bycatch, or are only rarely targeted, and have been categorised or are proposed for categorisation into tier 3. In this tier, no assessment is required because the catches and risk are considered low. Catch limits aggregated across species are in place and catches and risk will be monitored.
- Captures of marine mammals, seabirds, reptiles and other species of concern are rare in SPRFMO bottom fisheries and the risk to affected populations appears to be low. Work to assess these impacts cumulatively with other fisheries in the Southern Hemisphere is underway but will take time to complete.
- Impact and risk to benthic habitats and VMEs is a key focus of this assessment and analyses have been conducted at a range of scales:
    - Habitat suitability models are available for sixteen VME indicator taxa. Estimates of Relative Benthic Status for ten of these sixteen taxa have been updated to reflect proposed changes to the BTMAs to achieve a minimum level of 70% protection for suitable VME habitat, although the new RBS estimates do not reflect recent reductions in catch limits for the orange roughy fishery.
    - A Relative Benthic Status (RBS) assessment is presented for each of ten VME indicator taxa at the scale of the nine orange roughy FMAs. Overall, the results for the BTMAs implemented under CMM03-2023 generally show that RBS exceeds 95% for most combinations of taxa, FMA and sensitivity. Taxa and FMA combinations where RBS estimates were consistently less than 0.9 for most sensitivities for BTMAs implemented under CMM03-2023 include:
        - Stylasteridae in the North Lord Howe, Central Lord Howe, FMA
        - The stony coral *Enallopsammia rostrata* for high sensitivities in the Northwest Challenger FMA
    - Similarly, the results for the BTMAs proposed to be implemented in 2024 also generally show that RBS exceeds 95% for most combinations of taxa, FMA and sensitivity for future fishing effort. However, again there are some exceptions

to this, and taxa and FMA combinations where RBS estimates were consistently less than 0.9 for most sensitivities include:

    - The stony coral *Goniocorella dumosa* and Stylasteridae for ROC estimates in the North Lord Howe FMA
    - Stylasteridae in the Central Lord Howe FMA
    - The stony coral *Enallopsammia rostrata* for high sensitivities in the Northwest Challenger FMA

- Note however that the BFIA has not been updated to reflect actual fishing effort in 2020-2022, and orange roughy catch limits were substantially reduced in some FMAs in 2023. For this reason both the ‘current’ and ‘future’ status projections produced in 2020 and reproduced here will over-estimate impact and underestimate RBS, roughly proportional to the magnitude of the catch limit reductions.
- Estimates of the proportion of the estimated distribution of suitable habitat and abundance for each taxon outside areas open to bottom trawling have been calculated, on the basis of management measures implemented in CMM03-2023, and alternatives proposed to be adopted by Commission in 2024, as described for the 70% scenario in COMM10-Inf03. These calculations have been done at the scale of BTMAs within FMAs and using a variety of model structures where available and assumptions to assess sensitivity in the estimates.
- Under the spatial management measures implemented in CMM03-2023 over 70% of Habitat Suitability for most VME indicator taxa within an FMA is within areas closed to fishing, but this reference point is not met for some taxa, particularly within Northwest Challenger, Central Louisville and South Louisville.
- Under the spatial management measures that are proposed to be adopted by Commission in 2024 all VME indicator taxa with > 1% of their HSI within an FMA have at least 70% of Habitat Suitability within areas closed to fishing.
- A sensitivity analysis assuming VME indicator taxa significantly deeper than bottom trawl fisheries are not exposed to fishing disturbance increases estimates of the amount of suitable habitat protected for VME indicator taxa by 20–30 percentage points in these areas.
- A range of additional analyses have been undertaken to explore uncertainty in the habitat suitability index (HSI) modelling, including potential model over-prediction, as well as analyses of the relationships between HSI and abundance of VME indicator taxa on the seafloor and the catchability of VME indicator taxa in trawl gears. These analyses should be considered when interpreting results provided in the VME impact assessment and making inferences about the performance of CMM03-2023 (bottom fishing).

1.2 DESCRIPTION OF FISHING ACTIVITIES

Fishing gear and activity using the methods of bottom trawl (mostly targeting orange roughy), midwater trawl (targeting benthopelagic species like alfonsino), and bottom line fishing methods (mostly targeting bluenose or wreckfish but with more fishing recently for subtropical and tropical species) are described for Australian and New Zealand-flagged vessels separately.

1.3 MAPPING AND DESCRIPTION OF FISHING AREAS

Fishing areas for the methods of bottom trawl (mostly for orange roughy), midwater trawl (for benthopelagic species like alfonsino), and bottom line-fishing methods are described for New Zealand-flagged and Australian-flagged vessels, and maps are provided for New Zealand-flagged vessels.

1.4 IMPACT ASSESSMENT METHODS

A range of impact and risk assessment methods are applied to the various assets and hazards relevant to bottom fisheries in the southwestern portion of the SPRFMO Convention Area where bottom fishing currently occurs. Largely expert-based qualitative or semi-quantitative assessments have been completed for non-target fish stocks and marine mammals, seabirds, reptiles and other species of concern that are occasionally caught in SPRFMO bottom fisheries. Fully quantitative or semi-quantitative assessments have been completed for orange roughy, the main target species (by weight) for bottom fisheries, and for benthic habitats and taxa indicative of VMEs.

1.5 CHANGES MADE SINCE THE 2020 BFIA

Sections within this BFIA that have been substantively updated since the 2020 BFIA include:

- 2.2 A history of SPRFMO bottom fishing management arrangements – updated to reflect changes in Conservation Management Measures since 2020
- 4.4. Fisheries interactions with benthic habitats and VMEs – updated to reflect recent refinements to how performance of spatial management areas is evaluated and the inclusion of habitat suitability models for new taxa
- 4.5 Risk assessment for benthic habitats, biodiversity and VMEs – Relative Benthic Status (RBS) estimates have been updated to reflect refinements in reporting metrics, and to include RBS estimates for spatial management measures implemented under CMM03-2023 and proposed to be implemented in 2024 to provide a minimum of 70% protection of predicted suitable habitat for VME indicator taxa.
- 4.6 Mitigation, management and monitoring measures – updated to include changes to VME encounter thresholds in 2021, and inclusion of metrics reporting the performance of spatial management measures in protecting all 16 modelled VME indicator taxa, as implemented under CMM03-2023 and proposed to be implemented in 2024 to provide a minimum of 70% protection of predicted suitable habitat for VME indicator taxa.
- 4.7 High level assessment across all assets/objectives – updated with new summary results for RBS estimates and the performance of spatial management measures, and sensitivity analyses for excluding areas of low environmental coverage and fishable depth in areas proposed to be closed to fishing to achieve a minimum level of 70% protection.

- 4.8 Uncertainties, next steps and research requirements – updated to reflect recent work evaluating catchability of VME indicator taxa

1.6 STATUS OF STOCKS

Fully quantitative stock assessment modelling has been completed only for orange roughy in a range of areas thought to represent separate stocks. All such assessments for non-straddling stocks are data-limited and have broad uncertainty. The Scientific Committee considered at its 5th meeting in 2017 that, although the data were limited and none of the methods was ideal for the assessment of SPRFMO orange roughy stocks, these assessments are, collectively, indicative of stock status and potential yields. Based on these models, advice on catch limits was developed for the first time in 2017 for groups of stocks in the Tasman Sea (excluding the Westpac Bank area) and on the Louisville Seamount Chain (LSC). The proposed catch limits were more precautionary for the Tasman Sea stocks than the LSC stocks, based on the relative risk of these stocks being below 20% of the unfished biomass (a common limit reference point for commercial fisheries). A fully quantitative stock assessment undertaken in 2019 that suggested that the stock biomass had continued to increase since the fishery was re-opened in 2011. In light of subsequent uncertainty in the 2019 stock assessment highlighted in the 2022 stock assessment, a precautionary approach has been pursued. Using catch history, and age and length compositions, estimates were made of the minimum pre-fishing biomass that could have supported historical catches for Central, South, and North Louisville stocks, West Norfolk stock, Lord Howe Rise stock, and Northwest Challenger stock. These estimates were used to inform reductions in the catch limits for these stocks in 2023.

1.7 MONITORING, MANAGEMENT AND MITIGATION MEASURES

All fishing pursuant to CMM03-2023 (bottom fishing) and CMM03a-2023 (deepwater species) requires flag States to provide detailed information on the time and location of each fishing event, the catch of target and non-target species of fish, interactions with marine mammals, seabirds, reptiles and other species of concern, and benthic invertebrates, including VME indicator taxa. There is also a requirement to carry observers, with coverage specified as 100% for trawling and at least 10% for bottom line methods for each fishing year. Observers collect complementary and sometimes more detailed information (for example measuring fish lengths and collecting otoliths for age determination). The information requirements are detailed in CMM02-2022 (data standards). The measures in place to mitigate bycatch of seabirds in SPRFMO bottom fisheries is close to world best practice (as defined by Agreement on the Conservation of Albatrosses and Petrels (ACAP)). These are specified in CMM09-2017 (seabirds). Species- and area-specific catch limits for orange roughy and aggregate limits for all other fish species combined are specified in CMM03a-2023 (deepwater species). Minimum levels of observer coverage, spatial management (open areas by fishing method), a VME encounter protocol and a VME registry are specified in CMM03-2023 (bottom fishing).

2 DESCRIPTION OF FISHING ACTIVITIES

2.1 GENERAL HISTORY AND CHARACTERISTICS OF THE FISHERIES

The SPRFMO Convention Area has historically been fished by vessels from various nations using pelagic and demersal fishing gear. The main high-volume commercial fisheries resources managed by the SPRFMO are Chilean jack mackerel (*Trachurus murphyi*) and jumbo flying squid (*Dosidicus gigas*). The SPRFMO also manages fisheries for lower-volume demersal species such as orange roughy and alfonsino, which are caught using bottom and midwater trawl gears, and a variety of demersal species caught using bottom line gears. These demersal fisheries are the focus of this assessment. Historically, these demersal fisheries have targeted species associated with seamounts, ridges and plateaus in the southern Pacific Ocean. In recent decades, Australian and New Zealand fisheries have mostly been confined to the western part of the SPRFMO Convention Area. There are five main fishing grounds in the region: the high seas parts of the South Tasman Rise off Tasmania, the West Norfolk Ridge, Lord Howe Rise, the Northwest Challenger Plateau in the Tasman Sea west of New Zealand, and the Louisville Seamount Chain (LSC) to the east of New Zealand. Australia and New Zealand are the only two Members currently authorised to fish in the established demersal fisheries, although some other Members are authorised to fish in exploratory fisheries elsewhere in the Convention Area. These fisheries are assessed and managed under a separate regime.

Deep-sea features tend to attract and support fish resources because their physical and biological properties enhance local productivity. Some deepwater species form dense spawning aggregations over deep-sea features, potentially allowing high catch rates and large catches (Norse et al. 2012). Some demersal species are slow growing and long lived, and aggregations can represent the accumulation of numerous age classes recruited over many decades. Initial catch rates typically taken on these aggregations may not be sustainable and can lead to rapid declines in abundance and availability (Norse et al. 2012). Long-term sustainable yields are usually only a small percentage of initial high catches. The fishery and biological data and other information to support management are also often limited data, which poses challenges for their sustainable utilisation and exploitation (FAO 2009). Despite these challenges, sustainable and profitable fisheries for deepwater species such as orange roughy are achievable and, notwithstanding historical overfishing of several stocks globally, there are examples of sustainable, well-managed stocks (e.g., FRDC 2021).

Trawl fleets from the former Union of Soviet Socialist Republics (USSR) began fishing the high seas in the south Pacific for deepwater species in the early 1970s. These vessels fished several areas, taking pencil (or bigeye) cardinal fish (*Epigonus denticulatus*), orange roughy, blue grenadier (*Macruronus novaezelandiae*) and oreo dories (Oreosomatidae) (Clark et al. 2007). Before the advent of 200 nautical mile (NM) Exclusive Economic Zones (EEZ) in 1982, it is not possible to be categorical as to whether catches came from what are now high seas areas, or from within what are now EEZs. There was some exploratory fishing by both Australian and New Zealand vessels on the Challenger Plateau and Lord Howe Rise from the mid-1980s, but it was in 1988 that the first major fishery in this region was developed on Lord Howe Rise, followed by the northwest Challenger Plateau two years later. Subsequently, commercial fisheries were developed on the Louisville Ridge (1993), the South Tasman Rise (1997), and the West Norfolk Ridge (2001). Since 1992, catches have been dominated by New Zealand and Australian vessels but other nations, including Belize, Japan, Norway, Panama, the Republic of Korea and Ukraine, also accessed these deep-sea resources (Gianni 2004).

In recent years, most of the catch of orange roughy in the SPRFMO Convention Area is taken during winter on spawning aggregations associated with underwater topographical features such as seamounts. Australian and New Zealand fishing vessels also target alfonsino using demersal and midwater trawl gears. Australian and New Zealand bottom line fishing vessels have historically targeted species such as bluenose/blue-eye trevalla (BWS, *Hyperoglyphe antarctica*), gropers/hapuku (HAU, *Polyprion* spp.), tarakihi/jackass morwong (MOW, *Nemadactylus macropterus*), yellowtail kingfish (YTC, *Seriola lalandi*), and a variety of other species.

2.2 HISTORY OF SPRFMO BOTTOM FISHING MANAGEMENT ARRANGEMENTS

Up until the early- to mid-2000s, most deep-sea fisheries in high seas areas of the south Pacific Ocean were regulated by domestic provisions imposed upon fishers by relevant flag states. Illegal, unreported and unregulated (IUU) fishing has also been a major historical problem in the South Pacific and southern oceans more broadly (e.g., Österblom and Bodin 2012). The first push towards contemporary international fisheries management arrangements for non-highly migratory fisheries resources in the high sea’s areas of the South Pacific Ocean came in 2006, when Australia, Chile and New Zealand initiated a process of consultations to enable cooperation between states to address gaps that existed in the international conservation and management of fisheries resources and protection of biodiversity of the marine environment in the area.

Shortly after this, in 2006, the UNGA adopted Resolution 61/105 that called on States and Regional Fisheries Management Organisations (RFMOs) to take urgent action to protect VMEs from destructive fishing practices, including bottom fishing, in areas beyond national jurisdiction. Key elements of Resolution 61/105 included undertaking impact assessments to determine whether bottom fishing activities would have SAIs on VMEs, identifying VMEs, establishing move on protocols, sustainably managing the exploitation of deep-sea fish stocks, and establishing appropriate monitoring, control, and surveillance mechanisms[2].

Consistent with UNGA Resolution 61/105, the Bottom Fishing Interim Measures adopted by participants at the third international consultation to establish the SPRFMO in 2007 required participants to “Not expand bottom fishing activities into new regions of the Area where such fishing is not currently occurring” which resulted in individual ‘footprints’ for Australia and New Zealand representing the spatial distribution of effort between 2002 and 2006. The interim scientific working group subsequently recommended that areas that were ‘currently’ being fished be expressed as grid blocks of 20-minute resolution that had been fished over the period

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[2] In 2009, UNGA adopted Resolution 64/72. While reaffirming Resolution 61/105, it asserted that measures should be implemented by flag states and RFMOs in accordance with the FAO (2009) Guidelines, prior to allowing or authorising bottom fishing in the high seas. Resolution 64/72 calls for States and RFMOs to conduct impact assessments on bottom fishing on the high seas and to ensure that vessels do not engage in bottom fishing until such assessments have been carried out.

2002 to 2006, this being the reference period subsequently chosen for limiting bottom fishing effort and catch to ‘existing levels’.

2009 was a significant year in the development of high seas bottom fishing management. Following a series of international meetings, participants decided to establish a regional fisheries management organisation and on 14 November 2009, the 8th international meeting adopted the Convention on the Conservation and Management of High Seas Fishery Resources in the South Pacific Ocean. Also in 2009, the FAO published the International Guidelines for the Management of Deep-Sea Fisheries in the High Seas (FAO 2009), which provided recommendations on governance frameworks and management of deep-sea fisheries with the aim to ensure long-term conservation and sustainable use of marine living resources in the deep sea and to prevent SAIs on VMEs. Importantly, these guidelines also defined SAIs and VMEs, with these definitions having been used widely by demersal RFMO/As to the current day. In the same year, the UNGA adopted Resolution 66/68 reinforcing earlier Resolutions, and calling on States and RFMOs to apply a precautionary approach and these FAO Guidelines.

Based on the early international agreements, UNGA Resolution 61/105 and the FAO (2009) guidelines, once SPRFMO entered into force in 2012, Australia and New Zealand set about implementing management arrangements that would satisfy the varied international obligations and objectives as manifested through the SPRFMO Convention and related non-binding instruments.

The first formal CMM for the Management of Bottom Fishing in the SPRFMO Convention Area came into force on 4 May 2014. The CMM was reviewed annually, with minor changes, while Australia and New Zealand progressed a more comprehensive review.

In 2016, the UNGA adopted Resolution 71/123 which strongly emphasised the importance of strengthening procedures for carrying out, reviewing and evaluating impact assessments, taking into account individual collective and cumulative impacts, and ensuring that any measures are based on best available scientific information, and adopt an ecosystem approach. It also noted the unevenness of implementation of the earlier resolutions. The 2016 Resolution influenced the development of a more comprehensive measure, which applied a novel approach to spatial management and consistent rules for all Members, adopted as CMM 03-2019 in 2019.

Since then there were only minor changes until the adoption of a comprehensive measure in 2019, which was subsequently revised in 2020, 2021, 2022 and 2023. The historical management arrangements implemented by Australia and New Zealand up to 2019, and contemporary management arrangements from 2019 to 2023 are summarised briefly below. We also present a brief summary of the joint Australia-New Zealand BFIA completed in 2020.

2.2.1 New Zealand’s pre-2019 historical bottom fishing management arrangements

In 2008, New Zealand completed a bottom fishery impact assessment for bottom fishing activities by New Zealand vessels fishing in the high seas in the SPRFMO Convention Area during 2008 and 2009. The assessment concluded that there were a variety of impacts on different ‘assets’ (i.e., VMEs, fish stocks, deepwater elasmobranchs, seabirds, and impacts resulting from loss of gear) and proposed a series of management and mitigation measures to minimise risks and impacts.

New Zealand established measures to manage bottom fishing in the SPRFMO Convention Area in the form of high seas fishing permit conditions, imposed from 1 May 2008. The key elements of those permit conditions included:

- Schedules designating open, move-on and closed bottom trawling areas within the historical (2002–2006) New Zealand high seas bottom trawl fishing footprint, and prohibiting bottom trawling within closed areas and everywhere else in the SPRFMO Convention Area.
- The VME Evidence Process for bottom trawling within move-on areas, with the requirement to report to the Ministry for Primary Industries and move-on 5 nautical miles from where the VME evidence threshold was reached.
- A requirement to carry at least one observer on all bottom trawling trips.
- Setting an overall catch limit for New Zealand bottom fishing vessels at the level it was during the reference period (2002-2006), including a species-specific catch limit for orange roughy.

The effect of these measures was to close bottom trawling in 41% of the total 217 463 km^2 New Zealand bottom trawl footprint area, with 30% of that made subject to a move-on rule, and 29% left open to bottom trawling. The open area represented 0.13% of the entire SPRFMO Convention Area (noting that over 90% of the western part of the SPRFMO area is too deep for bottom trawling). New Zealand modified the status of a small number of blocks within its bottom trawl footprint in 2015 such that opportunities for midwater trawling for bentho-pelagic species like alfonsino could be maintained while decreasing the risk of SAIs on VMEs.

The New Zealand VME Evidence Process incorporated weight thresholds for different taxa, based on an analysis of bycatch weight-frequency distributions in historical trawl catches, mostly within New Zealand's EEZ. This protocol also included a biodiversity threshold, summing the scores for presence of each taxon and requiring a move-on if any three of the listed VME indicator taxa were caught, even if individual weight thresholds were not breached (Parker et al. 2009). Further, a three-level weighting was applied to each of the VME indicator taxa groups based on the known importance of each group. Groups that exhibit life-history characteristics that are known to contribute to higher vulnerability to fishing activities were scored high, while other groups that may be less vulnerable themselves, but indicate the presence of habitats containing VMEs, were scored low. If the total VME indicator score was three or greater, the trawl was considered to have generated evidence of having encountered a VME and the vessel was required to move away (Parker et al. 2009).

2.2.2 Australia's pre 2019 historical bottom fishing management arrangements

From 2007 until 2019, Australia restricted fishing to within its 2002–2006 bottom-fishing footprint (expressed as 20-minute resolution grid cells) and limited catch to the average annual levels during this same period. All areas within that footprint were open to Australian vessels; and all areas outside that footprint were closed. Australia implemented a VME encounter protocol where if combined catch of coral or sponge in any one shot exceeded 50 kg of corals and sponges in a trawl shot or 10 kg bycatch of corals and sponges in a 1000 hook section of line for automatic longline operations, then fishers were required to stop fishing immediately and not fish using the same method at any point within a 5 NM radius of any part of the shot until the Australian Fisheries Management Authority (AFMA) notified otherwise. Any evidence of a

VME such as coral or sponges in a fishing shot was required to be recorded in logbooks. These measures also required 100% observer coverage for all trawl operations, and for all other methods, mandatory observer coverage for the first trip of each season and ongoing coverage of at least 10% annually.

In 2011, Australia completed a bottom fishery impact assessment in the SPRFMO Convention Area to examine whether individual bottom-fishing activities by Australian vessels would have SAIs on VMEs (Williams et al. 2011). The study concluded that the overall risk of SAIs on VMEs by Australian bottom trawl and bottom longline operations was low, and the impact caused by midwater trawling and drop-lining was negligible (Williams et al. 2011).

2.2.3 Contemporary bottom fishing management arrangements (2019 to 2023)

Following a recognition by the SPRFMO Commission that the different implementation of SPRFMO bottom fishing measures by members was sub-optimal, Australia and New Zealand initiated discussions to agree and implement a revised bottom fishing measure so that consistent management arrangements would apply to all SPRFMO Members engaged in established bottom fisheries in the SPRFMO Convention Area. There were also ongoing concerns expressed by the international community, in particular environmental non-government organisations, that the measures in existence (and how they were being interpreted) were not meeting the intended objectives of the relevant UNGA Resolutions and associated instruments (e.g., the FAO (2009) Deep-Sea Guidelines).

In response, CMM03-2019 provided a comprehensive set of rules based on a spatial management approach that aimed to ensure the long-term conservation and sustainable use of deep-sea fishery resources. The approach aimed, through the protection of a large proportion of the predicted distribution of VME indicator taxa, to provide assurance that bottom fishing within the Evaluated Area[3] would not have SAIs on VMEs. The measure also contained complementary measures, including VME encounter thresholds, move-on protocols and review processes within areas that are open to fishing to provide further assurance that SAIs on VMEs will be prevented. The SPRFMO Scientific Committee reviewed and agreed that the methodology underpinning the measure was appropriate. The measure included:

a) An Evaluated Area within which the distribution of VME indicator taxa has been mapped between depths of 200 m and 3000 m[4] using predictive models (Georgian et al. 2019; Stephenson et al. 2022a) and which considers cumulative impacts of fishing, an

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[3] The Evaluated Area is those that parts of the Convention Area that are within the area starting at a point of 24°S latitude and 146°W, extending southward to latitude 57° 30S, then eastward to 150°E longitude, northward to 55°S, eastward to 143°E, northward to 24°S and eastward back to point of origin.

[4] It is recognised that VME indicator taxa and habitat found in the deeper parts of the areas open to bottom trawling are unlikely to be impacted by bottom trawling because they are too deep to be trawled using existing technology. Analyses (e.g. Delegation of New Zealand, 2019, POLI-55-1615) indicate that bottom trawling is very rare in waters deeper than 1250 m and has never been reported deeper than 1400 m, meaning that any part of the distribution of a VME indicator taxon that is inside the areas proposed open to bottom trawling but deeper than 1400 m is not likely to be disturbed by trawl gear in the foreseeable future.

improvement on the existing approach (which considers impacts only by individual flag State);

b) Three Management Areas[5] within the Evaluated Area in which bottom fishing may be conducted, based on spatial prioritisation using Zonation software (Moilanen et al. 2009) which are implemented consistently across the membership and differentiated by gear (bottom trawl, midwater trawl and bottom longline);
c) A VME encounter protocol within the bottom and midwater trawl Management Areas, to be implemented consistently across the membership;
d) Measures to assess, monitor and control bottom fisheries.

CMM03-2019 essentially allowed for two avenues for bottom fishing with a particular gear type in the SPRFMO Convention Area:

(1) In a defined Management Area (within the Evaluated Area) for that gear type pursuant to the revised CMM (CMM 03-2019), or
(2) Anywhere else in the Convention Area, or within the Management Area with a gear type other than that provided for in the revised CMM, under CMM 13-2016 (Exploratory fisheries).

Recognising that there is a level of uncertainty associated with VME habitat suitability models, CMM03-2019 also incorporated an encounter protocol that triggers an immediate management response to the capture of defined amounts of VME indicator taxa in areas open to fishing (defined as an 'encounter'). This approach was designed to be consistent with the UNGA Resolutions noted earlier, and the FAO (2009) guidelines with respect to RFMO/As having an appropriate protocol identified in advance for how fishing vessels in deep-sea fisheries should respond to encounters in the course of fishing operations with a VME, including defining what constitutes evidence of an encounter and requiring vessels to cease bottom fishing activities at the site and to report the encounter.

In designing the encounter protocol, the threshold for the move-on rule was set at a level that would be triggered only by very unusual events that suggest the models that underpin the spatial management areas may be misleading.

The 6th meeting of the SPRFMO Scientific Committee (SC-06) noted that insufficient data from bottom longline fisheries exist to develop a data informed VME indicator taxa threshold for that method, but within this context noted that line fishing within candidate areas open to fishing is likely to have risks to VMEs several orders of magnitude lower than bottom trawl fishing. Therefore, SC-06 agreed that VME encounter protocols should be developed for bottom trawl fishing only and should include taxon-specific weight thresholds for key VME indicator taxa and a biodiversity threshold where several VME indicator taxa are taken. In the absence of data allowing the calculation of biomass-derived thresholds (e.g., taxa specific biomass estimates, VME patch size estimates, taxon-specific catchability, probability of encounter with bottom

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[5] The three Management Areas are the 'open' areas, although each Management Area actually comprises several smaller, spatially discrete areas.

trawl gear, etc.), calculations were based on observed benthic bycatch of VME indicator taxa from the New Zealand bottom trawl fishery[6].

The FAO (2009) Deep-Sea Guidelines recommend that VME indicator taxa weight thresholds should ideally be specific to area and taxon. Although the Evaluated Area can be divided into two distinct geographic areas, the LSC to the east of New Zealand, and various Tasman Sea fisheries to the west of New Zealand, there was insufficient data for many taxa within each area to enable the generation of area-specific weight thresholds. Therefore, VME indicator taxon-specific weight thresholds were generated for the entire Evaluated Area. Recognising that the presence of a small amount of a single VME indicator taxon is unlikely to indicate an encounter with a VME (within the meaning of the term ‘encounter’ in CMM 03-2020), and that the presence of several VME indicator taxa in a single tow may indicate that the fishing event has encountered an area with a diverse seabed fauna, potentially constituting evidence of a VME, the encounter protocol includes both weight and biodiversity thresholds.

Weight and biodiversity thresholds were identified from taxon-specific plots of the cumulative distribution of historical non-zero catch weights using the points at which each curve begins to flatten. Thresholds indicating unexpectedly large catches should ideally fall to the right of such points, whereas “biodiversity weights” indicating increasing numbers of taxa in a single tow at weights below the threshold trigger might occur to the left. The choice of a percentile to the left or right of the threshold value depends on the desired sensitivity of the encounter protocol and is largely a management question relating to the desired level of precaution.

For CMM03-2019, the Commission adopted weight thresholds for Porifera, Gorgonacea, Scleractinia, Antipatharia, Actiniaria and Alcyonacea equal to the 99th percentiles of ordered values of bycatch weight from New Zealand bottom trawl tows conducted in the evaluated area of the SPRFMO Convention Area over the period 2008-2018 (with some rounding), which fell to the right of taxon-specific “inflection points” on the curves. This choice of threshold was intended to ensure that the encounter protocol is not too sensitive and responds only to very unusual events that suggest the models that underpin the spatial management areas may be misleading.

Following the initial implementation of the measure in 2019, additional work was done to explore uncertainties in the modelling and the management approaches that had been agreed. This work (Pitcher et al. 2019) identified uncertainties in the model predictions of habitat suitability and other outputs that underpinned the spatial management approach adopted in CMM03-2019, as well as providing advice on the appropriateness of the VME encounter thresholds specified in the measure. Following review of this work, the 7th meeting of the SPRFMO Scientific Committee (SC-07) agreed (amongst other things) that uncertainty in the predictions of the habitat suitability models for VME indicator taxa may be higher than previously thought and that this leads to increased uncertainty in estimates of the proportion of VME indicator taxa, in particular stony corals, protected across the modelled region. Specifically, the Scientific Committee noted the results might indicate that CMM03-2019 may provide less

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[6] Australian data were not included in this analysis because benthic bycatch records are not captured in databases with the same precision and resolution as New Zealand benthic bycatch data. Inclusion of these lower-resolution data would reduce the overall quality of the data set.

protection than previously thought. SC-07 also agreed that the VME indicator taxa thresholds outlined in CMM03-2019 were likely to correspond to high coverage and biomass of VME indicator taxa on the seabed and that further work was required to establish whether the thresholds specified in CMM03-2019 were consistent with the objectives of the measure to prevent SAIs on VMEs, and that it was important to evaluate whether bycatch of VME indicator taxa that correspond to these thresholds would result in SAIs. Further, SC-07 agreed that given these increased uncertainties, lower encounter thresholds for VME indicator taxa would help to mitigate risks of SAIs on VMEs until key uncertainties with the performance of the spatial management measures could be resolved. Subsequently, the SPRFMO Commission reduced the threshold for Scleractinia (stony corals) from 250 kg to 80 kg in CMM03-2020. CMM03-2020 (and its predecessor, CMM03-2019) includes a mandatory annual review process for VME indicator encounters and benthic bycatch data.

The spatial modelling of VME indicator taxa and estimates of the level of protection for each modelled VME indicator taxon was updated in a cumulative bottom fishing impact assessment (BFIA) in 2020 (Delegations of Australia and New Zealand 2020). The SC-08 evaluation of the BFIA found that the proportion of suitable VME indicator taxa habitat protected was uncertain and that there were a number of Fishery Management Areas where the level of suitable habitat protected for some VME indicator_taxa was less favourable (SC8 Report, 2020). SC-08 recommended that the Commission may wish to consider additional precautionary management measures for areas and taxa at higher risk from bottom trawl fisheries to address uncertainty and provide additional confidence that the CMM will meet its objective (SC8 Report, 2020). Subsequently, the Commission reduced the threshold for stony corals from 80 kg to 60 kg, the thresholds for Porifera from 50 kg to 25 kg, and updated the list of VME indicator taxa to include Zoantharia, Hydrozoa and Bryozoa, with corresponding weight and/or biodiversity thresholds (CMM03-2021). The Commission also tasked the SC to develop spatial management options that protect a minimum of 70%, 80%, 90%, 95% of suitable VME indicator taxa habitat at spatial scales comparable to the Fisheries Management Areas (CMM03-2021). In response, candidate spatial management scenarios were presented to Commission in 2022 (COMM10-Inf03), with Commission establishing at its 11th meeting in 2023 a 70% minimum level of protection for suitable habitat for each modelled VME indicator taxa, to be implemented at its 12th meeting in 2024. At the same meeting, the Commission revised CMM03 to require the Scientific Committee to adopt the Fisheries Management Area as the appropriate scale of management for assessing the performance of spatial management areas, develop a biologically-relevant multi spatial-scale risk-based approach to assess encounters with VME indicator taxa, develop an Encounter Review Standard by its 12th meeting, and develop a register of known VMEs, which are to be excluded from areas open to fishing.

In relation to fish stocks, prior to the implementation of CMM03-2019, demersal fish stocks were managed as part of the various historical bottom fishing CMMs by limiting catch to that taken by a flag state in the defined reference period between 2002 and 2006. In 2019, management measures for deepwater fish stocks were separated into the CMM for Deepwater Species in the SPRFMO Convention area (CMM03a-2019), which has subsequently been updated three times (CMM03a-2020, CMM03c-2021 and CMM03a-2023). This measure defines nine orange roughy fisheries management areas and sets specific catch limits for orange roughy stocks, and general catch limits for all other species caught by SPRFMO Members' vessels fishing in the SPRFMO

Convention Area (currently only Australia and New Zealand). Despite the separation of the CMMs 03 and 03a to reduce complexity, both measures share the same overarching objectives.

There is currently a large body of work underway leading up to full review of CMM03-2023 in 2026, including:

- Development of a process to review all recent and historical benthic bycatch data to determine the ongoing effectiveness of the spatial management measures
- Assessing the feasibility and develop a research programme within the SPRFMO Convention Area to allow the determination of taxon-specific estimates of catchability for VME indicator taxa
- Developing an encounter review standard
- Developing a multi-spatial scale risk-based approach to assess encounters with VME indicator taxa
- Exploring thresholds for "significant" adverse impact (SAI) for VMEs at different spatial scales, and understanding knowledge gaps and uncertainties
- Developing abundance models for VME indicator taxa.

2.2.4 Bottom Fishing Impact Assessment Standard, and current state of BFIA with respect to the requirements of the BFIAS

In 2019 New Zealand and Australia produced a revised Bottom Fisheries Impact Assessment Standard, or BFIAS, (SC7-DW19Rev1) outlining the requirements for best practice impact assessment methods to evaluate the impact of bottom fishing activities on VME indicator taxa in the SPRFMO Area. *The Scientific Committee Recommended to the Commission that the revised BFIAS at Annex A (of SC07-DW19) be adopted for any relevant BFIA processes undertaken in accordance with CMM 03-2019 and CMM 13-2019.* The Scientific Committee also noted that key issues remained unresolved, and requested that the Commission work with other RFMOs to and produce guidance to the SPRFMO SC to address them. Key unresolved questions included the definition of SAIs and VMEs, and determination of the appropriate spatial scale at which the potential for SAIs on VMEs should be assessed.

The BFIAS was adopted at the subsequent meeting of the Commission, providing clear guidance for the subsequent production of a cumulative Bottom Fisheries Impact Assessment by Australia and New Zealand in 2020 (BFIA, below).

The question of the appropriate scale at which impacts should be assessed was only settled in 2023, when the Commission advised that the performance of spatial management to avoid SAIs on VMEs should be evaluated at the FMA scale (COMM11, as expressed para 39 of CMM03-2023). Consistent with that guidance, this update of the BFIA includes estimates of VME status summarised at the FMA scale.

Regarding the definition of SAI, in 2022 the Scientific Committee requested that the Commission develop specific objectives for VME management and provide clarity on the choice of an operational / quantitative threshold defining what level of impact would constitute a significant adverse impact. In 2023 the Commission endorsed this recommendation as a priority for further work (COMM11 SC Multi-annual Workplan). Work to define this operational threshold is ongoing.

Providing up to date impacts of current intact status and RBS for all VME indicator taxa at the FMA scale is a high priority for future updates to the BFIA.

2.2.5 Cumulative Bottom Fishery Impact Assessment for Australian and New Zealand bottom fisheries in the SPRFMO Convention Area, 2020

The UNGA Resolutions influenced the development and adoption by the SPRFMO of a standard for impact assessment of bottom fisheries (SPRFMO 2012), compatible with the Food and Agricultural Organisation's (FAO) International Guidelines for the Management of Deep-sea Fisheries in the High Seas ('the FAO Deep-sea Guidelines') (FAO 2009). The SPRFMO bottom fishery impact assessment standard was updated in 2019 (SPRFMO 2019). The updated standard requires that impacts on marine mammals, seabirds, reptiles, and other species of concern be addressed as well as impacts on fish stocks and VMEs to deliver on the action called for in the UNGA Resolutions. Australia and New Zealand presented a joint cumulative bottom fishery impact assessment (SC8-DW07_rev1) in 2020 in accordance with the relevant obligations prescribed in SPRFMO Conservation and Management Measures (CMMs) and the SPRFMO Bottom Fishing Impact Assessment Standard (BFIAS) (SPRFMO 2019).

Following review of the BFIA SC-08 agreed that the cumulative BFIA provided by New Zealand and Australia represents: the best science available to the SC at the current time; provides a sound basis for formulating management advice to the Commission; meets international standards (such as the FAO Deep-Seas Guidelines) and complies with the SPRFMO BFIA Standard and, consequently, accepted the BFIA (Delegations of Australia and New Zealand 2020).

SC-08 also agreed that the impacts of bottom fisheries on target and non-target fish stocks were appropriately assessed under the SPRFMO assessment framework noting:

- for Orange roughy, stock assessments have been undertaken that indicate all stocks are likely above limit biomass reference points and several are above target biomass reference points used elsewhere for the management of this species
- for other target species caught in SPRFMO demersal fisheries, workplans are being developed for stock structure delineation studies, which may inform future assessment and management
- for non-target and bycatch (discarded) species, ecological risk assessments have been undertaken to categorise these species into the SPRFMO stock assessment framework and prioritisation of species estimated to be at high and extreme relative risk from fishing has been undertaken.

The SC-08 agreed that captures of marine mammals, seabirds, reptiles and other species of concern are rare in midwater trawl for bentho-pelagic species and bottom trawl fisheries and appears to be rare in bottom line fisheries but requested bottom fishing Members to collaborate to develop a framework for providing precautionary advice on such captures.

In paragraph 73 of its report, the SC-08 also agreed that, with respect to impacts on benthic fauna and VMEs, that:

- The habitat suitability models have high statistical skill in classifying suitable VME indicator taxa habitat. However, there is great uncertainty in translating model outputs to estimates of abundance of VME indicator taxa on the seafloor, as well as issues of potential model over-prediction leading to over-optimistic estimates of protection for some taxa.

- The estimated footprints of midwater trawls for benthopelagic species and demersal line gears are orders of magnitude lower than those for demersal trawl gears and are thought to represent a low risk to VME status and habitat protection.
- The equilibrium status of most VME indicator taxa in most areas is qualitatively favourable across a range of sensitivity analyses, although there is a high level of uncertainty.
- The proportion of suitable VME indicator taxa habitat protected is uncertain but qualitatively favourable at most scales assessed. However, there are a number of areas at smaller scales (Fishery Management Areas) where the level of suitable habitat protected for some VME indicator taxa is less favourable including Northwest Challenger, Central Louisville and Southern Louisville.
- Suitable habitat for VME indicator taxa deeper than 1400 m is unlikely to be impacted by fishing (which essentially ceases at 1250 m). If a depth cut-off of 1400 m is applied, the proportion of suitable habitat for a subset of VME indicator taxa including stony corals unlikely to be impacted increases on the Central and Southern Louisville Ridge and becomes qualitatively favourable, but the core depth distribution of many other VME indicator taxa likely overlaps with fishable depths in these areas.

The SC-08 also agreed that, although the appropriate scale to assess and manage impacts on VMEs has not been defined in SPRFMO, the smaller scale of the Fishery Management Areas is likely to be a more biologically appropriate scale at which to assess and manage these impacts than larger scales. The SC-08 went on to note that there is currently a lack of a scientific underpinning for defining ecologically appropriate reference points for VME status or protection, and that, in the absence of SPRFMO-agreed reference points for assessment and management of VME status and/or the proportion of suitable habitat protected, it is not possible for the SC to provide a quantitative interpretation of the BFIA results against such reference points.

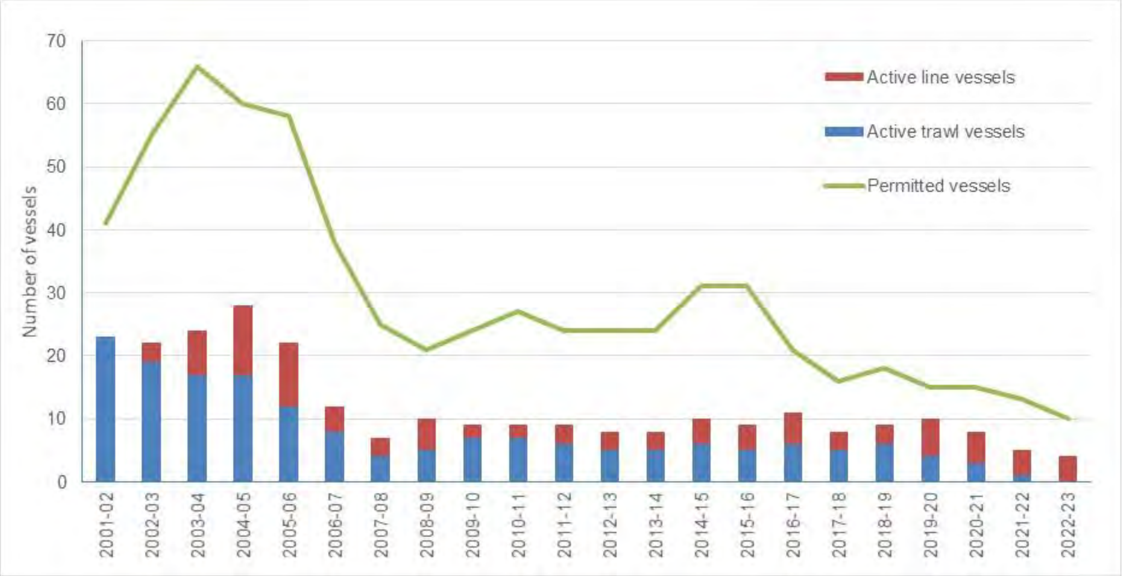
The Deep-Ocean Stewardship Initiative conducted a review of impact assessment for deep-sea fisheries on the high seas against the FAO Deep-sea fisheries guidelines in 2022, with the intent of identifying major issues with the current RFMO impact assessments and, where necessary, suggest ways to improve the effectiveness of future impact assessments in order to comply fully with the UNGA resolutions on deep-sea fishing. The results highlighted that SPRFMO is one of the few RFMO/As with a standardised impact assessment and reporting framework (and that other RFMOs could draw on the SPRFMO BFIAS to develop common standards for impact assessments), and that the SPRFMO 2020 BFIA was one of the most comprehensive impact assessments produced by RFMOs between 2009 and 2021. The 2020 SPRFMO BFIA was the only impact assessment of the nine evaluated that explicitly discussed the effectiveness of mitigation measures and how their implementation is monitored, and one of only three impact assessments that considered cumulative impacts of fishing activities. The main areas identified by the review as deficiencies within the 2020 SPRFMO BFIA included a lack of information on the topographical, environmental, hydrographic and other features of the area relevant to assessing ecological vulnerability and climate vulnerability not being included in VME assessments. It has not been possible to address these within the SPRFMO area as yet, but progress has been made toward assessing climate vulnerability (Anderson et al. 2022).

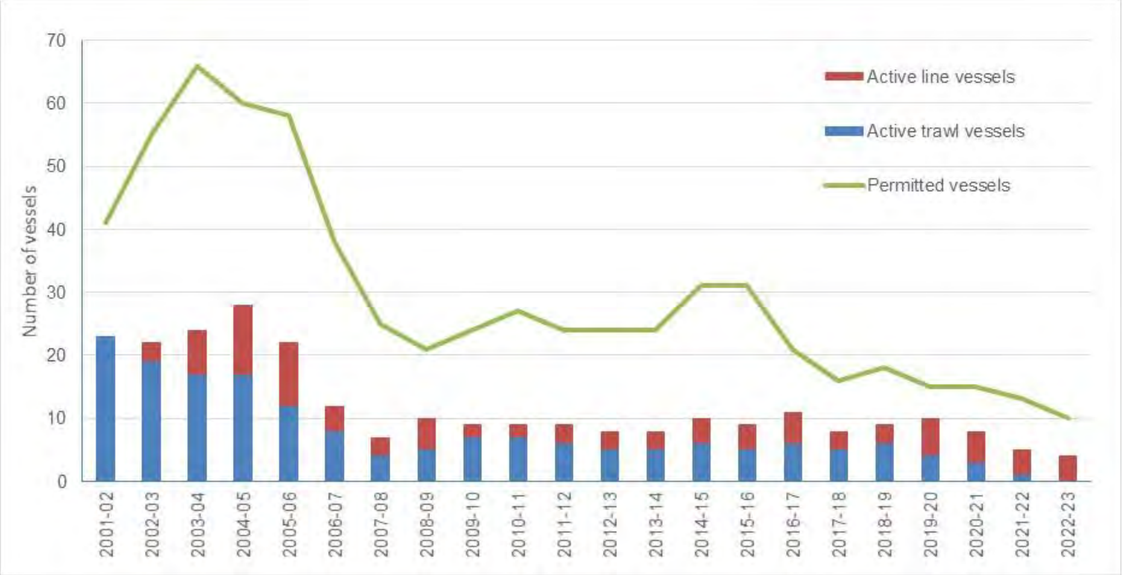
In 2022, the UNGA held a workshop to discuss the implementation of paragraphs 113, 117 and 119 to 124 of resolution 64/72, paragraphs 121, 126, 129, 130 and 132 to 134 of resolution 66/68 and paragraphs 156, 171, 175, 177 to 188 and 219 of resolution 71/123 on sustainable fisheries, addressing the impacts of bottom fishing on VMEs and the long-term sustainability of deep-sea fish stocks. It was pointed out that most RFMO/As had incorporated relevant Assembly resolutions and the Guidelines into their bottom fishing regulations. In that regard, examples of fisheries closures and area closures for the protection of seamounts were highlighted. It was noted, however, that implementation remained uneven, with little progress made in certain regions, and that more progress was needed in some areas, including in obtaining further biological information on the species that comprise VMEs and their interlinkages, protecting biodiversity beyond VMEs, consistent application of the VME criteria in the Guidelines by bottom fishing RFMO/As, the assessment of cumulative impacts and the improvement of move-on rules.

2.3 NEW ZEALAND BOTTOM FISHERIES

New Zealand has managed activities of its vessels fishing on the high seas by means of high seas permits since at least 2001 before the Interim Measures were adopted. SPRFMO management measures have been implemented through conditions on the high seas permits, which are updated regularly. Since specific conditions have been imposed for pre-SPRFMO or SPRFMO requirements (from 2008), numbers of vessels issued high seas permits to fish in the SPRFMO Convention Area initially fluctuated between 21 and 31 until 2015, but had declined steadily since this time, with only 10 vessels permitted to fish in 2022 (Table 1). The numbers of vessels actually fishing in any given year ranged between 8 and 11 until 2020, but declined to only 4 in 2022.

New Zealand fisheries in the SPRFMO Convention Area use trawl and various line methods. The number of vessels fishing using trawls declined steadily from a peak of 23 in 2002 and remained stable between 2008 and 2019 at between 5 and 7 vessels (Table 1, Figure 1) but has declined since then. The number of vessels fishing with bottom lines peaked at 11 in 2005 and has been stable between 2 and 5 vessels since (Table 1, Figure 1).





In recent years, there has been little change in the size of vessels permitted to fish (Table 2).

Table 1: Summary of the number of New Zealand vessels permitted to bottom fish in the SPRFMO Convention Area, and the number of vessels which actually fished in the Area by year with either bottom trawl or line, since 2001. The data are arranged by permit year, which is a split year from May to April. Data includes exploratory fishing.

Vessel Permit Year	Number of vessels permitted to fish the SPRFMO Convention Area	No. of vessels that actively bottom fished in the SPRFMO Convention Area	Bottom trawling	Bottom lining
2001–02	41	23	23	
2002–03	55	22	19	3
2003–04	66	24	17	7
2004–05	60	28	17	11
2005–06	58	22	12	10
2006–07	38	12	8	4
2007–08	25	7	4	3
2008–09	21	10	5	5
2009–10	24	9	7	2
2010–11	27	9	7	2
2011–12	24	9	6	3
2012–13	24	8	5	3
2013–14	24	8	5	3
2014–15	31	10	6	4
2015–16	31	9	5	4
2016–17	21	11	6	5
2017–18	16	8	5	3
2018–19	18	9	6	3
2019–20	15	10	4	6
2020–21	15	8	3	5
2021–22	13	5	1	4
2022–23	10	4	0	4

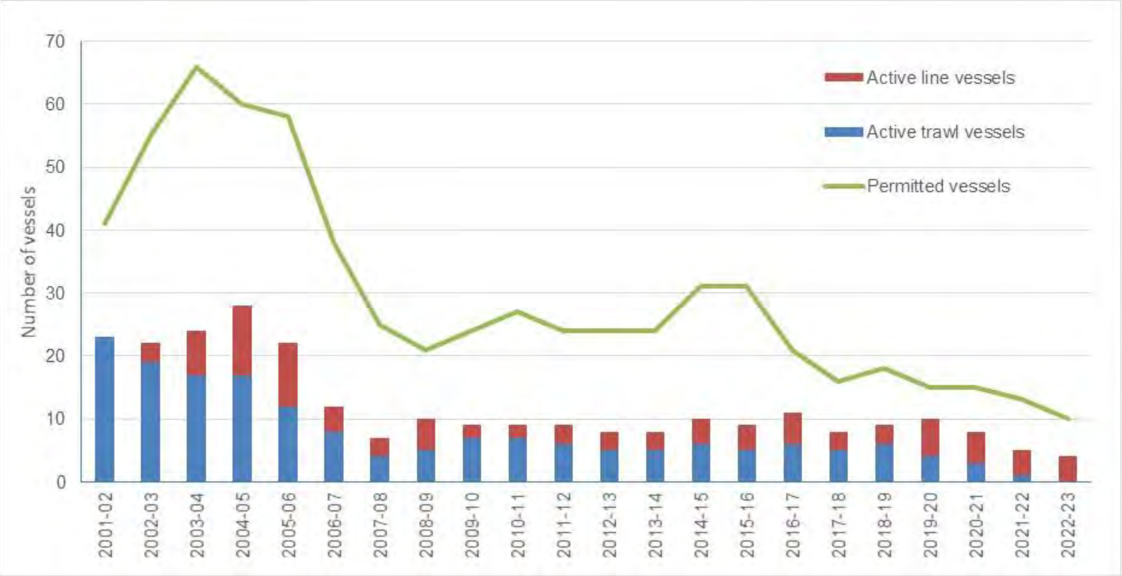


Figure 1: Summary of the number of New Zealand vessels permitted to bottom fish in the SPRFMO Convention Area and the number of vessels which were active in the Convention Area by year by method. The data are arranged by permit year, which is a split year from May to April. Data includes exploratory fishing.

Table 2: Frequency distribution of vessel size (length overall in metres, divided in 5 m classes) for New Zealand vessels permitted to bottom fish in the SPRFMO Convention Area for permit years (May–April) from 2008. Data includes exploratory fishing.

	Length overall (m)									
Permit year	**≤ 11.9**	**12–17.9**	**18–23.9**	**24–29.9**	**30–35.9**	**36–44.9**	**45–59.9**	**60–74.9**	**≥ 75**	**N. vessels**
2008–09	0	0	3	3	4	8	2	6	0	21
2009–10	0	1	3	1	5	6	0	6	2	24
2010–11	0	1	3	3	4	8	2	6	0	27
2011–12	1	1	3	1	2	8	2	6	0	24
2012–13	1	1	3	1	2	8	2	6	0	24
2013–14	0	1	3	2	2	7	2	6	1	24
2014–15	0	1	8	2	3	6	3	7	1	31
2015–16	0	1	7	3	4	7	3	4	2	31
2016–17	0	1	3	2	4	6	3	2	0	21
2017–18	0	1	3	0	3	5	3	1	0	16
2018–19	0	1	2	0	4	5	3	3	0	18
2019–20	0	1	4	0	2	4	3	1	0	15
2020–21	0	2	4	0	1	4	3	1	0	15
2021–22	0	1	3	0	1	3	3	2	0	13
2022–23	0	1	2	0	0	3	3	1	0	10

2.3.1 Trawl fisheries

2.3.1.1 General description

Trawl vessels flying the flag of New Zealand fishing in the SPRFMO Convention Area target orange roughy, alfonsino, cardinalfish and oreo species using either bottom or midwater trawl nets.

Modern deepwater trawling uses echosounders to target aggregations or plumes of fish when fishing on or near underwater features (e.g., seamounts). On flatter areas of seabed, where the fish are usually less aggregated and cannot be realistically detected using acoustic methods, more conventional "herding" trawl fishing is conducted using longer tows on flat, muddy or silty seabeds. Deepwater trawl gear has evolved in various ways towards agile net systems that minimise net size and unnecessary ground contact (particularly by non-fishing gear components such as trawl doors), including shortening groundrope lengths to reduce damage to fishing gear from hard substrates and ultimately enable nets to be more accurately aimed at fish aggregations.

Some typical deepwater trawl net designs currently used in New Zealand feature-based fisheries are shown in Figure 2. The nets are designed to provide net mouth width between wing-tips of 15–20 m under optimal towing conditions, with headline heights of 5–6 m above the footrope.

Net headropes are equipped with hard floats to provide the buoyancy needed to maintain the net open during trawling (see Figure 2). Nets are also equipped with netsounders and headline sensors to monitor the net opening, to determine position of the net relative to the seabed, and to facilitate accurate targeting of nets on acoustic fish targets. Nets are composed of panels of decreasing mesh size, made from braided nylon twines typically ranging 4–5 mm in diameter (wings vs end sections), doubled twines for areas of the net belly subject to abrasion and with heavier rope meshes in the codends. Codends and ground-gear (footropes designed to work on the sea bed, often including bobbins disks, weights, etc) can be rigged specifically, depending on the seabed type to be trawled and the species targeted.

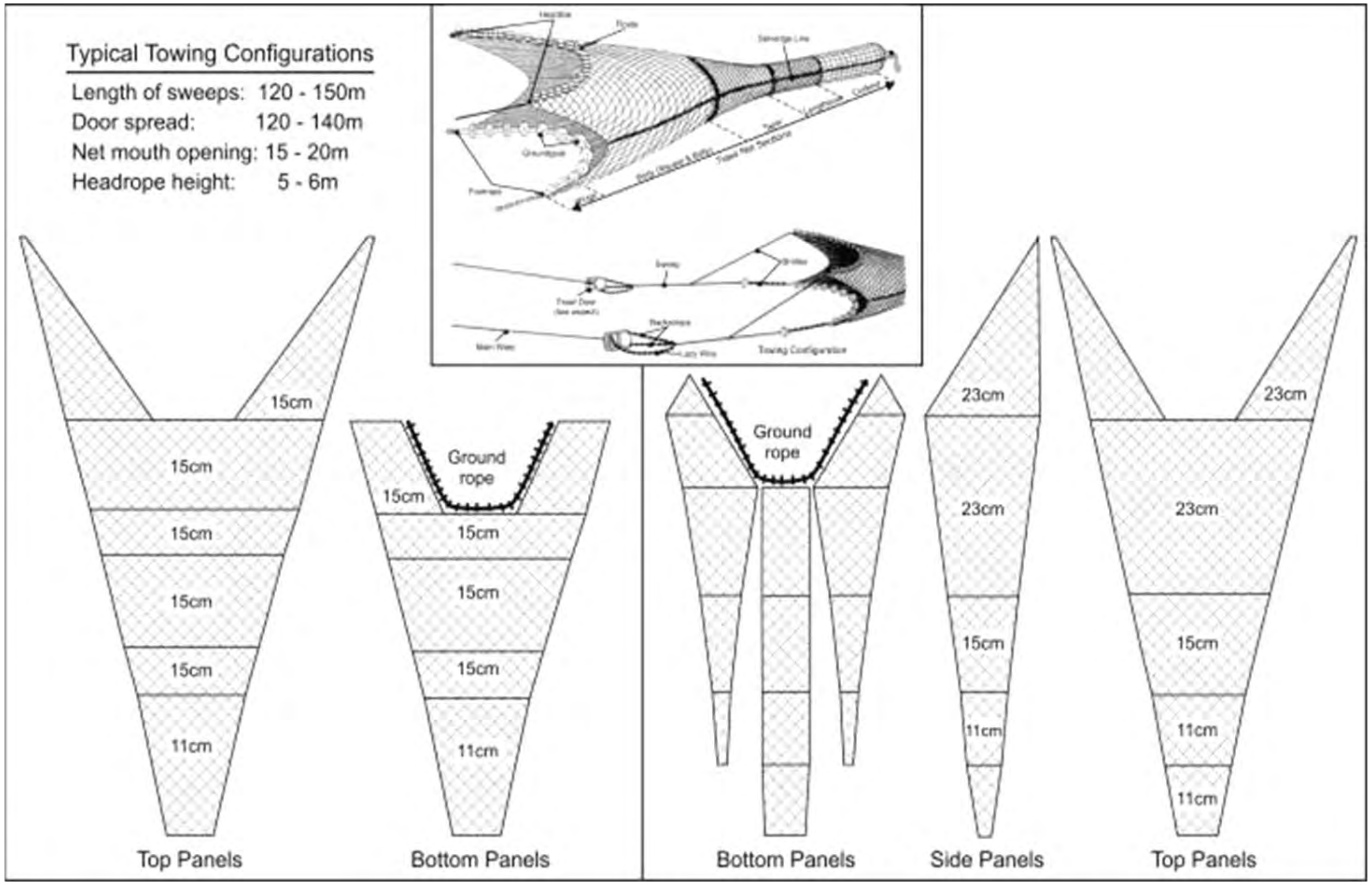


Figure 2: Stylised net construction diagrams for typical bottom trawl nets used in the New Zealand deepwater orange roughy targeted bottom trawl fishery. Numbers over the net describe mesh sizes of each panel. Two alternate simplified net designs are shown, using different mesh sizes and net wing configurations. Inset shows an illustration of the configuration of a typical bottom trawl net during trawling.

New Zealand deepwater bottom trawl fisheries initially used ‘vee-doors’, which have a low aspect ratio (i.e., their length is greater than their height, Figure 3a) and maximise the stability of doors during towing, but depend on bottom contact (ground sheer forces) to create their net spreading force. However, high aspect ratio doors (i.e., height 1.5 to 1.8 times length, see Figure 3b) were developed in parallel with better winch systems and increased use of electronics to accurately target fish aggregations. These doors do not require bottom contact and depend solely on hydrodynamic forces to generate spread. Efforts to reduce drag and increase control of trawl doors has also resulted in a move to smaller trawl doors (e.g., Nichimo, Hampidjan and Morgere high-technology doors).

The trawl doors currently used by New Zealand deepwater bottom trawlers typically weigh 1 200–2 000 kg and have an area of 4–8 m^2, depending on the vessel engine power and net design. Modern doors (such as the Morgere WX and WV doors shown in Figure 4b and c) are generally designed and rigged to operate off the bottom where the seabed is rough (e.g., on or near features), and are set to minimise the risk of digging in should there be any contact with the seabed. Deepwater trawl nets rigged in this way are often towed so that the net contacts the seabed only in the area of the aggregated fish, with the doors themselves not touching the seabed.

The length of sweeps and bridles (the towing and herding wires connecting the trawl doors and the net opening) has also been significantly shortened to provide better control over the gear and further reduce seabed contact. Currently, 120–140 m long sweeps and bridles combinations are typically used to connect the doors to the nets on orange roughy targeted trawls for feature-based fishing. With these configurations, the spread between the doors during towing is, at most, 120–150 m under good conditions, achieving net openings of 15–20 m between the wingtips. In areas where operators wish to accurately target fish aggregations and require maximal control of the net, they may even operate with very short bridles and no sweeps.

For bottom trawling on hard ground, net footropes are rigged with ground-gear to protect the footrope, and to enable the net to manoeuvre over rough terrain or minor obstacles. Early deepwater trawlers used steel bobbins on the groundrope when fishing hard ground, these being standard at the time on Northern Hemisphere cod trawlers. However, it has been found that these are not necessary, and that gear efficiency is improved, and bottom contact reduced by incorporating rubber components in the ground rope. Steel bobbins were first replaced with smaller 40–60 cm diameter rubber bobbins (Figure 5a) and, more recently, with 50–80 cm diameter rubber discs separated by spacers along the footrope (Figure 5b, the so-called ‘rockhopper’ gear). Whereas bobbins are designed to allow the footrope to roll over rough ground, the groundrope in a rockhopper system is rigged under tension, causing the net to ‘hop’ over encountered obstacles, rather than attempting to drag through or roll over them.

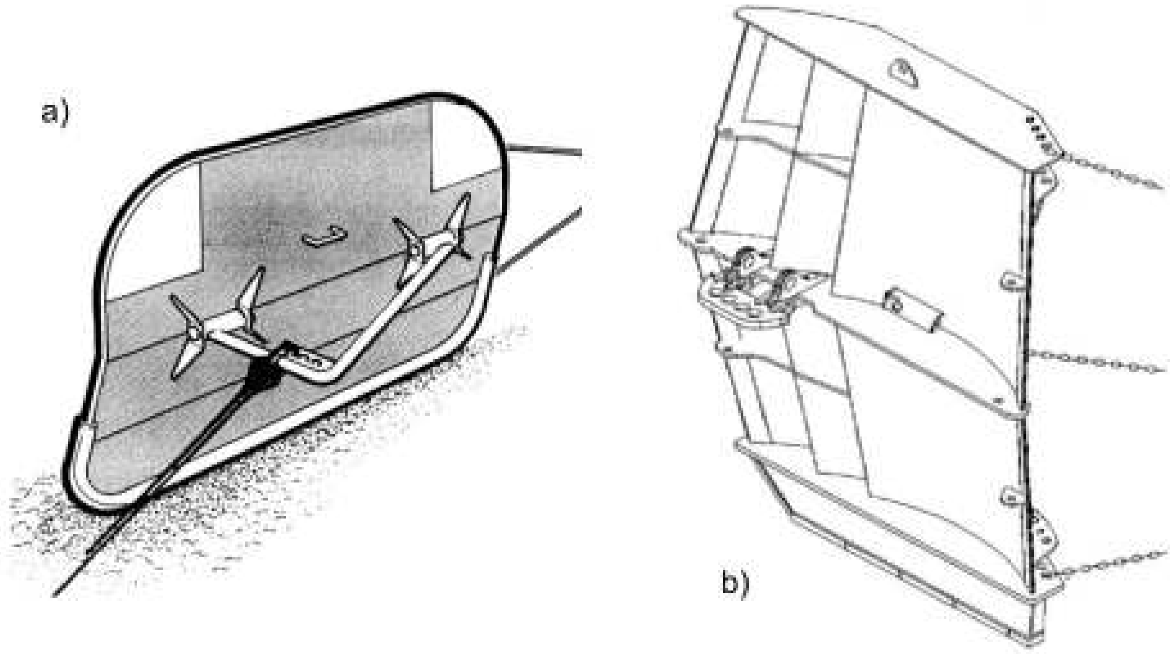


Figure 3: Illustrations of trawl doors used in New Zealand bottom trawl fisheries showing a) Older style low aspect-ratio 'vee' door, and b) More recent high aspect-ratio hydrodynamic door.

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Figure 4: Examples of trawl doors in use on New Zealand-flagged vessels using bottom trawls for orange roughy and midwater trawls for benthopelagic species like alfonsinos. a) Nichimo Super-Vee doors rigged on a trawler stern, b) a Morgere WX door and c) a Morgere WV door.

Figure 5: Typical ground-gear configurations used by New Zealand-flagged vessels when bottom trawling for orange roughy and oreos showing ground-ropes equipped with a) 50–60 cm rubber bobbins separated by rubber spacers, and b) with more closely spaced 60–80 cm 'rockhopper' rubber discs plus leading end steel bobbins.

Bentho-pelagic species like alfonsino and bluenose have also been taken using midwater trawls fished close to the bottom. This method is included in this bottom fishery impact assessment because the gear can occasionally come into contact with the bottom during normal fishing operations (Tingley 2014) and is therefore defined as bottom fishing by SPRFMO (CMM 03-2019). Midwater trawls are of lighter construction than bottom trawls, although the same doors are used to deploy them (see a representative net plan in Figure 6). Midwater trawls are generally not rigged with ground gear and the footropes are constructed of a relatively light chain or wrapped wire rope (Figure 7). Such trawls are towed in such a way that they should not touch the bottom. However, the footrope does sometimes contact the seabed and may break if the gear becomes snagged.

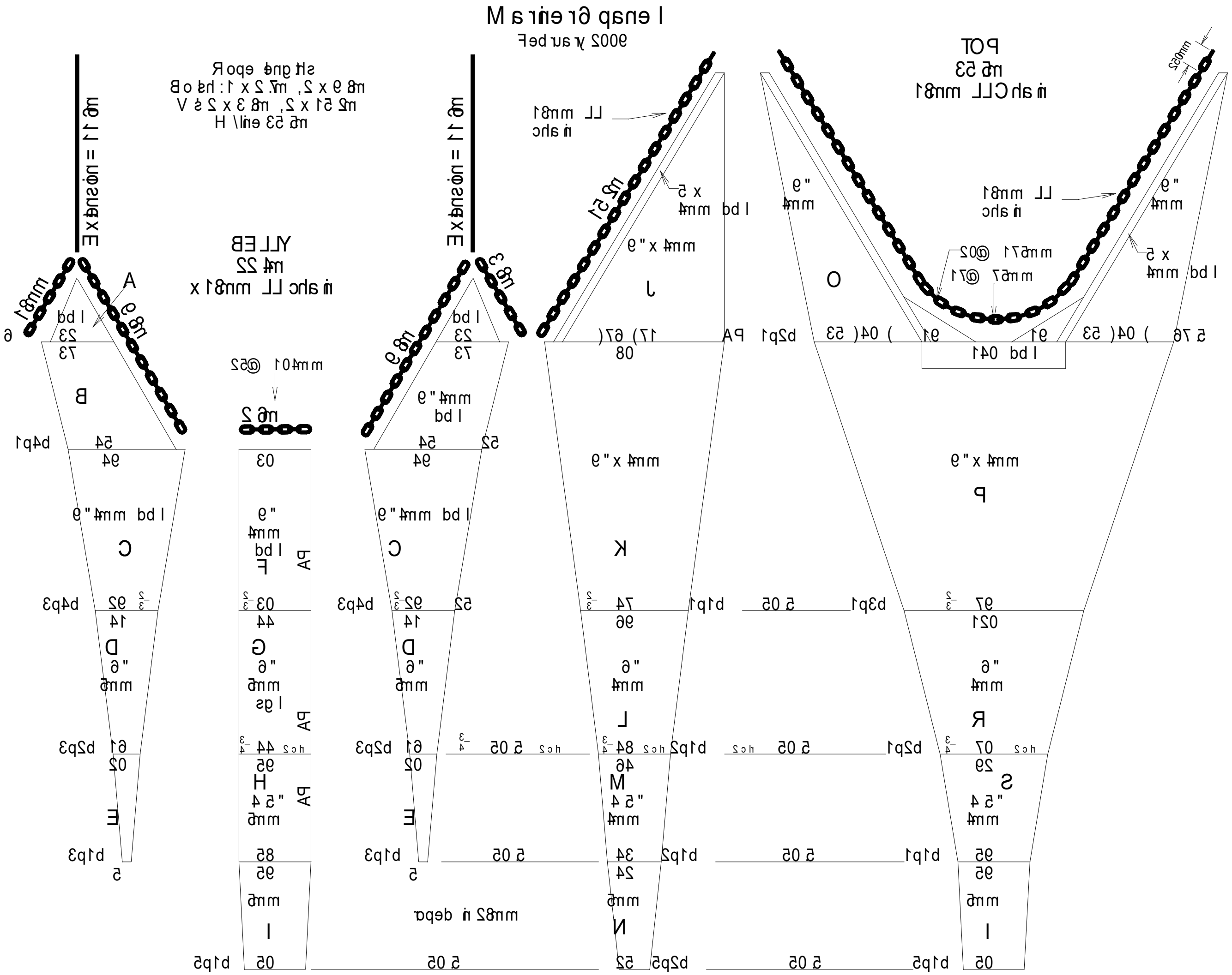

Figure 6: Net construction diagram for typical midwater trawl net used by New Zealand-flagged vessels targeting benthopelagic species like alfonsino in the SPRFMO Convention Area. Numbers over the net describe mesh sizes of each panel.

Figure 7: Wrapped wire rope used as footrope (top) and typical midwater trawl with light ground gear (bottom) used by New Zealand-flagged vessels when targeting alfonsino. Footropes can also be constructed using chains. Photos courtesy Talleys Ltd.

2.3.1.2 Fishing effort

The annual bottom trawl fishing effort by New Zealand vessels in the SPRFMO Convention Area declined from a maximum of 23 vessels completing over 3 500 tows in 2002 to 5 or 6 vessels completing 400–1 400 tows each year between 2015 and 2019, with no bottom trawl fishing in 2022 (Table 3 and 4).

Table 3: Recent bottom trawl effort (number of tows) in the main areas fished by New Zealand bottom trawl vessels fishing in the SPRFMO Convention Area by calendar year. Reported effort for the Westpac Bank only includes effort on the high seas since 2013. Areas presented in Figure 13.

Year	Challenger Plateau	Westpac Bank	West Norfolk Ridge	Lord Howe Rise	Louisville Ridge	Other Areas	All Areas
2009	156		252	229	–	11	648
2010	409		58	388	303	12	1 170
2011	437		84	379	258	–	1 158
2012	166		58	121	296	11	652
2013	189	7	27	238	299	7	760
2014	64	6	–	70	263	6	403
2015	582	24	32	124	221	–	959
2016	706	92	–	197	40	–	943
2017	421	44	25	583	352	–	1 423
2018	309	183	13	232	77	44	858
2019	74	23	1	87	36	30	251
2020	71	34	6	115	103	–	329
2021	0	17	0	0	0	–	17
2022	0	0	0	0	0	–	0

Table 4: Annual fishing effort (number of vessels and tows) and fisher-reported catch (tonnes) of the top five species by weight (identified by FAO species codes – Appendix A) by New Zealand vessels bottom trawling in the SPRFMO Convention Area from 2009. Year is calendar year. The number of tows reported here is the number of tows which recorded a fish catch and excludes tows where there was no catch.

Year	No. vessels	No. tows	Tows/ vessel	ORY	ONV	BOE	EPI	ALF	SSO	RIB	RTX	SCK	Total catch (t)
2009	6	547	91	928	5	–	16	5	<1	7	<1	2	958
2010	7	1 167	167	1 474	9	12	22	24	10	15	6	13	1 864
2011	7	1 158	165	1 079	16	12	108	17	4	22	7	9	1 486
2012	6	652	109	721	10	4	2	39	3	5	7	2	805
2013	5	760	152	1 164	11	20	3	28	5	6	1	-	1 261
2014	5	403	81	998	6	7	0	0	5	2	2	<1	1 028
2015	5	959	192	1 287	11	2	48	9	10	5	32	7	1 513
2016	6	943	157	954	27	0	19	87	0	23	55	34	1 326
2017	5	1 423	285	1 093	30	22	1	29	7	36	52	20	1 641
2018	6	858	143	1 232	38	11	7	57	5	24	30	7	1 570
2019	4	251	63	460	3	8	0	33	3	8	0	0	584
2020	3	329	110	301	9	28	10	78	5	9	0	0	470
2021	1	17	17	20	0	0	0	0	0	0	0	1	22
2022	0	0	0	0	0	0	0	0	0	0	0	0	0

Orange roughy (ORY) is the main target species and has made up 67–99% of the total catch since 2002 with 720–2 578 tonnes landed annually. Fishing effort and catch by area has varied over time, with the majority of catch since 2002 taken in the Challenger and Louisville areas. Other species that have been prominent in the catch include alfonsinos (ALF), cardinalfish (EPI), and oreos

(BOE/SSO/ONV), however catch of these species from bottom trawling has fluctuated over time and catch of any particular species has never exceeded 300 t (Table 4).

Most bottom trawl fishing for orange roughy by New Zealand vessels occurs between 750 and 1 000 m depth, although the maximum reported depth of tows in most years was between 1 200 and 1 400 m depth (Figure 8). Fisheries on the NW Challenger Plateau spanned the greatest depth range, while fisheries on the Westpac Bank and South Tasman Rise were concentrated on the narrowest depth interval. Disregarding obvious errors, only 22 tows between 1989 and 2022 were reported as being deeper than 1 400 m, 0.05% of the total. Some of these depths may still be reporting errors. The data for the NW Challenger Plateau fishery in 2001 and early 2002 include about 100 reported towing depths <100 m from a single vessel, distorting the lower tails of the plots for those years. These records are suspected to be reporting errors.

The duration of bottom trawl tows varies considerably within and between areas (Figure 9). Tows on features constitute the majority of recent tows and are typically shorter than tows on the continental slope, thus largely explaining the prevalence of tows shorter than 1 hour in most areas. This is particularly clear on the Louisville Ridge where almost all tows are on features, but there is also a strong pattern of increasing proportions of short tows in the Tasman Sea (excluding the Challenger Plateau). On the NW Challenger Plateau there have been three periods when a substantial proportion of tows exceeded 5 hours (2001–07, 2010–12, and 2015–18) but the underlying reasons for this pattern are unclear.

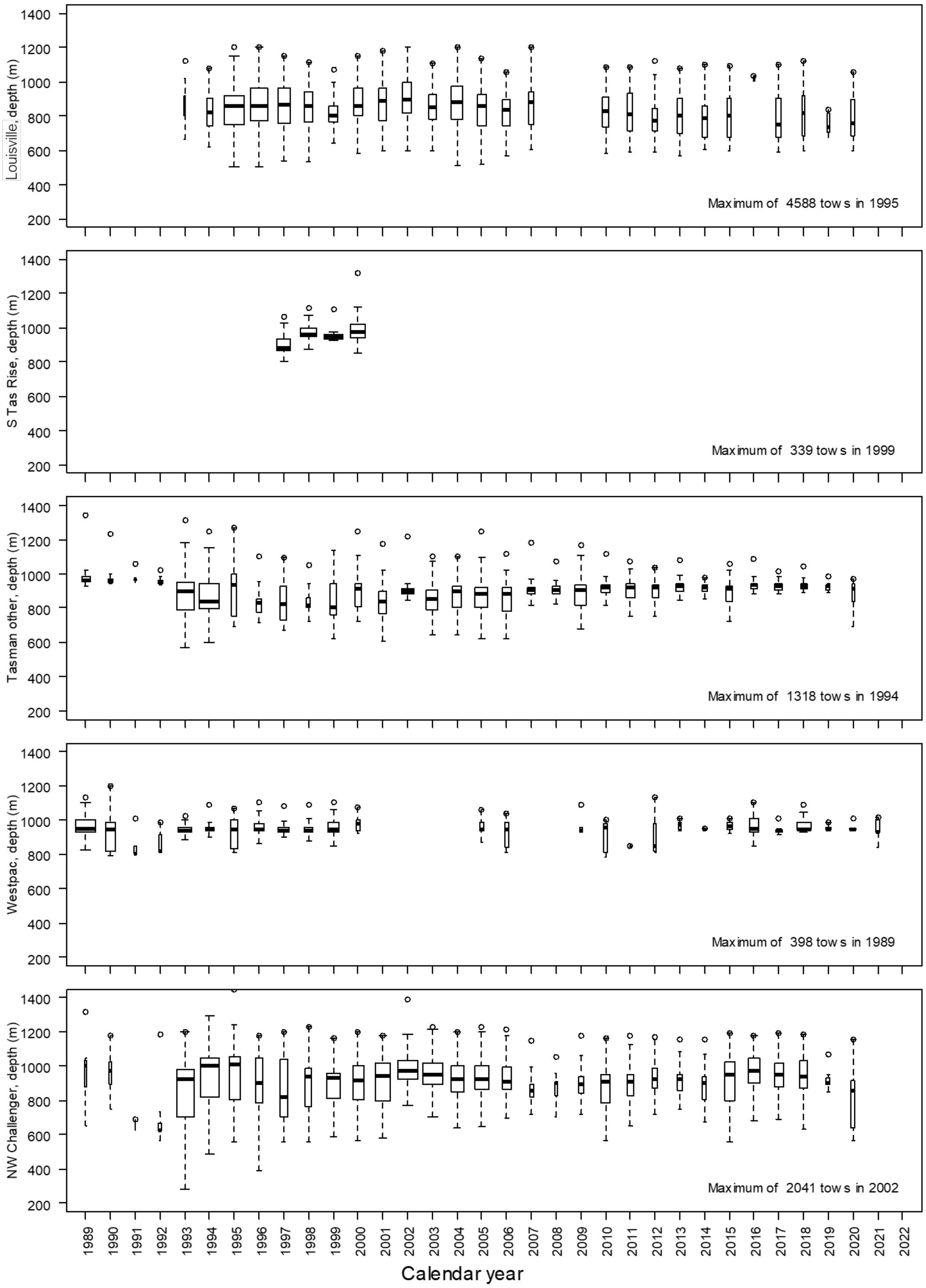

Figure 8: Depth distribution of bottom trawl tows for orange roughy in different parts of the western SPRFMO Convention Area, 1989 to 2023. The horizontal line for each year indicates the median, the boxes encompass the middle 50% of the tows, and the whiskers encompass values up to 1.5 times the interquartile range. The maximum reported depths after obvious errors have been removed are shown as

open circles. Boxwidth proportional to square root of observations, with maximum events indicated for each region. Areas presented in Figure 13.

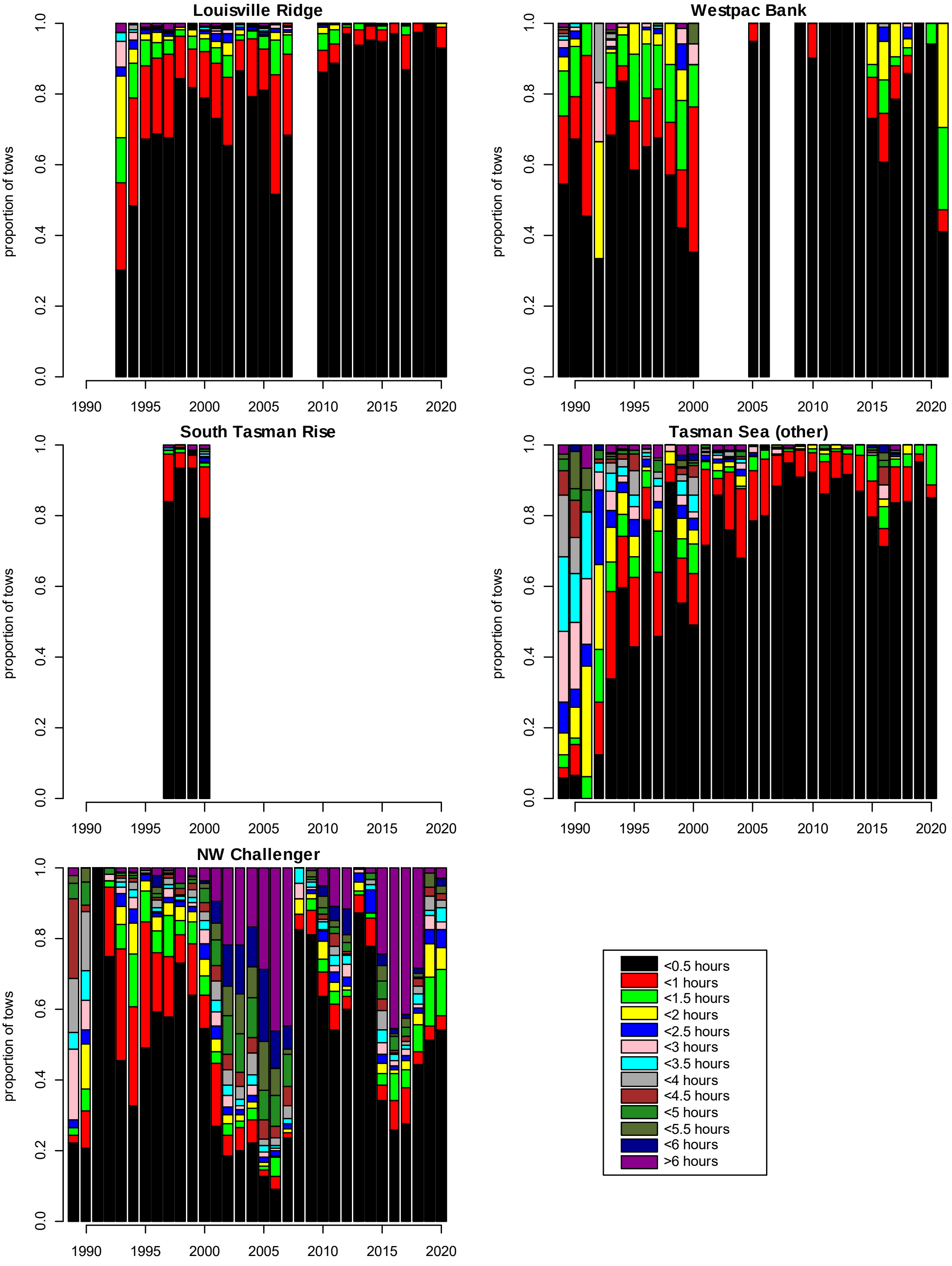

Figure 9: Distribution of reported duration of bottom trawl tows for orange roughy in different parts of the western SPRFMO Convention Area, 1989–2022. Areas presented in Figure 13.

Further information on bottom trawl effort and orange roughy catch by area is shown in Figure 10 and Table 4 and Table 5, and orange roughy catch limits since 2019 are provided in Table 6.

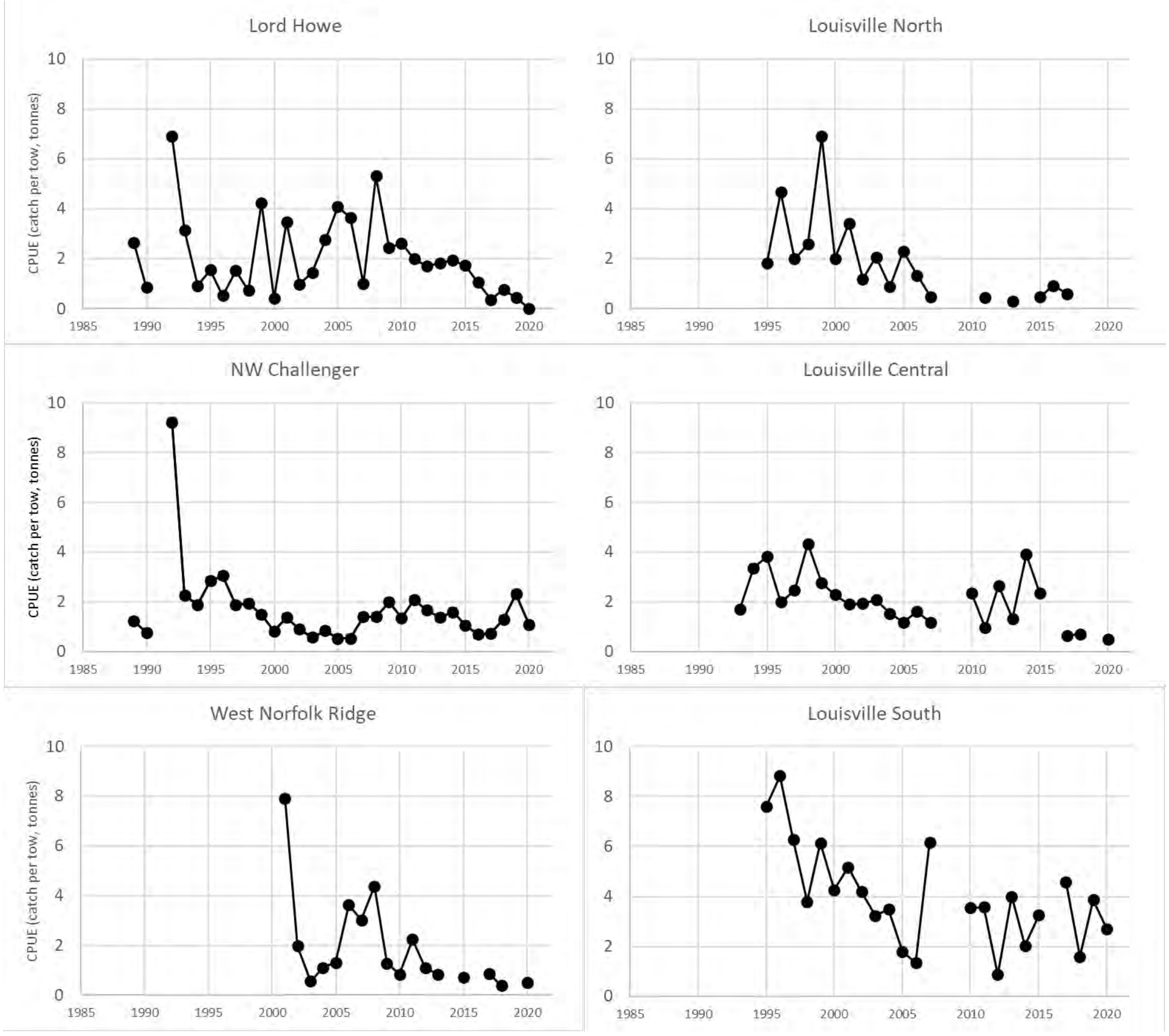

Figure 10: Nominal CPUE (estimated catch per tow) of orange roughy by New Zealand-flagged vessels in the main fishery areas in the western SPRFMO Convention Area, 1989–2022. Years with 10 or fewer tows excluded. Data up to 2015 have been groomed for errors (from Roux et al. 2017), more recent data have not been extensively groomed. Note there have been substantial changes in the lengths of tows over time and that the vertical axis scales might differ. Areas presented in Figure 13.

Most tows using midwater trawls for alfonsino occur in depths of 500–600 m (Figure 11) although a few tows are carried out in considerably deeper water. Bluenose is targeted in slightly shallower water, mostly 300–600 m. A variety of other species have historically been targeted (including hoki, squid, and southern blue whiting) and the depth of these tows varied widely. About two-thirds of tows using midwater trawls are reported as occurring within about 20 m of the seabed; since 1989, the median reported distance off bottom when targeting alfonsino or bluenose has been 6.5 m (Figure 12).

Table 5: Total estimated catches (tonnes) of orange roughy from the main areas fished by New Zealand bottom trawl vessels fishing in the SPRFMO Convention Area by calendar year from 2009. Landings from the Westpac Bank area (part of the Challenger Plateau) are also reported against New Zealand's domestic ORH7A area catch limit. Catches from Westpac Bank between 2007 and 2010 were largely from research surveys. –, less than 1 tonne. Areas presented in Figure 13.

Year	Challenger Plateau	Westpac Bank	West Norfolk Ridge	Lord Howe Rise	Louisville Ridge	Other Areas	All Areas
2009	238	23	233	403	–	31	928
2010	415	5	79	385	584	6	1 474
2011	675	5	113	1	285	–	1 079
2012	247	8	49	121	288	8	721
2013	230	3	19	344	565	3	1 164
2014	57	54	0	79	754	54	998
2015	530	118	20	157	462	–	1 287
2016	486	234	0	208	27	–	954
2017	307	129	22	215	420	–	1 093
2018	399	569	5	180	81	–	1 232
2019	171	111	0	38	139	–	460
2020	76	88	3	2	133	–	301
2021	0	20	0	0	0	–	20
2022	0	0	0	0	0	–	0

Table 6: Orange roughy catch limits in tonnes (for both New Zealand and Australia combined)

	North Louisville	Central Louisville	South Louisville	North-West Challenger	Lord Howe Rise	West Norfolk Ridge	Westpac bank
2019*	1 140			346			200
2020	1 140			346			258
2021-2022**	1 140			396	261	54	258
2023***	116	305	160	160	174	44	258

*2006-2018 Total bottom fishing catch for each member/CNCP was limited to average annual bottom fishing catch of that member/CNCP in the convention area between 2002-2006

** Tasman Sea stock was split into North-West Challenger, Lord Howe Rise and West Norfolk Ridge in 2021

*** Louisville stock was split into North, Central and South Louisville in 2023

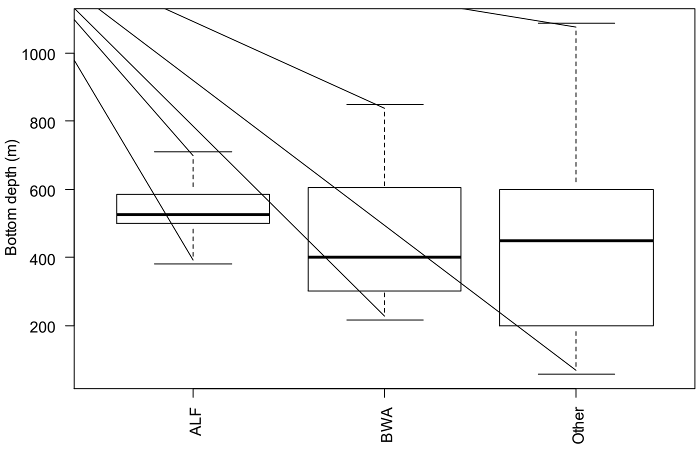

Figure 11: Distributions of bottom depth for midwater trawl tows for alfonsino (641 tows), bluenose (41 tows), and other target species (mainly hoki and squid, 251 tows), 1989 to 2023. The reported fishing depth is typically shallower than the reported bottom depth, median 6.5 m for alfonsino and bluenose target tows. The horizontal line for each year indicates the median, the boxes encompass the middle 50% of the tows, and the whiskers encompass values up to 1.5 times the interquartile range. The maximum reported depths after obvious errors have been removed are shown as open circles.

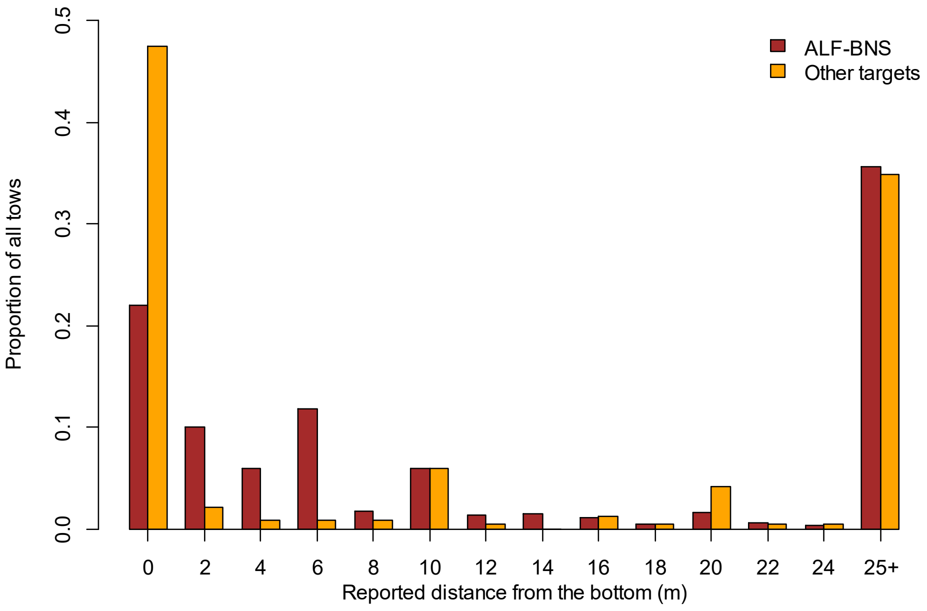

Figure 12: Distributions of distance off bottom (calculated from reported bottom and fishing depths) during fishing using midwater trawls for benthopelagic species (alfonsino and bluenose, 670 tows) and other target species (mainly hoki and squid, 238 tows), 1989 to 2022. About 38% of tows were >20 m off bottom.

Midwater trawling for bentho-pelagic species such as alfonsino by New Zealand-flagged vessels has been variable over time, declining in more recent years (Table 7). Catch from midwater trawling fluctuated around 150 tonnes per year in 2011–2013, was less than 100 tonnes in 2014–2017, increased to over 200 tonnes in 2018, but declined to only 7 tonnes in 2020, with no midwater fishing in 2021 or 2022. Alfonsino is the main species caught in midwater trawls, comprising over 95% of catch in the most recent three years.

Table 7: Annual fishing effort (number of vessels and tows) and fisher-reported catch (tonnes) of the top five species by weight (identified by FAO species codes – Appendix A) by New Zealand vessels midwater trawling for bentho-pelagic species in the SPRFMO Convention Area from 2009. Year is calendar year. The number of tows reported here is the number of tows which recorded a fish catch and excludes tows where there was no catch.

Year	No. Vessels	No. Tows	Avg. Tows/Vessel	ALF	EDR	ONV	BWA	All Species (t)
2011	3	61	20	64	76	21	2	164
2012	3	59	20	115	25	0	3	145
2013	1	120	120	122	9	0	10	145
2014	0	0	–	0	0	0	0	0
2015	2	21	11	34	0	0	2	37
2016	3	42	14	82	3	0	0	86
2017	1	33	33	35	0	0	0	36
2018	3	145	48	211	3	0	3	219
2019	2	9	5	12	0	0	0	12
2020	1	8	8	6	0	0	0	7
2021	0	0	–	0	0	0	0	0
2022	0	0	–	0	0	0	0	0

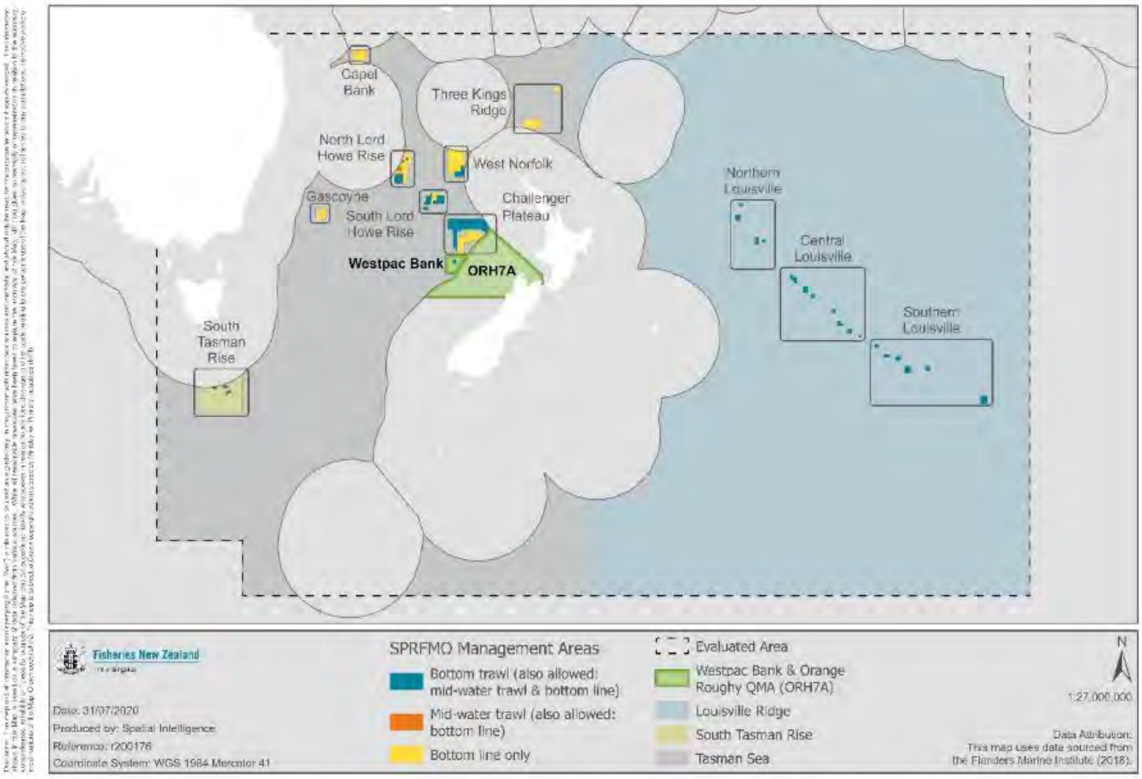

Figure 13: SPRFMO management areas open to different types of fisheries, and general fishery areas, within the Evaluated Area. Note that areas open to bottom trawling are also open to all other fishing methods and areas open to midwater trawling are also open to bottom long lines.

2.3.2 Line fisheries

Vessels flying the New Zealand flag use bottom line methods to target predominantly bluenose or wreckfish. For bluenose, the main fishing areas have been the Three Kings Ridge, the Challenger Plateau, and the West Norfolk Ridge. For wreckfish, the main area has been the West Norfolk Ridge. The annual fishing effort (number of vessels and hooks fished) and catch of the main bottom line target and bycatch species are summarised in Table 8. The number of active line vessels peaked at 11 in 2005, but successively declined in 2007 to 2–5 vessels and fluctuated on similar levels since. The number of hooks set per year has fluctuated over time, peaking at 780 000 hooks in 2014, but declined to fluctuate between about 100 000–180 000 hooks between 2016 and 2021 before decreasing to 63 000 hooks in 2022.

Three bottom line fishing methods have been used by New Zealand vessels in the SPRFMO Convention Area: bottom longline, Dahn line, and hand line. Dahn and hand line are very similar, with both methods employing a vertical line with hooks that is either attached to a float (Dahn line) or remains attached to the fishing vessel (hand line). Given the similarities, Dahn line and hand line are treated as a single fishery, and data reporting by commercial fishers and observers is the same for both methods.

Table 8: Effort and estimated catches for New Zealand vessels bottom longlining in the SPRFMO Convention Area by calendar year from 2009. Effort is presented as the number of vessels, trips, and number of hooks set, with catches in tonnes of the target and main bycatch species (codes detailed in Appendix A).

Year	No. Vessels	No. Trips	No. Hooks (000's)	Hooks/ Vessel (000's)	BWA	HAU	DGS	MOW	RTX	Total catch (t)
2009	5	12	236	47	58	23	7	1	<1	89
2010	2	5	48	24	15	24	–	1	<1	45
2011	2	6	71	36	23	25	6	<1	<1	57
2012	3	10	90	30	44	40	2	3	<1	95
2013	3	13	479	160	64	41	6	3	<1	124
2014	4	18	784	196	33	45	4	11	<1	99
2015	4	15	179	45	35	63	4	2	<1	126
2016	4*	10	111	28	20	54	5	3	<1	87
2017	3	14	115	38	46	47	3	3	2	106
2018	3	8	110	37	34	27	10	3	0	78
2019	5	16†	183	37	57	50	9	3	1	133
2020	5	11	105	21	17	26	1	3	0	57
2021	4	11	97	24	20	7	1	1	0	43
2022	3	6	63	21	8	33	8	2	0	53

* This includes one vessel that fished only using hand lines

†This includes a trip that began in Dec 2018 and ended in Jan 2019

Bluenose (BWA) catches peaked in 2006 at 271 t but have declined and have fluctuated around 20–46 t through the 2010s and declined further to 8 t in 2022 (Table 9). The other main species caught by bottom line are wreckfish (HAU, *Polyprion oxygeneios* and *P. americanus*), catches of which have fluctuated from 7–50 t in the last 5 years without any trend (Table 8). Together, these species have made up around 80% of the catch in the most recent 5 years. CPUE for bluenose and wreckfish show significant interannual variability (Figure 14).

Other species making minor contributions to bottom line catches in established fisheries include spiny dogfish (DGS, *Squalus acanthius*), king tarakihi (MOW), yellowtail kingfish (YTC), and sea perch (ROK, *Helicolenus* spp.).

Line fishing for bluenose occurs in three main areas on the Three Kings Ridge, the West Norfolk Ridge, and the Challenger Plateau, with most fishing at depths of about 500 m. Line fishing for wreckfish by New Zealand-flagged vessels occurs predominantly on the West Norfolk Ridge, mostly at depths of 300–400 m. Line fishing for other species is dispersed and mostly at depths close to 300 m.

Bottom longline comprised the vast majority of the bottom line fishing effort, with effort using other bottom line methods (Dahn line and hand line) reducing significantly in recent years. Table 10 shows effort and catch from fishing using other bottom line methods from 2014.

Table 9: Estimated catches (t) of bluenose in each of the main fishing areas by New Zealand vessels bottom longlining in the SPRFMO Convention Area by calendar year from 2009.

Year	Three Kings Ridge	Challenger Plateau	Lord Howe Rise	Other	West Norfolk Ridge	All Areas
2009	16	13	7	<1	22	58
2010	–	2	0	0	13	15
2011	11	0	0	0	11	23
2012	18	11	0	0	15	44
2013	24	31	0	0	10	64
2014	14	8	0	0	11	33
2015	2	23	0	0	10	35
2016	0	5	0	0	15	20
2017	3	31	4	0	8	46
2018	0	27	0	0	7	34
2019	9	31	0	<1	17	57
2020	0	7	2	0	8	17
2021	2	12	0	0	4	20
2022	1	1	0	0	4	8

Table 10: Effort and estimated catches for New Zealand vessels using Dahn and hand longlines in the SPRFMO Area by calendar year from 2014. Effort is presented as the number of vessels and number of hooks set, with catches in tonnes of the target and main bycatch species (codes detailed in Appendix A).

Year	No. Vessels	No. Hooks	BWA	HAU	MOW	YTC	Total catch (t)
2014	1	12 250	4	1	2	1	8
2015	3	4 861	19	10	4	0	33
2016	1	128	1	<1	1	0	2
2017	1	49	<1	<1	<1	0	<1
2018	1	120	<1	<1	<1	0	<1
2019	1	20	<1	-	<1	0	<1
2020	1	30	<1	<1	<1	<1	<1
2021	0	0	0	0	0	0	0
2022	0	0	0	0	0	0	0

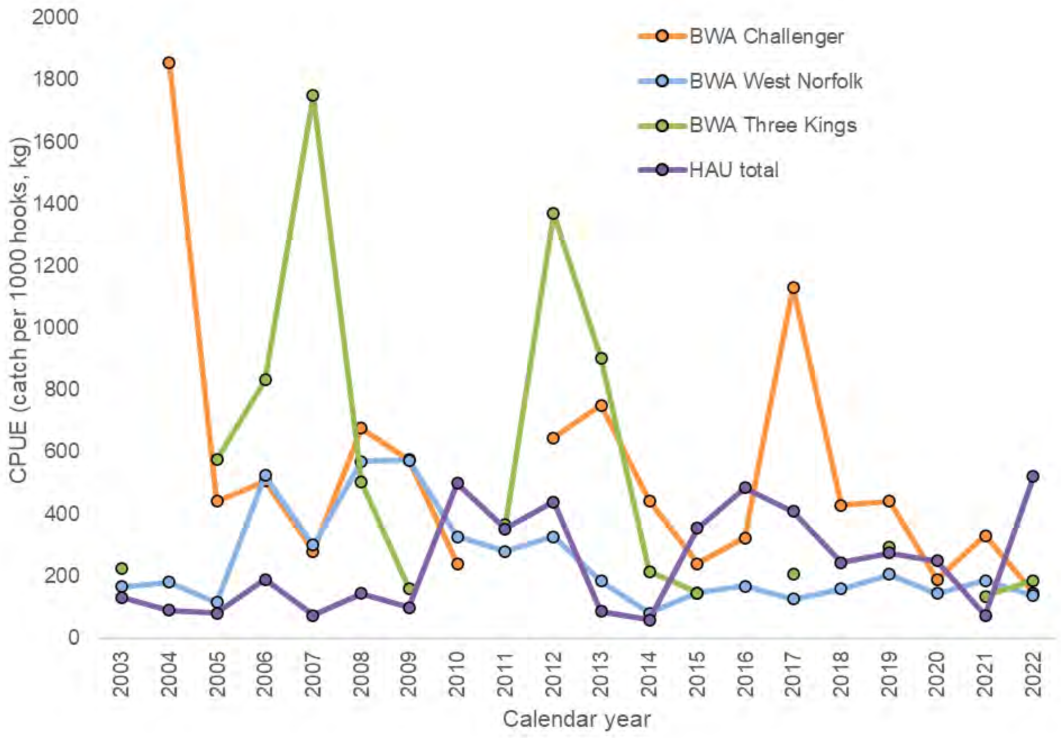

Figure 14: Trends in nominal CPUE (kg per 1000 hooks set) for bluenose (BWA) for the three main areas fished and wreckfish (HAU) by New Zealand bottom longline vessels fishing in the SPRFMO Area by calendar year 2003–2022.

New Zealand has had an exploratory fishery for toothfish (using the method of bottom longlining with integrated weight line) since 2016 based on an application to the Scientific Committee in 2015 (Delegation of New Zealand 2015) that included a detailed impact and risk assessment. The fishery was initially established under CMM4.14 for 2 years of fishing with a catch limit of 30 tonnes each year for one vessel (both species of toothfish combined: Antarctic toothfish, *Dissostichus mawsoni*; and Patagonian toothfish, *Dissostichus eleginoides*). Fishing occurred in 2016 and 2017 and, based on results from that work, the exploratory fishery was expanded spatially (Figure 15) and the catch limit increased to 140 t in each of three years, spread across two vessels (under CMM14a-2019). The initial exploratory fishing blocks were completely outside the Evaluated Area that encompasses all other recent fishing by New Zealand-flagged vessels and the expanded exploratory fishing blocks overlap only slightly with the south-eastern corner of the Evaluated Area. Impact and risk assessments for this and other exploratory fisheries[7] are not considered in detail in this BFIA but, rather, in the individual applications and CMMs. Exploratory fishing was continued and spatially expanded (Figure 16) under CMM 14a-2022 (Exploratory Toothfish NZ) (sprfmo.int), setting the

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[7] The Cook Islands has an exploratory fishery for rock lobster and deepwater crab under CMM14b-2020, and Chile has an exploratory fishery for toothfish under CMM14d-2020. Both lie outside and to the east of the Evaluated Area. The EU had an exploratory fishery for toothfish under CMM14c-2019, now expired, on the high seas areas of South Tasman Rise, within the South Tasman Rise, within the Evaluated Area.

annual catch limit to 240 t in each of three years, with an individual research block limit of 40 t per year.

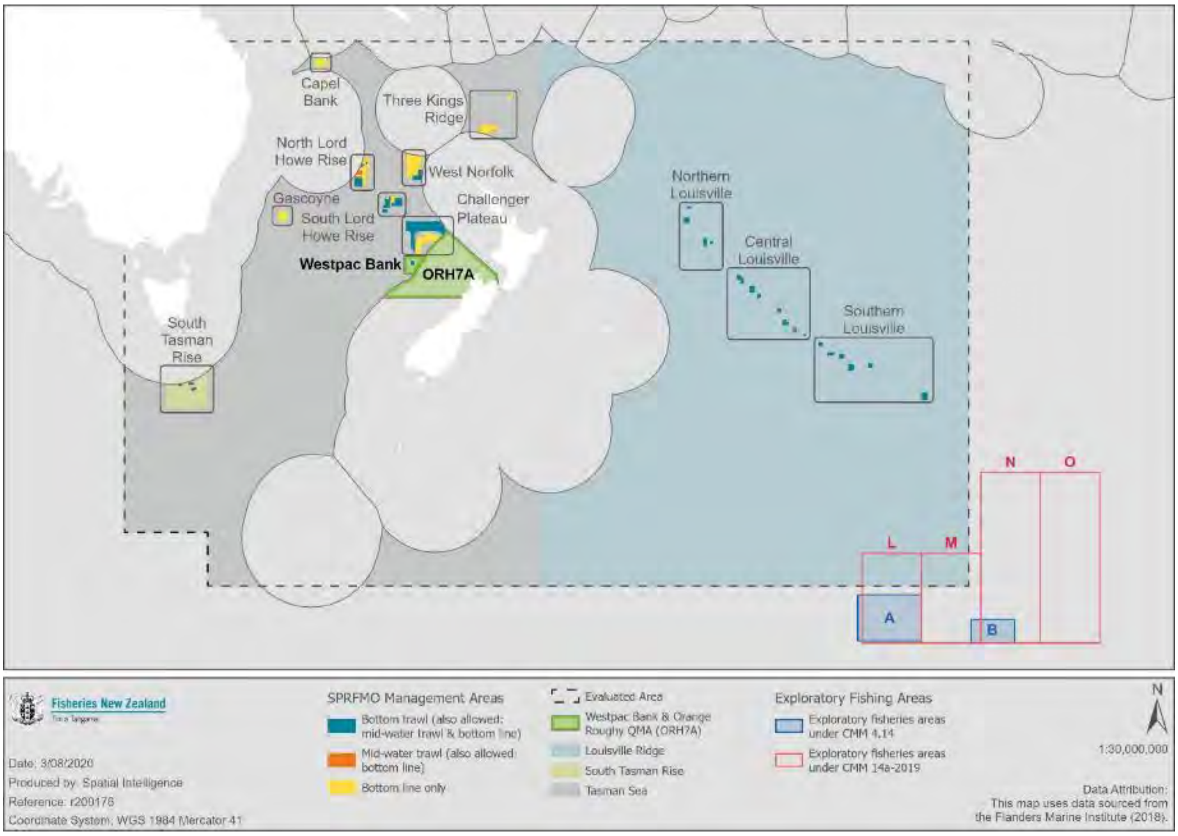

Figure 15: Locations of the exploratory fishing blocks (red boxes) for New Zealand's exploratory fishery for toothfish permitted under CMM14a-2019. The blocks for the initial 2-year exploratory fishery under CMM4.14 are shown as blue boxes and the Evaluated Area is shown as a black dashed box.

The exploratory fishery took 29 tonnes of toothfish in each of 2016 and 2017 and the results were reported in detail to the Scientific Committee in 2018 (Delegation of New Zealand 2018). The continuing exploratory fishery under CMM 14a-2019 took 37 tonnes in 2019, 41 tonnes in 2020, 33 tonnes in 2021 and 39 tonnes in 2022. The initial results of this work were presented to SC8 in paper SC-08-DW-09 (Fenaughty 2020), with the final report provided by Fenaughty (2021, SC9-DW04), and the interim report relating to CMM 14a-2022 provided by Fenaughty (2022, SC10-DW07).

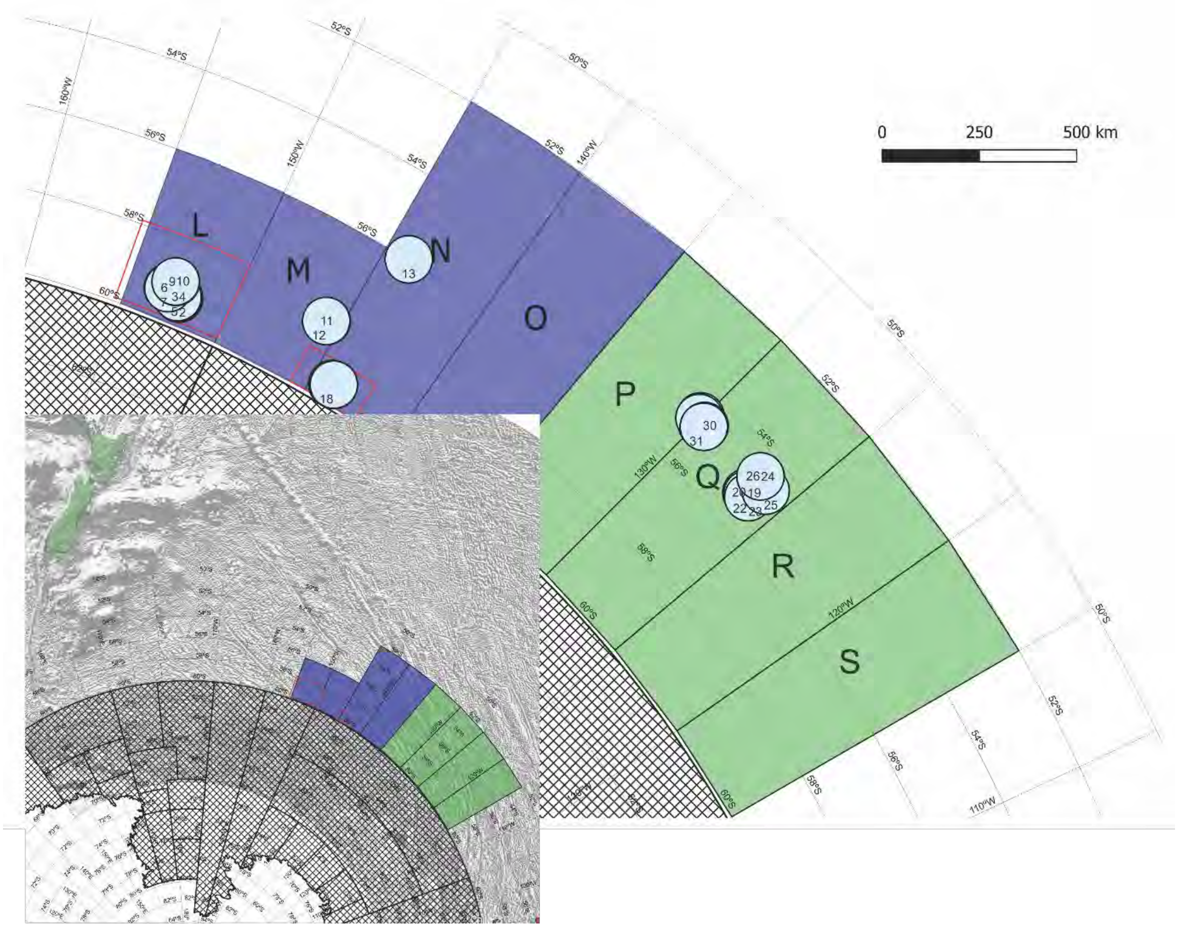

Figure 16: General location (circles) of exploratory research sets during 2022 SPRFMO exploratory fishing for toothfish (March 2022). Research areas P, Q, R, and S are new research areas added in 2022 to the 2019-21 research areas L, M, N, and O. The hashed area is the CCAMLR Convention Area. Numbers in circles represent sequential longline sets (Fenaughty 2022).

2.4 AUSTRALIAN BOTTOM FISHERIES

A small number of Australian fishing vessels target demersal fish species (those associated with the sea floor) in high-seas areas of the South Pacific Ocean. Australian operators in the SPRFMO Convention Area are authorised under permits granted by AFMA to target various species with midwater and demersal trawl, dropline, handline, automatic longline and demersal longline gears. Fishing methods have been specified on Australian high seas permits since 2008. Prior to 2008, deepwater gillnetting was allowed and used but formed a very minor part of the fishery (occurring in two years, 2002 and 2003, within a restricted area) (Williams et al. 2011). Deep-sea gillnets were prohibited in 2010 under an interim measure applicable to all fishing vessels within the SPRFMO Convention Area, prior to SPRFMO adopting a gillnet prohibition in January 2013 (SPRFMO 2013).

Permits to fish in the SPRFMO Convention Area are granted by AFMA for a period of up to five years. Australian high-seas permits require the implementation of all SPRFMO CMMs, 100% observer coverage on all trawl vessels and for the first trip of the season (for all other methods) and a minimum of 10% observer coverage annually on all non-trawl vessels. At the time of writing, there were 6 permits allowing fishing in the SPRFMO Convention Area by Australian fishing vessels.

The number of Australian fishing vessels active in the SPRFMO Convention Area has decreased from a maximum of 10[8] in 2003 to two in 2022.

Detailed vessel characteristics have been provided to the SPRFMO Secretariat in accordance with the requirements in the SPRFMO Record of Vessels, (CMM 05), and are not repeated here. This assessment does not preclude Australia from issuing high seas permits and registering new and/or different vessels to fish in the SPRFMO Convention Area using the gears assessed herein in the future.

2.4.1 Trawl fisheries

A total of 16 Australian vessels trawled in the SPRFMO Convention Area between 2002 and 2022, with no trawling occurring in 2008, 2009, 2010, 2018 and 2020–2022. Figure 17 provides the number of active Australian-flagged demersal trawl and midwater trawl fishing vessels from 2002 to 2022. Table 11 shows active Australian-flagged trawl vessels in the SPRFMO area between 2002–2022, showing the target stratum (midwater or demersal) and the number of operations (trawl shots).

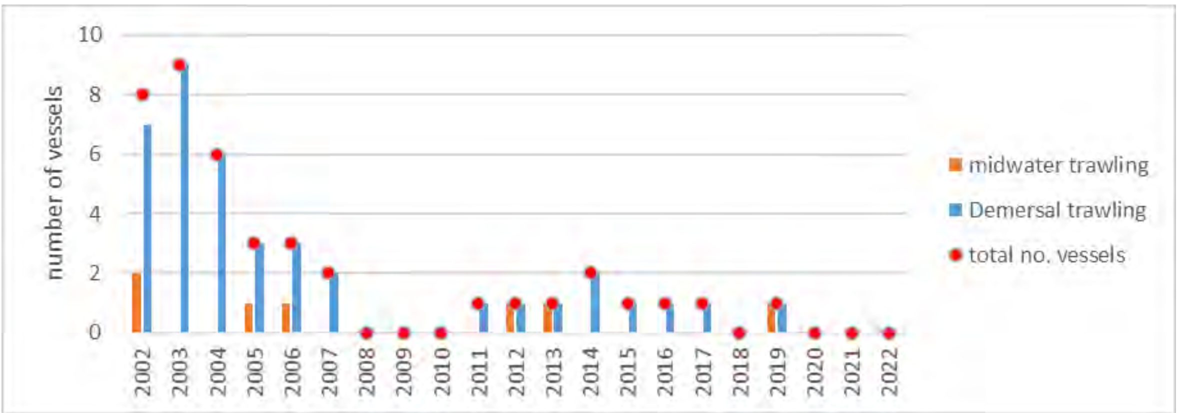

Figure 17: The number of active Australian-flagged demersal trawl and midwater trawl vessels operating in the SPRFMO Convention Area from 2002–2022.

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[8] Note that this total does not match the sum of vessels shown in Figure 17 and 20 due to some vessels using multiple gear types.

Table 11: Active Australian-flagged trawl vessels in the SPRFMO Convention Area between 2004–2022 showing the target stratum and the number of operations (trawl shots).

	Stratum		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
No. active vessels	demersal		6	3	3	2	0	0	0	1	1	1	2	1	1	1	0	1	0	0	0
	midwater		0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0
Vessel ID	**Stratum**	**Total no. Operations**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
1	demersal	2																			
2	demersal	61																			
3	demersal	15																			
4	demersal	19																			
5	demersal	31	6																		
6	demersal	2																			
7	demersal	11																			
8	demersal	654	108	52	29	7							77	20	44	58					
9	demersal	17	1																		
10	demersal	1	1																		
11	demersal	63																			
12	demersal	234	4	18		##															
	midwater	25		25																	
13	demersal	89			89																
	midwater	310			310																
14	demersal	101	14	17	6																
	midwater	2																			
15	midwater	10																			
16	demersal									110	85	143	18					72			
	midwater										269	83						17			

Species composition of catches has varied over time. Historically, Australian high-seas trawl fishing effort targeted orange roughy using demersal trawl gear. There has also been some historical effort for alfonsino using demersal and midwater trawling. Figure 18 and 19 show catch (t) of key species plus 'other' species taken by Australian-flagged demersal and midwater trawl vessels, and fishing effort (trawl-hours) in the SPRFMO Convention Area from 2002–2022.

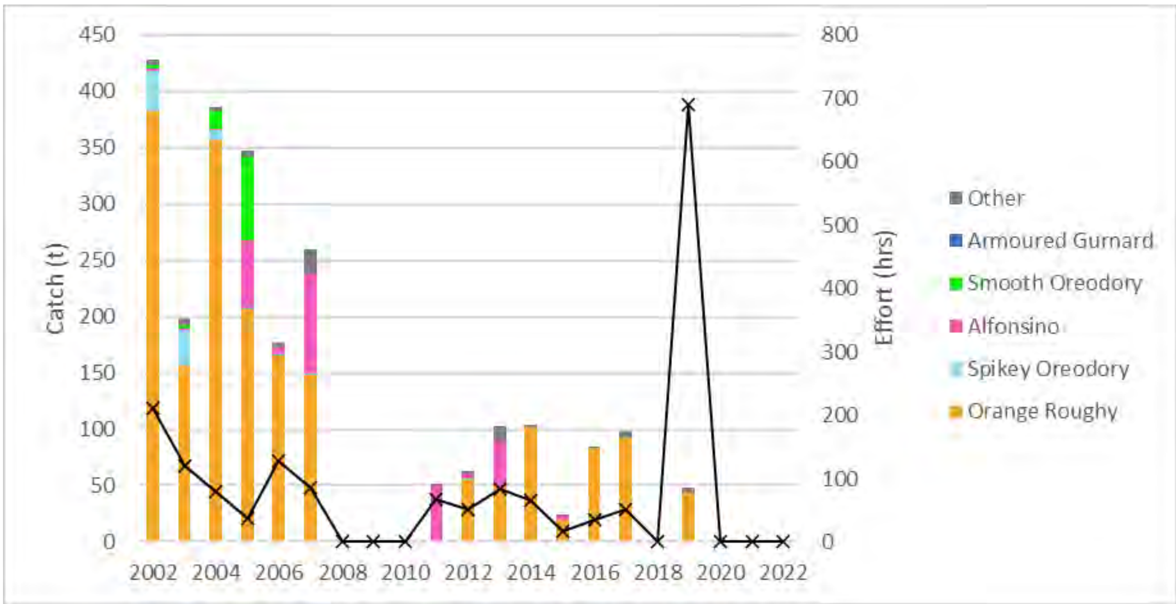

Figure 18: Catch (t) of key species and 'other' species taken by Australian-flagged demersal trawl fishing vessels, and trawl effort (trawl-hours) in the SPRFMO Convention Area from 2002–2022.

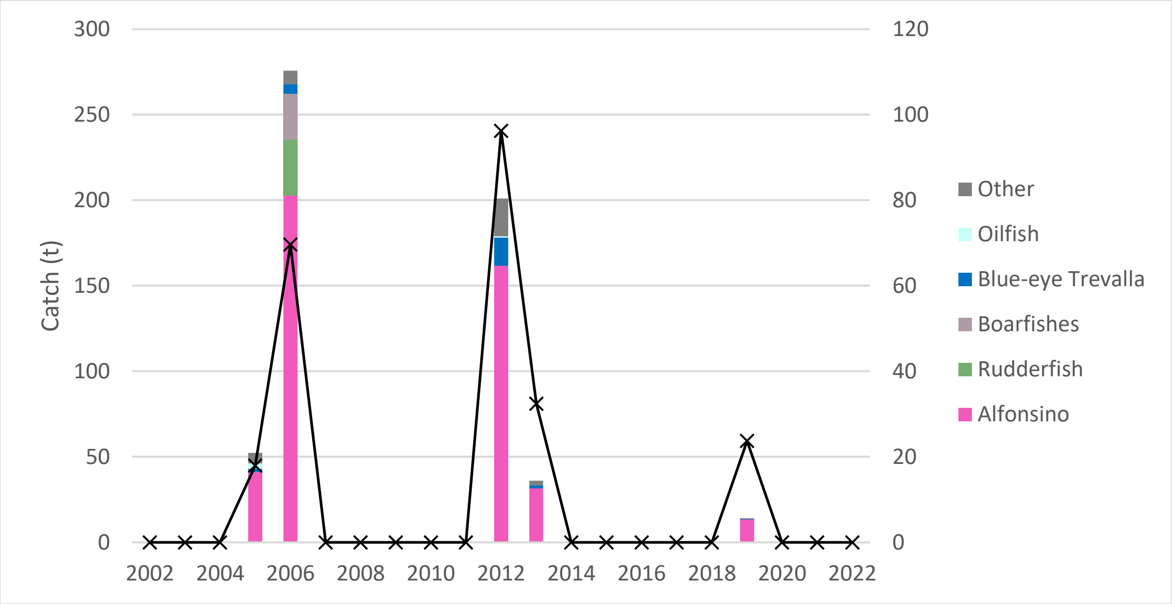

Figure 19: Catch (t) of key species and 'other' species taken by Australian-flagged midwater trawl fishing vessels, and trawl effort (trawl-hours) in the SPRFMO Convention area from 2002–2022.

From observer descriptions and discussions with operators, midwater trawl operations typically use a pelagic net designed for off-bottom fishing, with large meshes (i.e., 20 metre diagonal meshes in the wings of the net). Midwater trawl nets typically have a sacrificial footrope in case the net touches the bottom. Demersal trawl operations typically use a simple 2-seam 'cut-away' orange roughy demersal trawl net with 80m sweeps and 40m bridles. The headrope and groundrope length is up to 60m and has 12-inch rubber bobbins. Fishing typically occurs in depths from 400–1100 m, depending on the target species. Demersal trawl operations typically fish with the trawl doors just off the bottom.

It is important to note that some Australian vessels have recorded fishing effort in the logbooks as 'demersal trawl' or 'midwater trawl' based on whether the net is fished on or off the bottom, with the data indicating that the same net is used. For example, one operator fishing in 2012 used a standard otter trawl net for both demersal and midwater trawl operations targeting orange roughy, alfonsino and other mixed species. Efforts are being made to resolve these and other uncertainties in the recording and reporting of logbook data.

The typical depths fished by Australian-flagged demersal and midwater trawl vessels are similar to those given for New Zealand vessels, typically ranging from ~400–1100m depending on the target species. Fishing for alfonsino typically occurs at the shallower end of this range, while fishing for orange roughy typically occurs at greater depths depending on the feature being fished.

2.4.2 Line fisheries

A total of six Australian vessels fished with demersal line gears in the SPRFMO Convention Area between 2002 and 2022, with five active vessels in 2006 being the maximum operating in any one year. Most of Australia's line fishing effort has occurred using auto-longline and dropline gears.

Figure 20 provides the number of active Australian-flagged dropline and auto-longline vessels operating in the SPRFMO Convention Area from 2002–2022. Table 12 shows active Australian-flagged vessels using demersal line fishing methods in the SPRFMO Convention Area from 2002–2022 showing the line deployment method (dropline or auto-longline) and the number of operations (line sets).

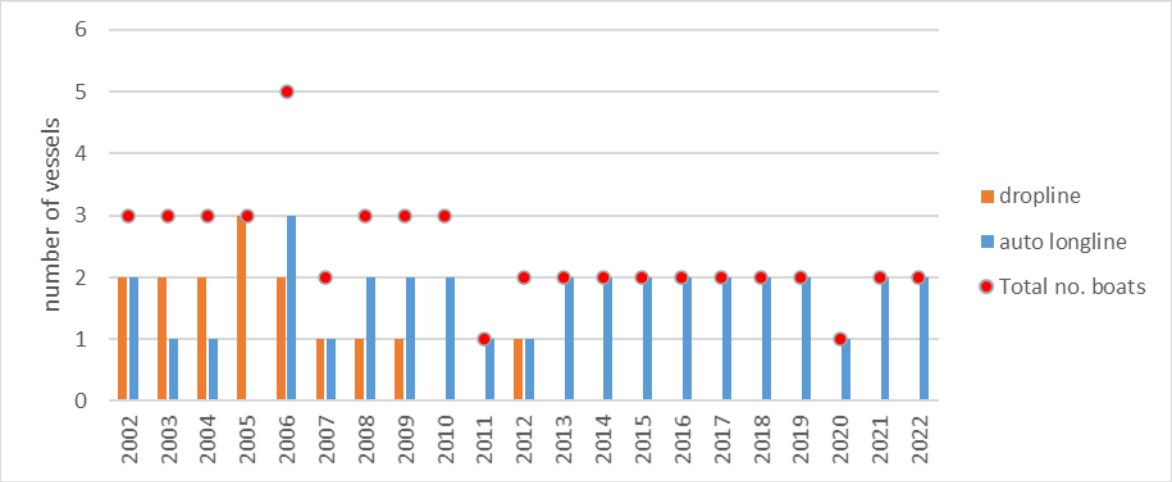

Figure 20: The number of active Australian-flagged dropline and auto-longline vessels operating in the SPRFMO Convention Area from 2002–2022.

Table 12: Active Australian-flagged vessels using demersal line fishing methods in the SPRFMO Convention Area from 2004–2022 showing the line deployment method and the number of operations (line sets). AL = Auto-longline; DL = Dropline.

	Line Method		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
No. active vessels	AL		1	0	3	1	2	2	2	1	1	2	2	2	2	2	2	2	1	2	2
	DL		2	3	2	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Vessel ID	**Line Method**	**Total no. Operations**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
1	AL	638			9	20	68	65	41	53	58	50	40	46	67	59	62	44		43	40
2	AL	278	4		13		22	10	10			29	17	45	27	33	39	40	10	50	55
3	AL	3			3																
4	AL	2																			
	DL	45	24	10	6																
5	DL	1		1																	
6	DL	39	7	8	7	4	1	2	3												
7	DL										2										

Historically, most Australian line fishing effort in the SPRFMO Convention Area has targeted species such as jackass morwong/tarakihi, yellowtail kingfish and blue-eye trevalla/bluenose. An increase in catches of emperors (Lethrinidae) and deepwater snappers (*Etelis* spp.) (as well as other more subtropical and tropical species) in Australia's line fishery in recent years reflects a change in the main fishing grounds used by some Australian line fishing vessels for part of their operations. Figure 21 and 22 show catch (t) of key species and 'other' species taken by Australian-flagged auto-longline and dropline fishing gears, respectively, in the SPRFMO Convention Area, and effort ('000 hooks) from 2002–2022.

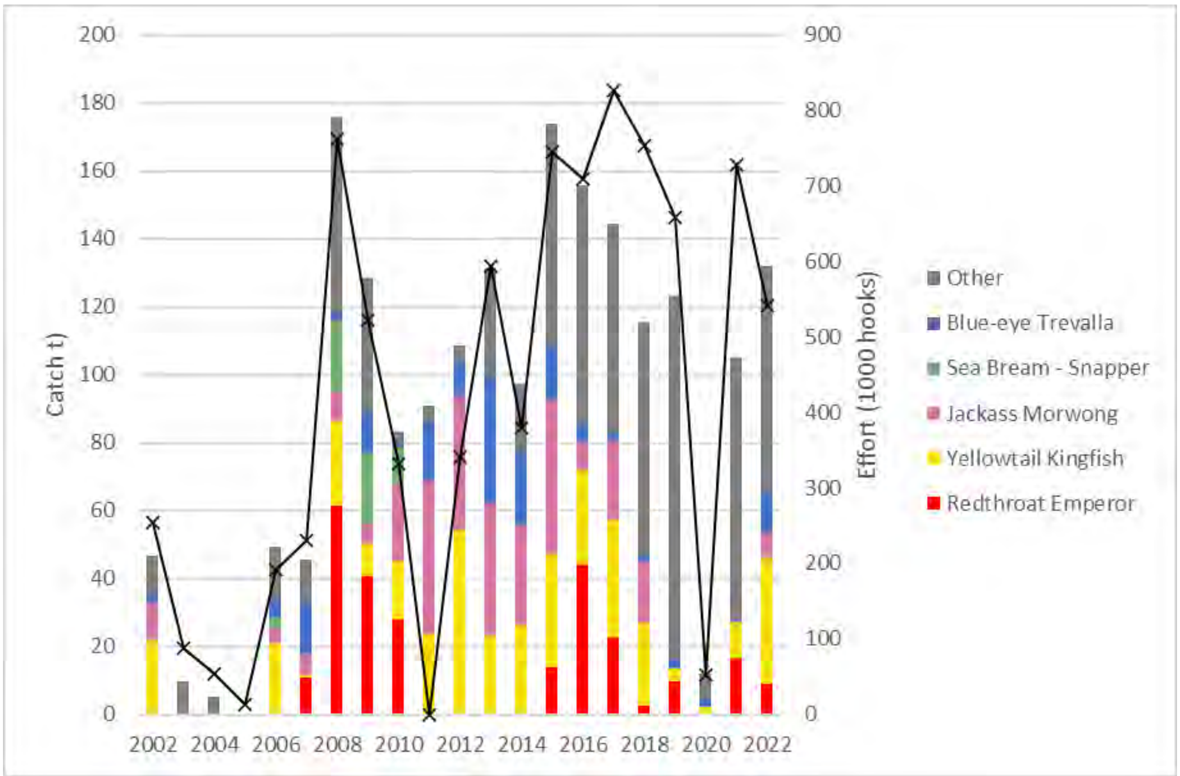

Figure 21: Catch (t) of key species and 'other' species taken by Australian-flagged auto-longline fishing vessels in the SPRFMO Convention area, and effort ('000 hooks) from 2002–2022.

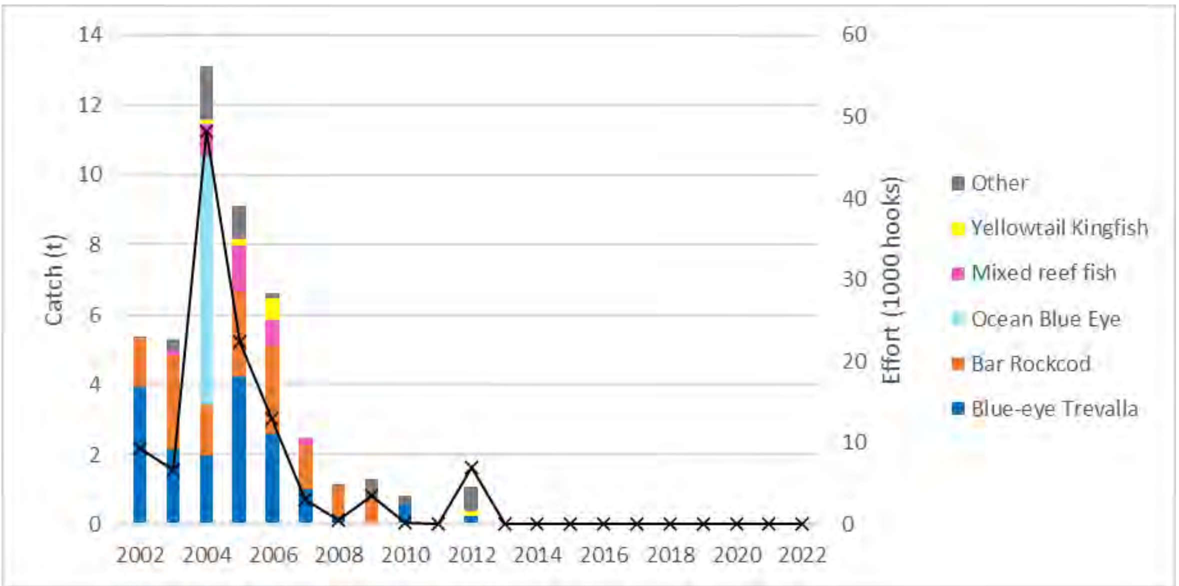

Figure 22: Catch (t) of key species and 'other' species taken by Australian-flagged dropline fishing vessels in the SPRFMO Convention area, and effort ('000 hooks) from 2002–2022.

From observer descriptions and discussions with operators, auto-longline equipped vessels use technology that allows semi-automated setting of large numbers of hooks in a short time. Part of the gear is an auto-baiter that can bait around two hooks per second while the mainline is shot from the stern of the vessel. Currently, auto-longline vessel use a bottom set mainline of 7–10 mm in diameter and can be weighted. Snoods of ~300-400mm length with a 12/0 or 13/0 hook are spaced between 1 and 1.4 m 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 midwater along to prevent dragging. Droplines are set vertically with a single weight of ~40 kg at the bottom and a large float at the surface with around 100–200 hooks attached to the bottom part of the vertical line.

3 MAPPING AND DESCRIPTION OF FISHING AREAS

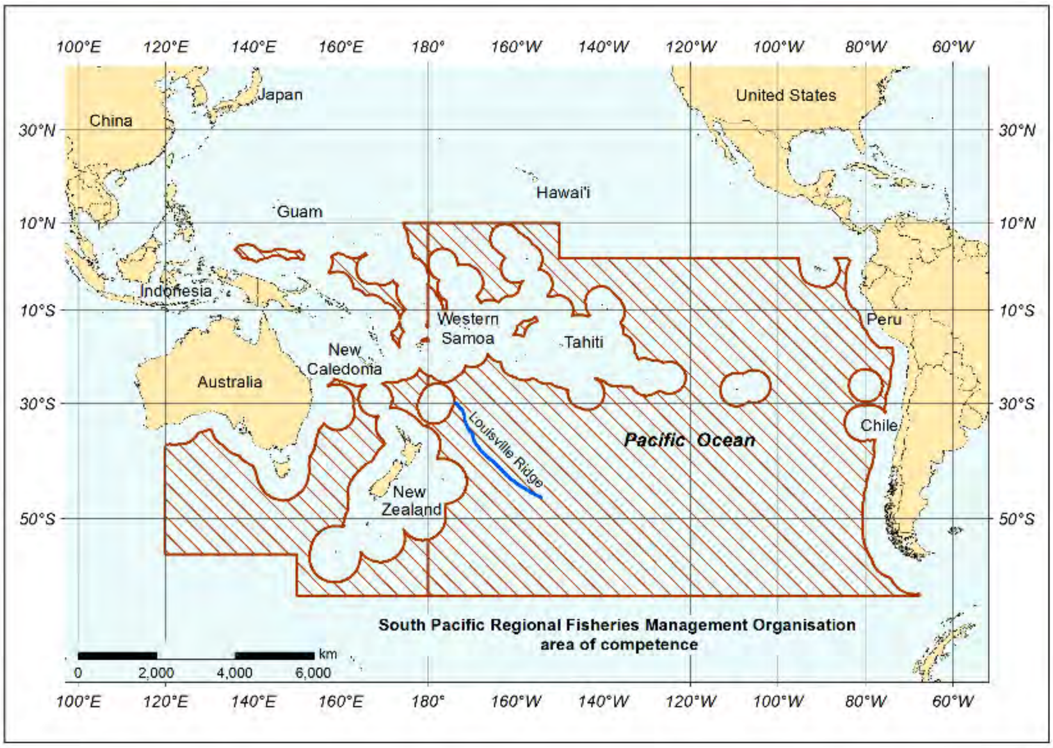

Figure 23: Map of the SPRFMO Convention area.

Within the SPRFMO Convention Area (Figure 23), the main bottom fishing areas for existing participants in the fisheries (Australia and New Zealand) are defined in the bottom fishing measure CMM03a-2023 (Figure 24). Areas are defined separately for different fishing methods and bottom fishing is not allowed outside the defined areas unless authorised as an exploratory fishery pursuant to CMM13-2021. Bottom trawling is the most restricted spatially, given it has the greatest potential impact on benthic communities. Bottom line fishing is allowed in any defined management area and midwater trawling for bentho-pelagic species is allowed throughout bottom trawl fishing areas as well as in areas specific to the method.

For the purposes of CMM03-2019 onwards until its latest revision CMM03-2023, the term Evaluated Area means those parts of the Convention Area that are within the area starting at a point of 24°S latitude and 146°W, extending southward to latitude 57° 30S, then eastward to 150°E longitude, northward to 55°S, eastward to 143°E, northward to 24°S and eastward back to point of origin (Figure 24).

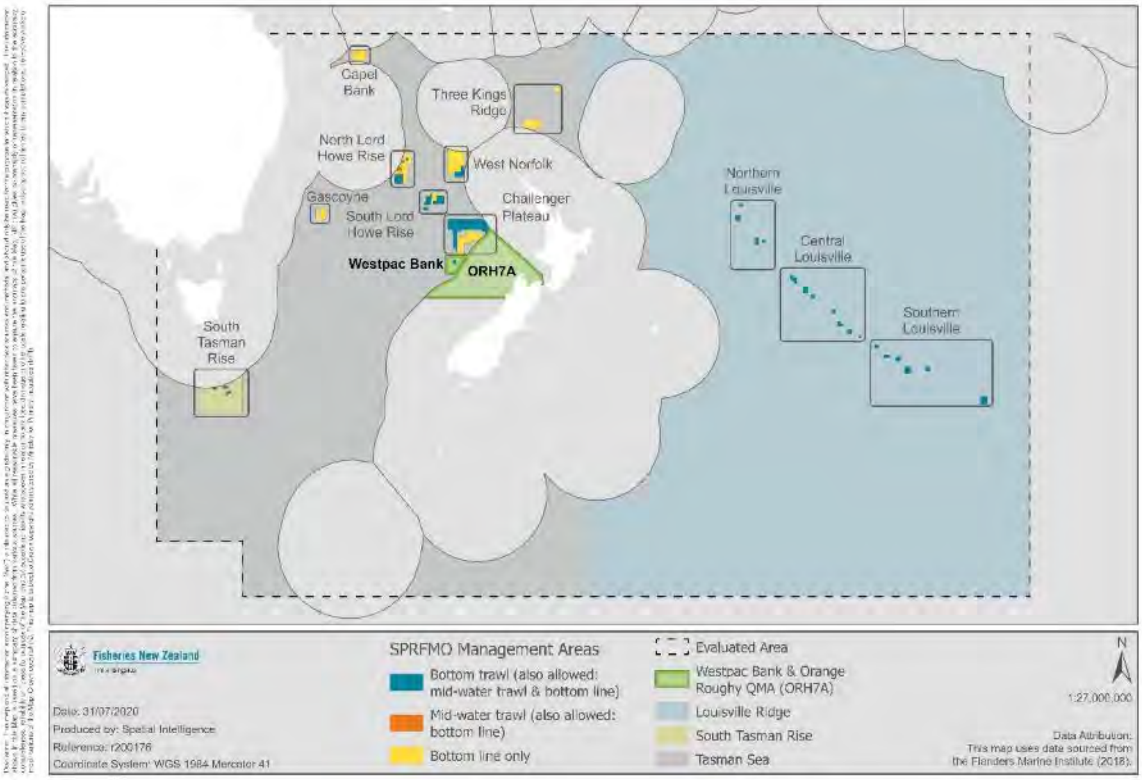

Figure 24: Areas open to different types of fisheries under SPRFMO CMM03-2020. Note that areas open to bottom trawling are also open to all other fishing methods and areas open to midwater trawling are also open to bottom long lines. The Evaluated Area is shown as a dashed line.

3.1 NEW ZEALAND BOTTOM FISHERIES

3.1.1 Trawl fisheries

3.1.1.1 Bottom trawl

The spatial extent of New Zealand bottom trawl fishing effort in the SPRFMO Evaluated Area in 1989–2022 was the largest of all gears, as well as the most intense.

Bottom trawl tracks were built from start and end tow positions, and effort was represented as the number of trawl tracks within each of the 5 minutes of arc cells. Intensity scales in the maps are consistent, to aid comparisons.

Orange roughy was the main target of bottom trawl fisheries effort and was widespread on the Louisville Ridge and on rises and plateaus alike (Figure 24). The effort targeting all other species had a lower intensity but showed a consistent spatial pattern with the orange roughy bottom trawl effort (Figure 25).

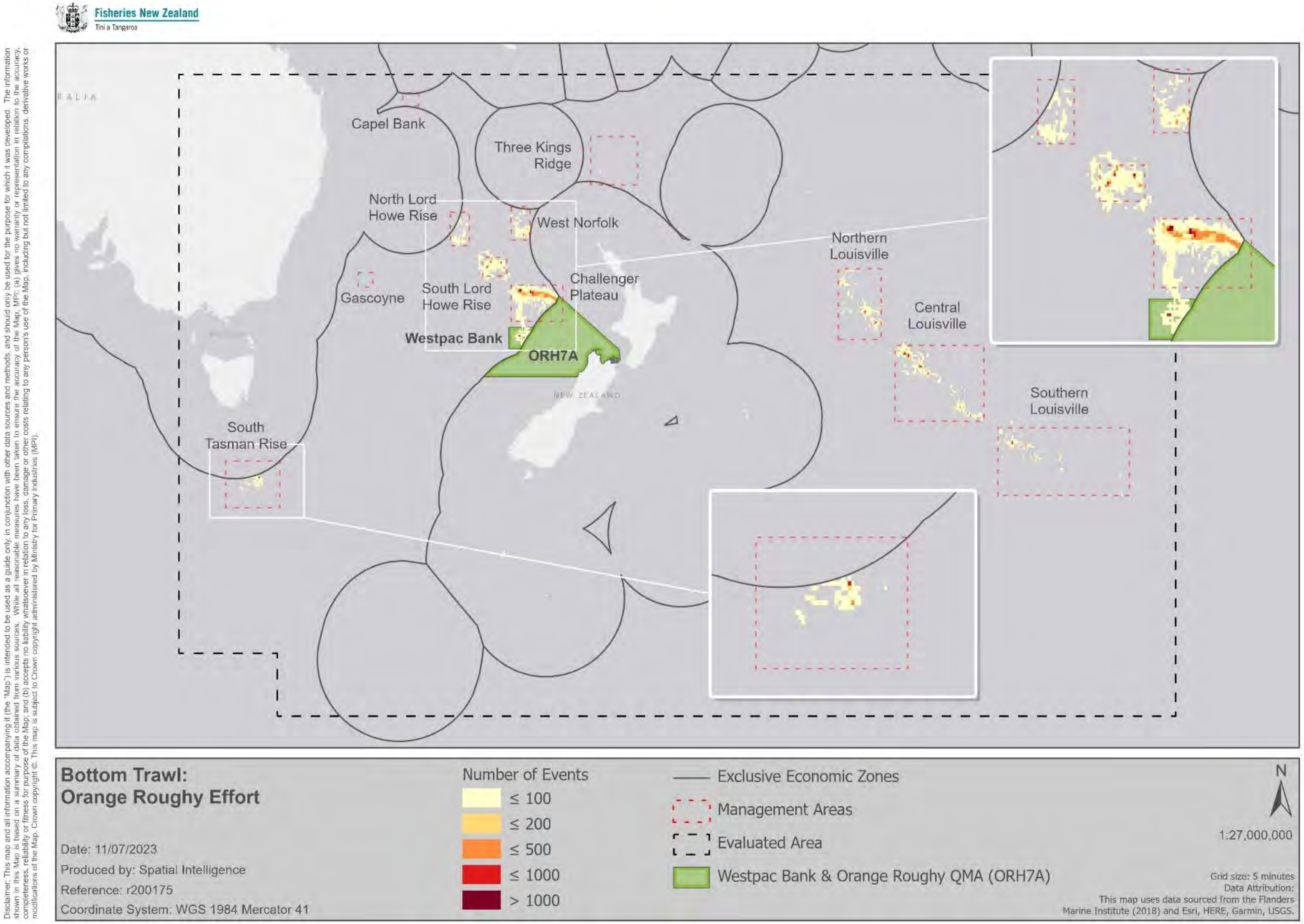

Figure 25: Map of fishing effort in the SPRFMO Evaluated Area by New Zealand vessels targeting ORH with bottom trawls, 1989–2022

Fisheries New Zealand
Tini a Tangaroa

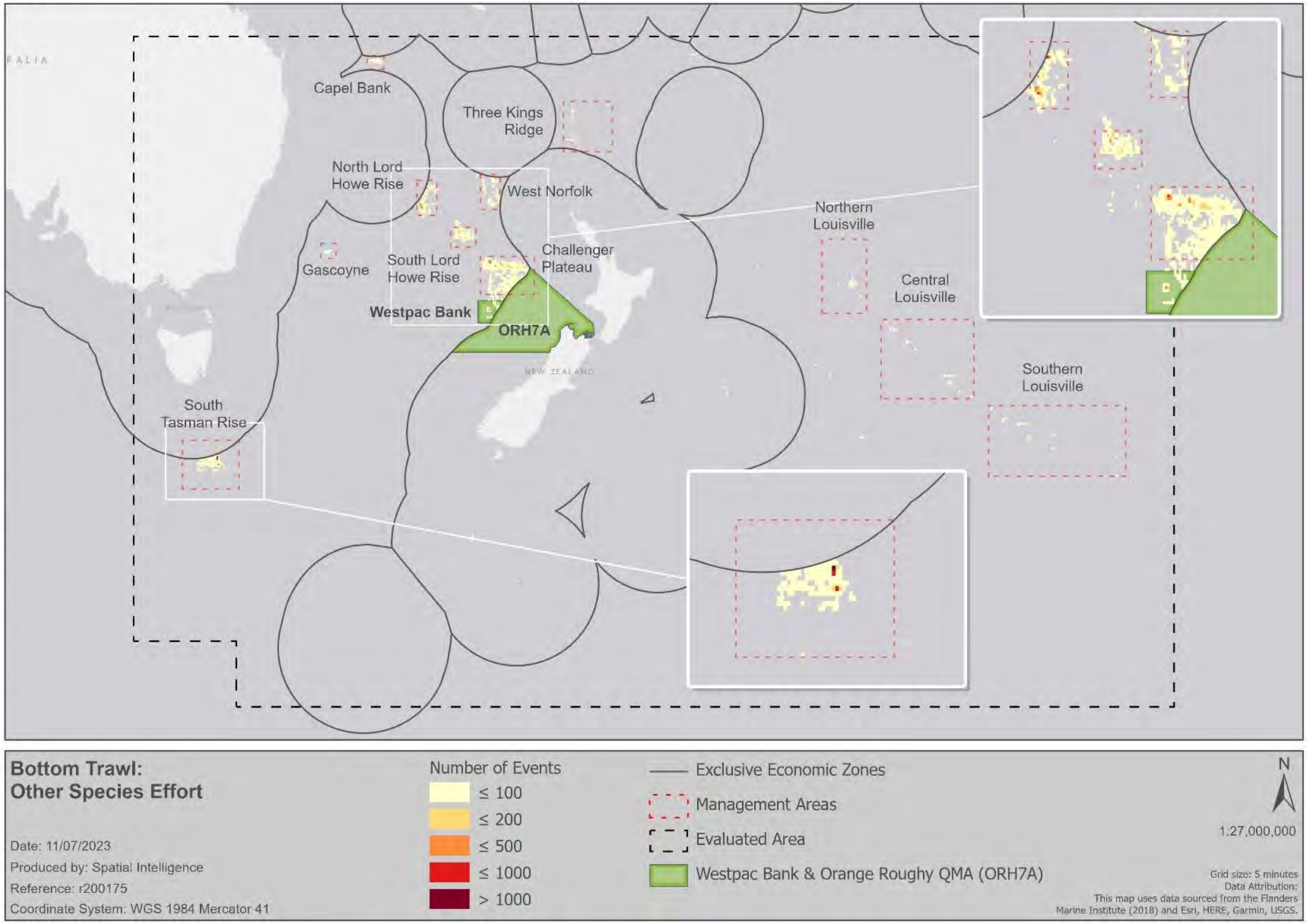

Figure 26: Map of fishing effort in the SPRFMO Evaluated area by New Zealand vessels targeting all other species with bottom trawls, 1989–2022

3.1.1.2 Midwater trawl

The spatial extent of New Zealand midwater trawl fishing effort in the SPRFMO Evaluated Area in 1989–2022 was much smaller than bottom trawl.

As for bottom trawls, midwater trawl effort was represented as the number of trawl tracks within each of the 5 minutes of arc cells. Intensity scales in the maps are consistent, to aid comparisons.

Alfonsino and bluenose / blue eye trevalla were the main target of the midwater trawl fishing effort, with a main cluster on the Lord Howe Rise (Figure 26). Effort targeting other species was relatively minor but showed a consistent spatial pattern with the main target species (Figure 27).

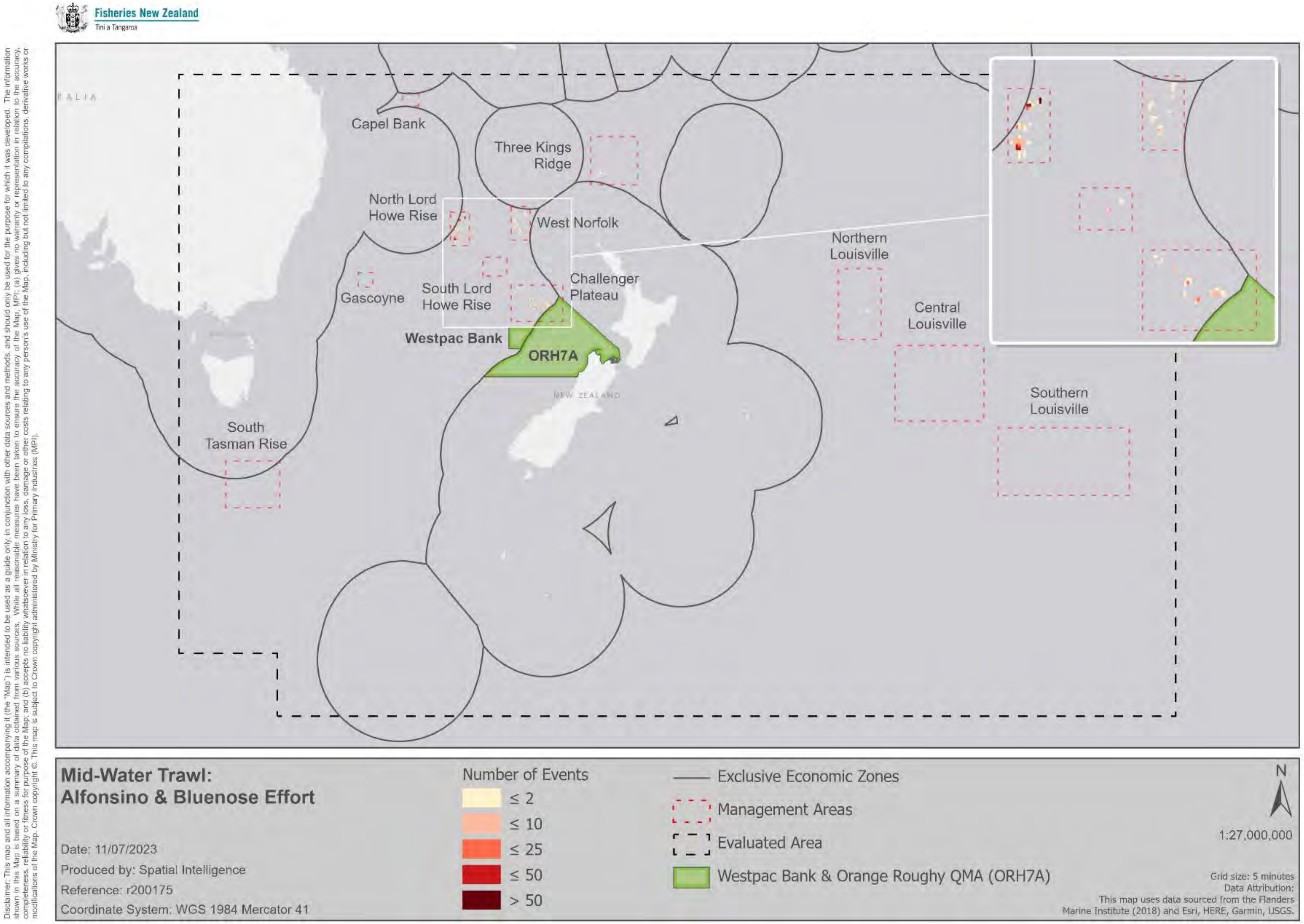

Figure 27: Map of fishing effort in the SPRFMO Evaluated Area by New Zealand vessels targeting ALF and BWA with midwater trawls, 1989–2022

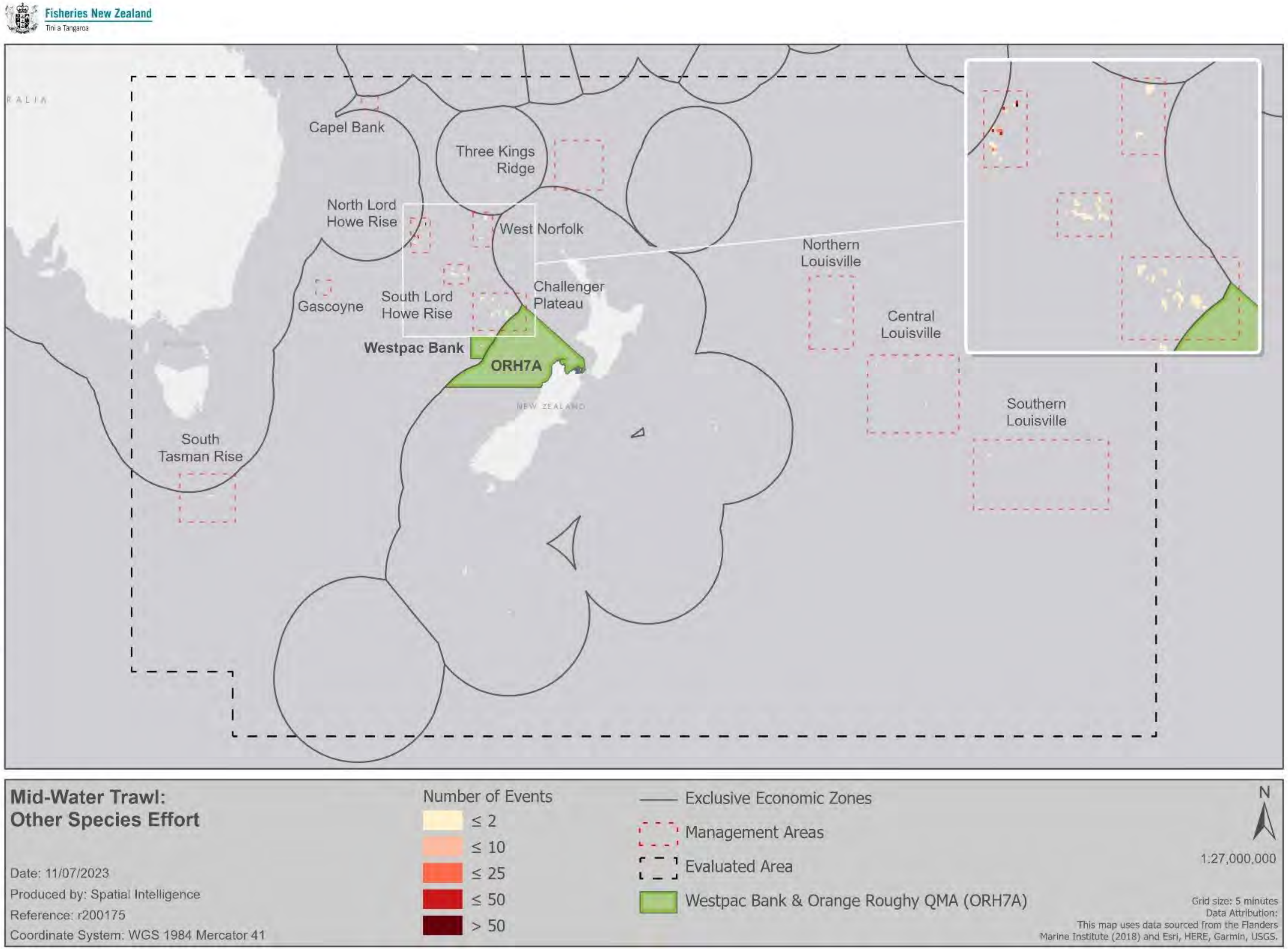

Figure 28: Map of fishing effort in the SPRFMO Evaluated Area by New Zealand vessels targeting all other species with midwater trawls, 1989–2022

3.1.2 Line fisheries

The spatial extent of New Zealand bottom longline fishing effort in the Evaluated Area in 1992–2022 was relatively minor, compared with trawl effort. Given that some of the records were missing end positions, and that longline sets are usually much shorter than trawl tracks, effort was represented as the number of starting set locations within each of the 5 minutes of arc cells. Intensity scales in the maps are consistent, to aid comparisons.

Bluenose was the main target of bottom longline fishing effort, with clusters on the Three Kings Ridge, the West Norfolk Ridge and the Challenger Plateau (Figure 28). Bottom longline fishing effort targeted at wreckfish (hapuku and bass combined) largely overlapped with bluenose effort but was most concentrated on the West Norfolk Ridge (Figure 29). Effort targeting other species was minor but showed some clustering in the Tasman Sea and in the northern part of the assessed area, including Capel Bank (Figure 30).

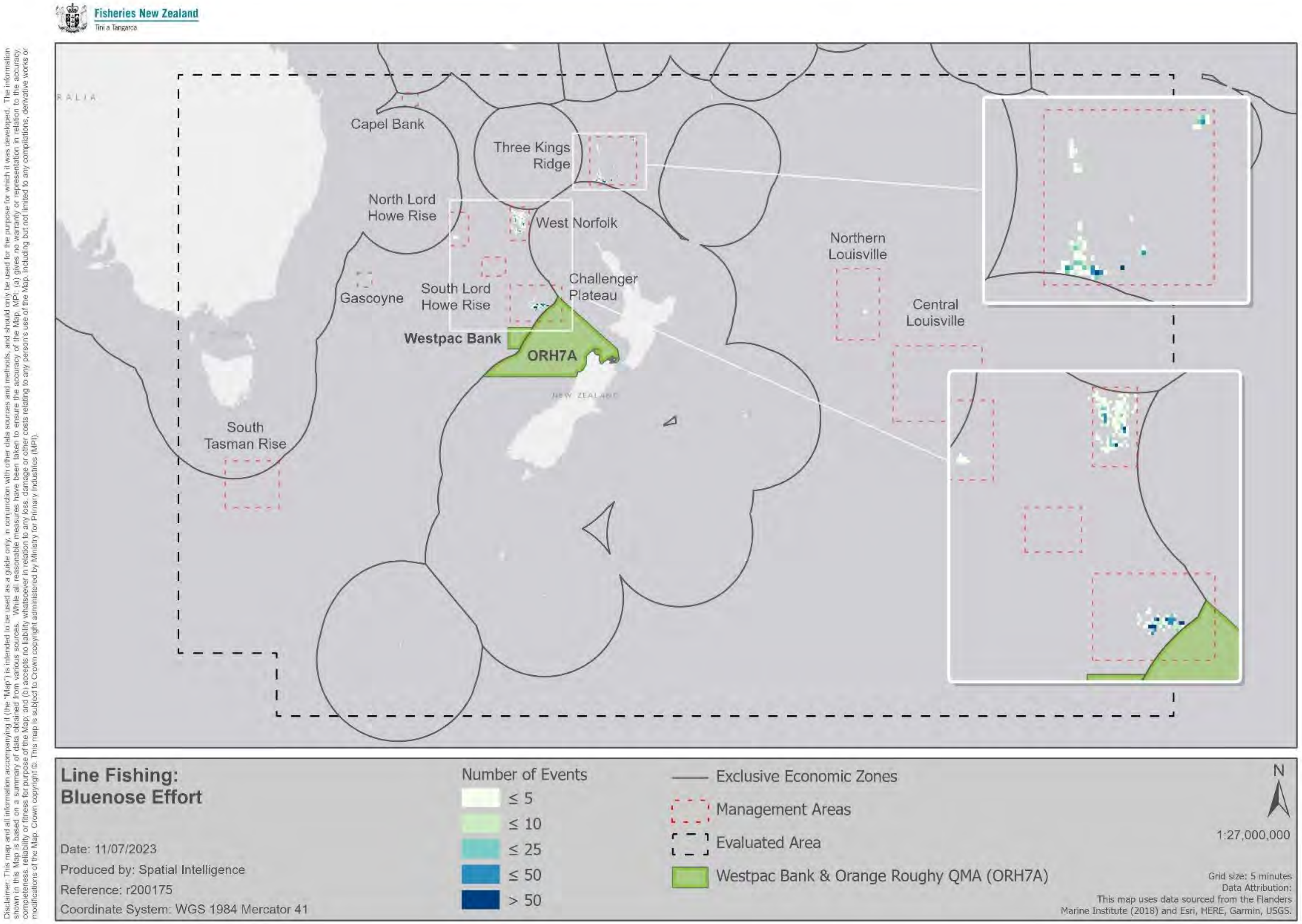

Figure 29: Map of New Zealand bottom longline fisheries effort targeted at BWA in the SPRFMO Evaluated Area, 1992–2022

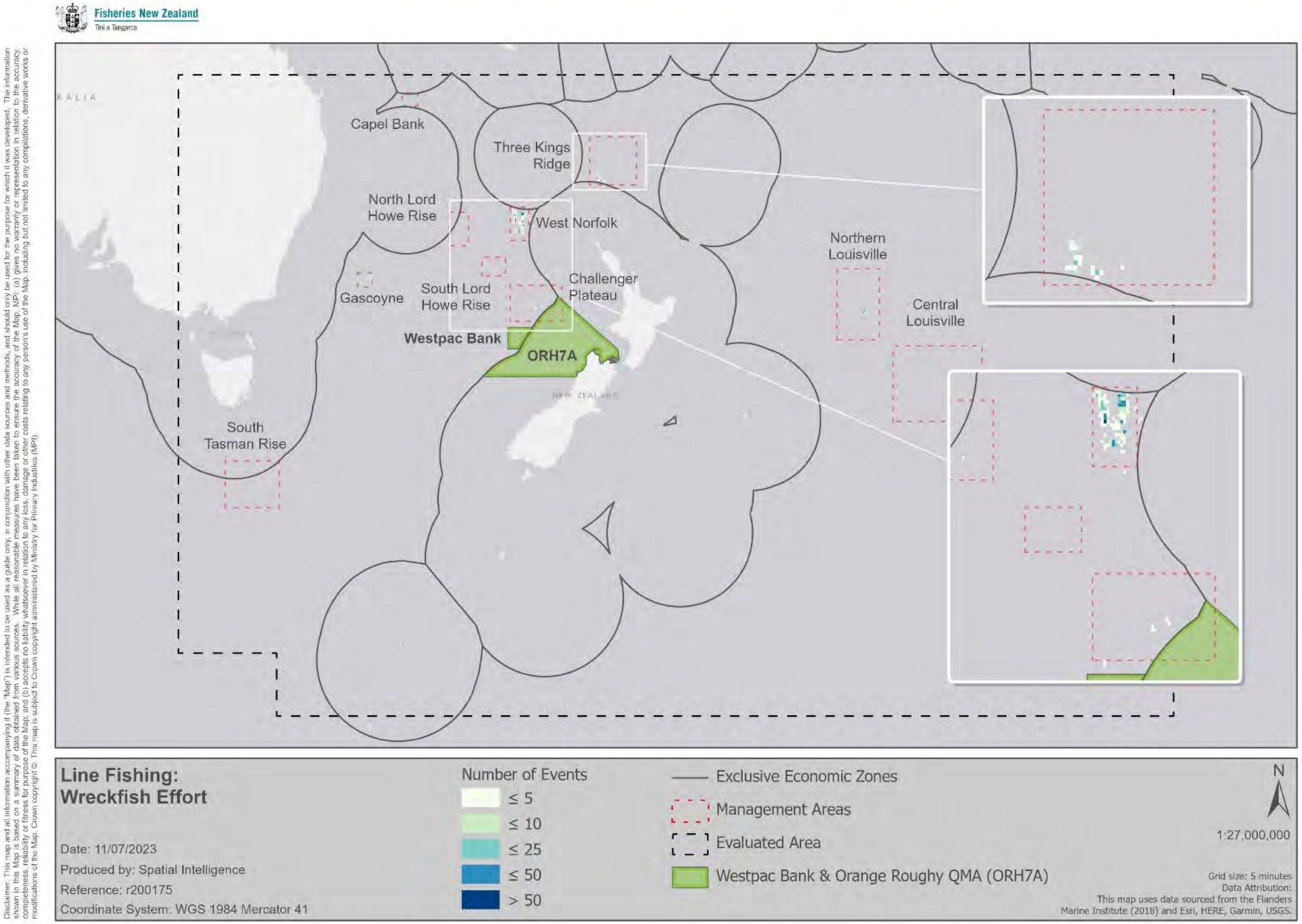

Figure 30: Map of New Zealand bottom longline fisheries effort in the SPRFMO Evaluated Area, targeted at wreckfish (HAU and HPB), 1992–2022

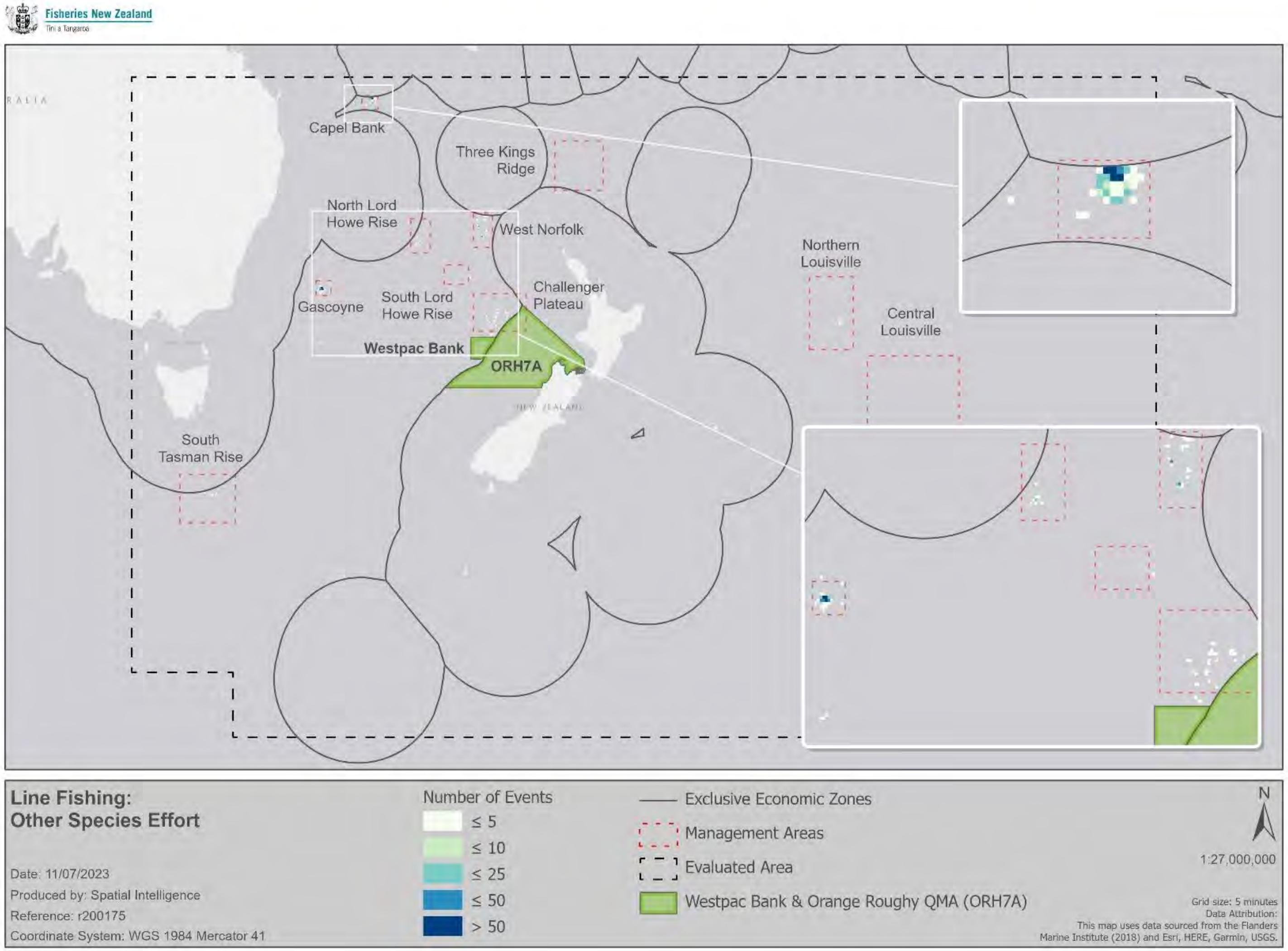

Figure 31: Map of New Zealand bottom longline fisheries effort in the SPRFMO Evaluated Area targeting all other species not included in the figures above, 1992–2022

3.2 AUSTRALIAN BOTTOM FISHERIES

Fine-scale maps of Australian fishing areas cannot be provided due to confidentiality and privacy constraints. Maps showing Australian fishing locations at an appropriate resolution may be provided in future updates to the BFIA. A general description of fishing areas is provided below.

3.2.1 Trawl fisheries

Most Australian demersal and midwater trawl fishing in the SPRFMO Convention Area has occurred in the Tasman Sea, although there has been some historical effort on the South Tasman Rise and the LSC. The main Tasman Sea trawl fishing areas are the South Tasman Rise (closed since 2007), Challenger Plateau and West Norfolk Ridge.

3.2.2 Line fisheries

Historically, most Australian demersal line fishing in the SPRFMO Convention Area has occurred around the Gascoyne and Lord Howe Rise seamounts in the Tasman Sea and around the Capel Bank in the Coral Sea.

4 RISK AND IMPACT ASSESSMENT

In accordance with the SPRFMO BFIA Standard (BFIAS), this impact assessment contains the following components:

1. Identification of objectives, assets, hazards and risks using a hierarchical risk assessment approach
2. Identification and assessment of impacts
3. Identification of mitigation, management and monitoring measures relevant to impacts and residual risks
4. Iterative and adaptive review (i.e., periodic reassessment and improvement).

In this assessment, risk is assessed at each level of a hierarchy based on the uncertainty inherent in various types of assessments (e.g., benthic assessments, stock assessments, productivity-susceptibility analyses etc.). The Hobday et al. (2011) approach (Figure 32) is an ecological risk assessment approach that, in this context, has been applied within the SPRFMO BFIAS framework of impact assessment, management of impacts, ongoing monitoring and iterative review.

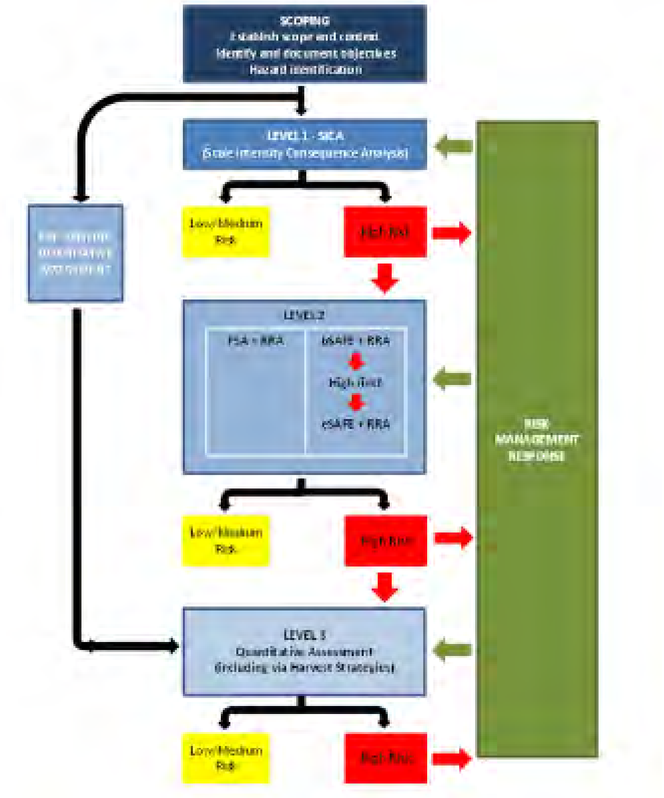

Figure 32: Structure of the three-level hierarchical methodology for the Ecological Risk Assessment for the Effects of Fishing methodology. Indicative methods available at each tier are shown, e.g., SICA – Scale Intensity Consequence Analysis; (Level 1); PSA – Productivity-Susceptibility Analysis; SAFE – Sustainability Assessment for Fishing Effects; (Level 2); Quantitative Assessment (Level 3); RRA – Residual Risk Analysis. Modified from Hobday et al. (2011).

The Hobday et al. (2011) risk assessment approach is structured around three tiers: the first is largely expert-based / qualitative assessment, the second is semi-quantitative and the third is fully quantitative estimates of the status of assets at various levels of detail. Within each tier there are various methods that can be adapted to fish stocks, other species of interest or concern, and VMEs, benthic habitats and communities. In this BFIA, we apply assessments at all levels of the hierarchy depending on the availability of information and data. Any risk that cannot be demonstrated to be low-medium with justification at a given tier needs to be assessed at the next tier or managed to reduce risk. Impacts need to be actively managed and/or mitigated and monitored.

In this assessment expert-based/qualitative assessments are applied for seabirds, marine mammals and reptiles; semi-quantitative or fully quantitative assessments for a range of fish stocks and other species of concern (including deepwater chondrichthyans); and fully quantitative assessments for VMEs.

4.1 SCOPING OF OBJECTIVES, ASSETS AND HAZARDS

The initial step in an assessment is to identify objectives as well as all 'assets of value' against all potential hazards the fisheries may pose.

The shared **objective** of CMM 03 (Bottom Fishing) and CMM 03a (Deepwater Species) are:

> *"through the application of the precautionary approach and an ecosystem approach to fisheries management, to ensure the long-term conservation and sustainable use of deep sea fishery resources, including target fish stocks as well as non-target or associated and dependent species, and, in doing so, to safeguard the marine ecosystems in which these resources occur, including* inter alia *the prevention of significant adverse impacts on vulnerable marine ecosystems."*

The scope of this impact assessment is constrained to historical and current fishing activities by Australia and New Zealand within the historical fishing footprints used to spatially manage fishing effort under previous bottom fishing CMMs and fishing that has occurred (and will likely occur) within the Evaluated Area and associated Management Areas specified in CMM03-2023 (Bottom Fishing).

Assessment of SAIs to VMEs is informed by the definitions and characteristics outlined in the FAO Deep-sea Fisheries Guidelines. Assessment of the impacts of fishing on fish stocks, seabirds, marine mammals and other species of concern is undertaken using a variety of methods and against various objectives depending on the asset.

The **assets** considered in this bottom fishing impact assessment are:

- Target species.
- Non-target (bycatch) species, which may be retained as byproduct or discarded.
- Seabirds, marine mammals, reptiles and other species of concern.
- Benthic habitats, biodiversity and VMEs.

The **hazards** considered in this bottom fishing impact assessment are:

- Fishing activity: this is evaluated for each gear type used by all vessels (e.g., trawling, longlining, etc.) engaged in fishing. This assessment includes consideration of the cumulative impacts of fishing gears on VMEs and the impact of each gear type on target species, non-target (bycatch) species, seabirds, marine mammals, reptiles, and other species of concern.

- Loss of bottom fishing gear, including the risk of ghost fishing and ongoing physical impact of lost gear.
- Non-gear impacts, for example bird strikes with vessels, discharge of offal or oil/fuel and other pollution, use of lights at night, noise pollution etc.

For each hazard evaluated a description of the impacts is provided in terms of what has been or may be affected and how.

Non-fishery related hazards that may result in cumulative risk and/or impacts include:

- a changing climate, including changes in oceanographic dynamics, ocean temperatures, ocean acidification, changes in oxygen, chlorophyll, carbon, salinity and other drivers of productivity.
- deep-sea mining and exploration, including seismic testing.
- ocean pollution, including plastics, chemical runoff, discharge from non-fishing vessels.
- hazards from non-fishing vessels, including noise/light pollution and non-fishing vessel related interactions with marine fauna.

These non-fishery related hazards are not assessed in this impact assessment.

4.2 INFORMATION ON STATUS OF THE DEEPWATER STOCKS TO BE FISHED

This section describes information on the key target and bycatch species encountered in SPRFMO deepwater fisheries. Bycatch species can be separated into those that are retained and those that are typically discarded. A list of demersal teleost and deepwater chondrichthyan species that have been assessed in SPRFMO fisheries (using a variety of methods) is included in Appendix B. This section also describes a framework for the assessment of SPRFMO deepwater stocks.

4.2.1 SPRFMO stock assessment framework

In accordance with SPRFMO CMMs 03 and 03a, the SPRFMO Scientific Committee is required to provide scientific advice to the SPRFMO Commission on the sustainability of a large number of target and non-target stocks, as well as advice on the impact of fishing on associated and dependent species with which the fishery interacts. The quantity, quality and suitability of data varies among species over time and space. This variability influences the parameters that can be estimated and associated uncertainties which, in turn, will affect the advice that the Scientific Committee can provide to the Commission. To improve the efficiency of processes run by the Scientific Committee, a tiered framework for assessing and prioritising stocks for assessment of status or other measures has been adopted based on the parameters that can be estimated given the data available. Such a tiered framework is intended to (eventually) assist the Scientific Committee with developing transparent decision rules for advice on recommended biological catches and potential buffers (e.g., ‘discount factors’), or other management measures (e.g., for non-target stocks), that may be applied to account for assessment uncertainty. The tiered levels consist of:

1. Full Benchmark Assessment that utilises catch data from fishery monitoring, ideally in combination with stock abundance from independent surveys, catch rates and biological data with the purpose of estimating depletion levels and fishing mortality rates;
2. Data Limited Assessment that may utilise catch only or simple indicators to track status (e.g., CPUE, size composition, PSA);

3. No assessment necessary.

Two subsets may apply after initial classification of stocks into Tier 1 or Tier 2:

i. Research Assessment where new methods or data types are applied which may require substantive review of the methods by the Scientific Committee; and

ii. Update Assessment where previous accepted assessments are updated with new data.

A preliminary categorisation into the tiered assessment framework has been undertaken for species with records of interaction with SPRFMO demersal fisheries. A small number of stocks have been categorised into tier 1 of the assessment framework, whereby they are (or may need to be) assessed using fully quantitative assessments (e.g., Cordue 2019a). A number of target and non-target (but generally retained) species have been categorised into tier 2, while the vast majority of bycatch species (which are generally caught in small volumes and discarded and also include species that rarely interact with the fisheries) have been categorised into tier 3. Categorisation into tiers 2 and 3 of the hierarchy has been informed by ecological risk assessments for SPRFMO teleosts and chondrichthyans (e.g., Georgeson et al. 2019; Georgeson et al. 2020) and associated analyses of species biology and the characteristics of fishing effort and catches.

The following sections describe key target stocks that have been categorised into tiers 1 or 2.

4.2.2 Predominantly trawl fisheries

4.2.2.1 Orange roughy (Hoplostethus atlanticus)

4.2.2.1.1 Stock structure

The biological structure of orange roughy stocks in the SPRFMO Convention Area is uncertain. Research indicates that there is a greater level of genetic structure in global orange roughy populations than has previously been detected (Varela et al. 2013). Analyses of biological data and various stock assessments have identified separate and geographically distinct fishing areas for orange roughy in the SPRFMO Convention Area due to substantial distances or abyssal-depth waters. These fishing areas are the high seas area of the South Tasman Rise, the northern and southern Lord Howe Rise, the Challenger Plateau and the West Norfolk Ridge.

In 2013, the first meeting of the SPRFMO Scientific Committee recommended that work be done to identify the existence and distribution boundaries of stocks of orange roughy (and alfonsino) that straddle EEZ boundaries and extend from EEZs into the SPRFMO Convention Area.

Several regional management units of orange roughy have been assumed for assessment purposes in the SPRFMO Convention Area. In addition to the South Tasman Rise stock (which straddles the Australian EEZ and the SPRFMO Convention Area), these units are Louisville North, Louisville Central, Louisville South, Lord Howe Rise, NW Challenger Plateau, and the Southwest Challenger Plateau (which straddles New Zealand's EEZ and the SPRFMO Convention Area) and West Norfolk Ridge. Work is currently underway to improve the delineation of biological stocks of orange roughy in the SPRFMO Convention Area.

Successful management of orange roughy in SPRFMO is partly contingent on the stock structure hypotheses used in the assessments (e.g., Cordue 2019a) being approximately correct. In light of uncertainty, a precautionary approach to their management has been pursued.

4.2.2.1.2 Stock assessment and status

Previous stock assessments are described in the 2020 BFIA (Delegations of Australia and New Zealand 2020). In 2022, stock assessment models using catch history, and age and length compositions, were used to estimate the minimum pre-fishing biomass that could have supported historical catches for each stock (Stephenson et al. 2022b). Estimates of the minimum pre-fishing biomass (B_{min}) were made for central, south, and north Louisville stocks, West Norfolk stock, Lord Howe Rise stock, and Northwest Challenger stock.

The B_{min} estimates replaced the previous Bayesian stock assessments after simulation modelling in 2022 found the data were insufficient to inform the most-likely (median) biomass estimates (B_0), and the previous assessments were therefore misleading (Stephenson et al. 2022b).

B_{min} was assumed to be the minimum initial biomass that did not incur a catch penalty (in deterministic calculations), or that incurred a catch penalty less than 5% or 10% of the time (in stochastic calculations). The catch penalty was incurred if the proportion of any age of fish that was caught in any year (the exploitation rate) was greater than 0.67. Recruitment was assumed constant in all estimates. B_{min} was calculated across a range of fixed B_0 and natural mortality rate (M) values, with deterministic calculations made for all stocks, and stochastic calculations also made for stocks having age frequency data (Central Louisville Ridge, Lord Howe Rise, and Northwest Challenger).

B_{min} was used as a proxy for B_0, with sustainable yields calculated by applying a fixed scalar associated with an MCY policy (1.45%) to the B_{min} (i.e., sustainable yield = $0.0145 \times B_{min}$). The MCY scalar of 1.45% was intended to be applied to B_0, therefore the yields here, being calculated using B_{min}, are precautionary.

The status of the stocks in the SPRFMO Convention Area is not well-known. The SPRFMO Scientific Committee has accepted stock assessments based on deterministic B_{min} with $M = 0.03$ for the main stocks (Table 13 and 14).

Table 13: B_{min} estimates (t) as a proxy for *B_0* for different assumed *M*, stochastic estimated probability of incurring the catch penalty (5% or 10%), and deterministic estimate (all parameters fixed).

	5%		10%		Deterministic	
	$M = 0.030$	$M = 0.045$	$M = 0.030$	$M = 0.045$	$M = 0.030$	$M = 0.045$
Louisville Ridge central	26 000	28 000	25 000	26 000	21 000	23 000
Louisville Ridge north	–	–	–	–	8 000	8 000
Louisville Ridge south	–	–	–	–	11 000	10 000
West Norfolk Ridge	–	–	–	–	3 000	3 000
Lord Howe Rise	12 000	11 000	12 000	11 000	12 000	11 000
Northwest Challenger	11 000	9 000	11 000	9 000	11 000	9 000

Table 14: Sustainable yield estimates (t) by multiplying B_{min} from different assumed M and calculation methods (Table 13) by a fixed scalar of 0.0145.

	5%		10%		Deterministic	
	$M = 0.030$	$M = 0.045$	$M = 0.030$	$M = 0.045$	$M = 0.030$	$M = 0.045$
Louisville Ridge central	377	406	363	377	305	334
Louisville Ridge north	–	–	–	–	116	116
Louisville Ridge south	–	–	–	–	160	145
West Norfolk Ridge	–	–	–	–	44	44
Lord Howe Rise	174	160	174	160	174	160
Northwest Challenger	160	131	160	131	160	131

The Southwest Challenger Plateau orange roughy stock straddles the New Zealand EEZ and the Westpac Bank area in the SPRFMO Convention Area. New Zealand has historically managed this fishery as a single biological stock, setting a domestic catch limit that applied to the New Zealand fleet across the whole range of the stock. The fishery in this area began in the 1980s and the first New Zealand catch limit in the area was set in 1986. New Zealand has completed a number of surveys and stock assessments of the area, to support the setting of catch limits for the full biological stock. The in-zone portion of the stock makes up New Zealand Quota Management Area ORH 7A, although New Zealand fishers have been required to report catch from the SPRFMO Convention Area against the domestic catch limit. The fishery was closed by New Zealand from 2000 to 2010 at which time it was re-opened with a total allowable commercial catch (TAC) of 500 t following a stock assessment that estimated there to be at least a 70% probability that the biomass had increased above New Zealand's "soft limit" of 20%B_0 (Ministry for Primary Industries 2008). The stock was assessed again in 2014, supported by trawl and acoustic surveys in 2010 and 2013 with the stock estimated to be well above the lower end of the New Zealand management target range of 30-50% B_0. The New Zealand total allowable commercial catch (TACC) was subsequently increased in 2014 to 1,600 tonnes.

The New Zealand bottom trawl footprint under CMM03-2018 before the significant changes in 2019 included two open blocks (of six within New Zealand's declared footprint) on the Westpac Bank in the SPRFMO Convention Area where the stock straddles the New Zealand EEZ. New Zealand vessels fishing in those two open blocks are required to report all catches against New Zealand's SPRFMO catch limit and also balance those catches with New Zealand Annual Catch Entitlement to ensure catches are accounted for within the New Zealand TAC for the whole stock.

In 2018, New Zealand undertook a combined trawl/acoustic survey and subsequently updated the stock assessment of the Southwest Challenger Plateau orange roughy stock. The stock assessment suggested the current biomass of the entire stock to be 47%B_0, and that a maximum catch of 2 448 t would maintain the biomass above 40%B_0 for the next 5 years (Cordue 2019b). These estimates informed a review of New Zealand's domestic catch limit (Total Allowable Commercial Catch, TACC) for the ORH 7A management area and the New Zealand Minister of Fisheries decided to increase the TACC to from 1 600 to 2 058 t. Bock and Cryer (2019) summarised the options presented to the New Zealand Minister of Fisheries and, based on its own consideration of these options, SPRFMO's Scientific Committee recommended to the Commission in its 2019 report that a catch limit for Westpac Bank could sustainably be set at a level up to 306 t, but that a catch limit of 258 t would represent a suitably precautionary approach. The SPRFMO catch limit for the Westpac Bank was increased from 200 t to 258 t in 2020 (Table 6).

SPRFMO CMM 03a-2023 was implemented in 2023 and sets catch limits based on stock assessment modelling and advice from the Scientific Committee for the Louisville Ridge and Tasman Seas FMAs assessed by Stephenson et al. (2022b) as presented in Table 14 (deterministic B_{min} with $M = 0.03$). Within CMM 03a-2023 the catch limit for Westpac Bank remained 258 t.

It should be noted that the results of the Cordue (2019b) assessments are conditional on the stock hypotheses being approximately correct and estimates of stock status have a high level of uncertainty. Nonetheless, catch limits derived from the subsequent Stephenson et al. (2022b) stock assessment are likely to be highly precautionary.

4.2.2.2 Alfonsino

4.2.2.2.1 Stock structure

Beryx splendens is a widely occurring benthopelagic species that aggregates around seamounts and features on the upper continental slope. It is likely that the majority of catches reported as '*Beryx* spp.' in SPRFMO are *Beryx splendens* although reported catches may also contain small amounts of *Beryx decadactylus*[9]. There have been taxonomic uncertainties within the *Beryx splendens* taxon (e.g., Hoarau and Borsa 2000) and evidence of extremely high intra-specific genetic diversity, even at small scales (Lévy-Hartmann et al. 2011).

FAO (2016) reviewed knowledge of alfonsino population structuring in the Pacific and identified a high level of complexity but a general lack of conclusive knowledge of distinct population structuring. Nonetheless, FAO (2016) presents two distinct populations relevant to the South Pacific; one for a New Caledonian population and another for a New Zealand population.

Hoarau and Borsa (2000) found evidence for two reproductively isolated sibling species (A and W) within the *Beryx splendens* taxon based on analysis of the gene composition of 250 alfonsino sampled from seamounts and continental margins in New Caledonia, New Zealand and southeast Australia and from the Northeast Atlantic. Hoarau and Borsa (2000) found no heterogeneity in the distribution of haplotype frequencies within either *B. splendens* species A or species W at the scale of New Caledonia and noted that three haplotypes from *B. splendens* sp. A in the Northeast Atlantic were also the three most common in the Southwest Pacific populations. This led to a conclusion that *B. splendens* sp. populations share a recent evolutionary history at the worldwide scale, which in turn implies genetic mixing at an interoceanic scale.

No information is available as to whether alfonsino is a single stock in New Zealand waters. Overseas data on alfonsino stock distributions suggest that New Zealand fish could form part of a widely distributed South Pacific stock (Fisheries New Zealand 2019). Horn and Massey (1989) found substantial differences in length frequency distributions between alfonsino from the Palliser Bank compared with those from other locations on the east coast of New Zealand's North Island, suggesting that there may be some age-specific migration occurring. Alekseev et al. (1986) suggested that *B. splendens* could comprise widespread populations in large oceanic eddy systems. FAO (2016) also noted that alfonsino might be contained within a large gyre system, or complex of gyres, that reach from the east coast of the North Island to the Louisville Ridge based on the presence of alfonsino on Louisville Ridge seamounts. If New Zealand alfonsino form part of such a system then the east coast North Island may be a non-reproductive zone where fish mature before leaving for a possible reproductive zone further east of the mainland (Horn and Massey 1989).

In summary, genetic studies have suggested a high level of interoceanic mixing but extremely high intra-specific genetic diversity. This may suggest that management units for alfonsino based on prevailing oceanographic currents and gyres, which may act to constrain certain populations to certain areas or influence reproductive connectivity, may be a sensible unit of assessment and management for this species. The evidence also suggests that such oceanographic dynamics may play an important role in the abundance and availability of alfonsino. It should be noted that there is very little new information on alfonsino stock structure in the South Pacific Ocean since 2000,

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[9] New Zealand generally reports catches of *Beryx* spp. using the code ALF and this code is associated with the majority of alfonsino catches in the SPRFMO database; the FAO 3-alpha code for *Beryx splendens* is BYS.

and very limited genetic work. Given the advances in genetics since then, we may draw some very different conclusions about stock structure if more contemporary techniques were applied.

It is likely that alfonsino on northern Lord Howe Rise constitutes a straddling stock. Under the SPRFMO Convention, such stocks are subject to compatible management arrangements within EEZs and on the high seas.

4.2.2.2.2 Stock assessment and status

There is no stock assessment for alfonsino in SPRFMO and biomass status is unknown[10]. *Beryx* spp. (code ALF) is listed as the second most caught demersal fish species by volume (~ 1 180 t) for the 2013–2022 period and *Beryx* spp. comprised around 9% of the total catch of demersal species over the last 10 years (93% of the midwater trawl catch and 6% of the bottom trawl catch).

4.2.2.2.3 Future workplan

The 7th meeting of the SPRFMO Scientific Committee agreed that a workplan to drive stock structure delineation efforts should be developed for *Beryx splendens* and presented to SC8 in 2020, but these efforts have been delayed. The 2023 Scientific Committee multi-annual workplan adopted by the 11th meeting of the SPRFMO Commission includes tasks to *Develop workplan to drive stock structure delineation studies for orange roughy and alfonsino and other key target species* (2023+) and *Review the list for deepwater stock structure analyses based on assessment for non-orange roughy stocks* (2025).

4.2.3 Predominantly line fisheries

4.2.3.1 Bluenose/blue-eye trevalla (Hyperoglyphe antarctica)

4.2.3.1.1 Stock structure

A number of studies on population structuring of *Hyperoglyphe antarctica* have been undertaken (e.g., Horn 2003; Hindell et al. 2005; Robinson et al. 2008; Williams et al. 2017) which have relevance to SPRFMO. Earlier studies (e.g., Hindell et al. 2005; Robinson et al. 2008) indicated that genetic variation was not significant among Australian fishery regions; however, Williams et al. (2017) note that genetic homogeneity can be maintained over broad scales even where reproductive exchange and/or movement is limited. In these situations, genetically homogenous populations may be comprised of a number of subpopulations that differ in terms of growth rate, reproduction, size at maturity, fecundity, recruitment patterns, etc. (Williams et al. 2017), indicating that regional management at a subpopulation level may be important even despite genetic homogeneity.

Williams et al. (2017) used three lines of evidence—phenotypic variation in age and growth, otolith microchemistry and potential larval dispersal—and identified four geographically distinct subpopulations around southern and eastern Australia (West, South, East and Seamounts-Lord Howe). Three of these subpopulations (South, East and Seamounts-Lord Howe) were found to be

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[10] A number of assessments exist for stocks that may straddle the Australian and NZ EEZs and the SPRFMO Convention area, e.g. Klaer, N. (2013) Yield, total mortality values and tier 3 estimates for selected shelf and slope species in the SESSF 2011. In: G.N. Tuck (Ed). *Stock assessment for the Southern and Eastern Scalefish and Shark Fishery 2012, part 2*. AFMA & CSIRO Marine and Atmospheric Research, Hobart. for alfonsino in Australia’s East Coast Deepwater Trawl Sector)

interconnected through regional exchange of larvae (Williams et al. 2017). Larval dispersal modelling and other findings of this research suggest that the Seamounts-Lord Howe population is likely to straddle Australia's EEZ and SPRFMO.

Horn (2003) made inferences as to stock structure of *H. antarctica* off the north-east coast of New Zealand based on results of a detachable hook tagging programme and found that *H. antarctica* off the eastern coast of New Zealand between North Cape and Kaikōura probably comprise a single biological stock. Stock boundaries are unknown, but similarity in trends in catch and CPUE across fisheries occurring in each of the five New Zealand *H. antarctica* Quota Management Areas (QMAs) suggests the possibility that there may be a single *H. antarctica* stock across all these areas, or of some close relationship between stocks in these QMAs. Tagging studies have shown that *H. antarctica* are capable of extensive migration, i.e., from the Wairarapa coast to Kaikōura, Bay of Plenty, and North Cape (Horn 2003).

Given knowledge of *H. antarctica* biology (i.e., long-lived, slow growth and late maturity), the characteristics of fishing for them (e.g., on and around seamounts), and the relatively significant catches compared to other SPRFMO demersal species, it may be prudent to prioritize the species for additional stock structure analyses in important SPRFMO fishing areas. There is evidence that targeting *Polyprion* spp. has replaced *H. antarctica* as a key focus of New Zealand line fisheries.

4.2.3.1.2 Status and/or catches

The stock status of *H. antarctica* in the SPRFMO Convention Area is unknown. The species has comprised around 3.3% of total SPRFMO demersal catches over the last 10 years. It was the third most caught demersal fish species by volume in SPRFMO during the 2013–2022 period (~ 416 t).

The eastern stock of the species is assessed domestically in Australia using standardized CPUE, which indicates biomass has varied over time, but between the relevant limit and target reference points (Haddon 2017). The species is assessed in New Zealand using a fully quantitative stock assessment. The Mean Posterior Distribution (MPD) estimates of stock size in 2016 was in the range of 17–27% B_0. Biomass was estimated to have declined continuously from the 1980s to 2011 and then to have either levelled off or increased slightly. Biomass has been below the default 40% B_0 target since around 2000 (Fisheries New Zealand 2023).

4.2.3.2 Hapuku, groper, wreckfish (Polyprion spp.)

4.2.3.2.1 Stock structure

Stock structure of *Polyprion oxygeneios* in Australian and New Zealand waters is unknown. The species has similar life history characteristics to *P. americanus* (long-lived, late age-at-maturity), which may suggest a broad population structure (Chick et al. 2018). Paul (2002) reviewed available data for New Zealand *Polyprion* spp. ('groper') and concluded that stock structure could not be described due to an absence of life history data.

4.2.3.2.2 Status and/or catches

Catches of *Polyprion* spp. (code HAU) in the SPRFMO database comprise the fourth most caught fish by volume (~ 393 t) for the most recent ten years (2013-2022). Low catches of *P. americanus* (code WRF) also occur.

Biomass status of *Polyprion* spp. in the SPRFMO Convention Area is unknown. In Australian waters, stock status for eastern Australian state-managed stocks of *P. oxygeneios* (New South Wales, Queensland and South Australia) is ‘undefined’ and the Commonwealth-managed stock is classified as ‘depleting’ (Chick et al. 2018). No estimates of biomass are available for New Zealand *Polyprion* spp. stocks (Fisheries New Zealand 2023).

4.2.3.3 Tarakihi/Jackass morwong (Nemadactylus macropterus)

4.2.3.3.1 Stock structure

Nemadactylus macropterus is a widely distributed species occurring around the southern half of Australia, New Zealand, southern South America, southern Africa and some islands in the Atlantic and Indian oceans. Genetic studies have shown no evidence of separate stocks in Australian waters, but found that Australian and New Zealand stocks are genetically distinct (Elliott and Ward 1994). Otolith microchemistry studies have indicated differences between Tasmanian and New South Wales/Victorian fish (Thresher et al. 2008) and larvae from New South Wales/Victoria have significantly different otolith microstructure to Tasmanian caught larvae (Bruce et al. 2001), but it is unclear if these differences indicate separate stocks. Bruce et al. (2001) found that the dispersal of long-lived larval stages is linked to offshore mesoscale oceanographic processes off south-eastern Australia. More recent studies using whole genome resequencing a weak but significant differentiation between tarakihi from New Zealand and Tasmania, but no significant clustering within New Zealand, although there was some evidence of fine scale structure between locations around central New Zealand off the east (Wairarapa, Cape Campbell, and Hawke’s Bay) and the west coast (Tasman Bay/Golden Bay and Upper West Coast of South Island) (Papa et al. 2022).

N. macropterus stocks around New Zealand have been identified as having a long pelagic larval phase, large scale movements from tagging (e.g., Annala 1987) and a lack of genetic isolation (Papa et al. 2022). (Fisheries New Zealand 2023) identifies considerable connectivity of *N. macropterus* along the east coast of the South and North Islands. The current stock hypothesis is that the Canterbury Bight/Pegasus Bay area represents the main nursery area for the eastern stock unit. At the onset of maturity, a proportion of the fish migrate northwards to recruit to the East Cape area and, subsequently, the Bay of Plenty and east Northland areas. This hypothesis is further supported by the northward movement of tagged fish from the Kaikōura coast to the Wairarapa, East Cape and Bay of Plenty areas.

It is worth noting that the recent advances in genetic approaches have enhanced the ability to evaluate population structure and may lead us to different conclusions than these previous studies.

4.2.3.3.2 Status and/or catches

Nemadactylus spp. (mostly *N. macropterus*) have comprised around 1.8% of demersal catches in the SPRFMO Convention Area over the last 10 years. Approximately 231 t was caught in SPRFMO bottom fisheries during 2014–2018. There have been some concerns around stock status in both Australia (Stobutzki et al. 2009) and New Zealand (Fisheries New Zealand 2023) in the past, but the Australian eastern stock has since recovered (Tuck et al. 2015). The New Zealand east coast stock (management units TAR 1E, TAR 2, TAR 3 and parts of TAR 7) was recently assessed to be below 20%B_0 and experiencing overfishing (Fisheries New Zealand 2023).

4.2.3.4 Yellowtail kingfish (Seriola lalandi)

4.2.3.4.1 Stock structure

Seriola lanandi is a highly mobile pelagic species with a widespread distribution that extends throughout temperate waters of the Atlantic, Pacific and Indian Oceans (Nugroho et al. 2001). Genetic analyses have shown the population off Western Australia to be genetically distinct from the *S. lalandi* found on the eastern and southern Australian coasts or within New Zealand waters (Miller et al. 2011). These findings confirm results from previous analyses that found no evidence of genetic differentiation between New Zealand and New South Wales *S. lalandi* (Smith et al. 1991) and results of tagging studies which show that *S. lalandi* undergo movements between Australia and New Zealand waters (Gillanders et al. 2001).

For New Zealand *S. lalandi*, a study based on meristic characteristics and parasite loads suggests two stocks of kingfish off the west and east coasts (Fisheries New Zealand 2019). These stocks are contained within the Tasman current on the west coast and the east Auckland current and east Cape current on the east coast, with little mixing between them (Fisheries New Zealand 2019). Tagging results suggest that most adult kingfish do not move outside local areas, with many tag returns close to the release site. However, some tagged kingfish have been found to move very long distances. For example, New Zealand Fisheries (2019) note reports of New Zealand tagged *S. lalandi* being caught in Australian waters and Australian tagged kingfish being recaptured in New Zealand waters.

4.2.3.4.2 Status and/or catches

Seriola spp. (mostly *S. lalandi*) have comprised around 1.7% of total SPRFMO demersal catches over the last 10 years. Catches from 2013-2022 totalled approximately 223 t.

Status of the eastern Australian stock is uncertain (Hughes et al. 2018). Catches in the SPRFMO Convention Area by Australian vessels in 2017 (~35 t) comprised a significant proportion of total mortality (~120 t in 2017) from commercial fishing by Australian vessels for this stock. Various indicators (CPUE, spawning potential ratio, tag recaptures and F/M estimates) suggest that the eastern Australian stock is depleted in at least part of its range (Hughes et al. 2018). For New Zealand stocks, CPUE in a variety of commercial and recreational fisheries increased considerably between 2006 to 2016 and has been relatively stable at a high level since. Overfishing is assessed to be unlikely (Fisheries New Zealand 2020). In New Zealand waters kingfish is mostly taken as bycatch while fishing for other species (Fisheries New Zealand 2018). Recreational catches in Australia and New Zealand comprise a significant proportion of overall catches.

*4.2.3.5 Toothfish exploratory fisheries (*Antarctic toothfish, *Dissostichus mawsoni*, or Patagonian toothfish, *Dissostichus eleginoides)*

Dissostichus (the toothfish) is a genus of notothen found in the Southern Hemisphere. Both Patagonian and Antarctic toothfish are distributed circumpolarly near the Antarctic, at depths between 600 and 1900 m. Both species are long-lived (up to 50 years), relatively slow growing (but reach maximum sizes exceeding 100 kg) and are benthopelagic as adults.

An exploratory bottom longline fishery started for New Zealand in 2016. This exploratory fishery used a stepwise process of ground location, ground observation for fishing feasibility, structured test fishing, and ultimately fishing in accordance with annual precautionary catch limits (SPRFMO SC03, subsequently approved with CMM 4.14). Other countries have since been granted approvals for toothfish exploratory fisheries: the EU (CMM 14c-2019, limited to 45 tonnes per year) and Chile (CMM 14d-2020, limited to 54 tonnes each year). A minimum tagging rate of three fish of each *Dissostichus* species per greenweight (live weight) tonne is implemented in these exploratory fisheries.

Toothfish exploratory fisheries are limited in spatial extent (with areas identified in the CMM for each country) and follow management measures consistent with relevant measures in force in the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Area (see CM 41-10, 2014). Bycatch species include: macrourids (*Macrourus whitsoni*, with probably lesser amounts of *M. holotrachus* and *M. carinatus*); violet cod (*Antimora rostrate)*; other morid cods; and low numbers of skates, typically *Amblyraja georgiana*. A move-on rule applies if deepwater shark bycatch exceeds 250 kg in any cluster of lines.

4.2.3.5.1 Status and/or catches

An annual retention limit (greenweight) of toothfish catch, regardless of species, is in force for this exploratory fishery. Fish that are tagged and returned alive to the sea are not counted against this limit. Catch and effort are monitored on a shot-by-shot basis and fishing operations cease once the limit is reached. The catch limit was increased from the initial 30 tonnes in 2016 and 2017 to 140 tonnes (with additional vessel and stratum catch limits) under CMM 14a-2019 and increased further to 240 t under CMM 14a-2022.

No results have yet been reported to the Scientific Committee from exploratory fisheries for toothfish by Chile, but the European Union (EU) has reported on a survey conducted in 2021 (European Union 2022). The stock hypotheses and status of toothfish stocks in the SPRFMO Convention Area are still under investigation.

4.2.4 Priority species for stock structure delineation studies

Based on the outcomes of the 7th meeting of the SPRFMO Scientific Committee (SC-07) (and following consideration of SC-07-DW09 and the teleosts ecological risk assessment (discussed below in Section 4.2.5), SC-07 noted that stock structure delineation studies would be useful in the short to medium-term for *Hoplostethus atlanticus* and *Beryx splendens*, and agreed that a workplan to drive stock structure delineation efforts should be developed for each of these species. SC-07 further noted that stock structure delineation studies could be useful in the medium to longer-term for the following species: *Hyperoglyphe antarctica*, *Polyprion oxygeneios* and *P. americanus*, *Nemadactylus macropterus*, *Seriola lalandi,* emperors (Lethrinidae) and snappers (Lutjanidae, *Etelis* spp.). SC-07 agreed that fish species not included above are caught in SPRFMO fisheries in such low volumes that stock structure delineation studies are a very low priority. It has not been possible to progress these stock structure tasks to date, but the 2023 Scientific Committee multi-annual workplan adopted by the 11th meeting of the SPRFMO Commission includes tasks to *Develop workplan to drive stock structure delineation studies for orange roughy and alfonsino and other key target species* (2023+) and *Review the list for deepwater stock structure analyses based on assessment for non-orange roughy stocks* (2025).

4.2.5 Ecological risk assessment for SPRFMO demersal teleost species

A series of ecological risk assessments (e.g., Georgeson et al. 2019; Georgeson et al. 2020) have been undertaken as part of the requirement for the SPRFMO Scientific Committee to provide advice to the Commission on a large number of target and non-target species. These semi-quantitative assessments are useful for rapidly assessing the relative vulnerability of a large number of species to fishing activities, particularly in data-limited fisheries. These have not been updated for the 2023 BFIA.

The Georgeson et al. (2019) assessment used Productivity-Susceptibility Analysis (PSA) and Sustainability Assessment for Fishing Effects (SAFE) tools to assess the vulnerability of 159 teleost species to demersal trawl, midwater trawl and demersal longline gears in the SPRFMO Convention Area. This assessment is described in this section as it contains a large number of targeted and byproduct species, as well as the large number of species that are not commercially important. Methods are described in the relevant Scientific Committee papers and publications and are not repeated here.

For this assessment, PSA was run primarily to check if vulnerability rankings using the PSA and SAFE tools were comparable. Running both methods side-by-side enhanced the ability to identify potential false negatives and false positives. Given a number of methodological limitations of PSA and the fact that it is, by design, extremely precautionary, more emphasis should be given to the SAFE results. As expected, the PSA results from the Georgeson et al. (2019) assessment resulted in a large number of probable false positives (species incorrectly found to be at ‘high risk’). This was largely due to the PSA assuming that species may still be at risk to fishing even if they do not overlap with fishing effort, whereas the SAFE gives a true zero (i.e., zero overlap between species distribution and fishing effort results in zero risk).

It is important to note that these assessments were undertaken to prioritise species that may warrant additional attention, and not to provide absolute estimate of true risk. Consequently, the relative risk and vulnerability scores described herein should be viewed in the context of the understanding of the characteristics of SPRFMO fisheries, including the catches of each species that have been taken over time; the life history traits and biology of each species; and the additional work underway to respond to the prioritisation of certain species based on the results.

4.2.5.1 Productivity-Susceptibility Analysis (PSA)

Given the caveats describe above, we do not describe PSA results in detail here.

Of the 159 teleost species assessed, 23 were classified in this assessment as PSA data deficient (i.e., missing three or more productivity and/or susceptibility attributes). Many of these data deficient species are classified as high vulnerability in the PSA (Figure 33) and most are likely to be false positives as catch records indicate they rarely interact with the fishery. These species have been proposed for inclusion into Tier 3 of the SPRFMO stock assessment framework (no further assessment required).

4.2.5.2 Sustainability Assessment for Fishing Effects (SAFE)

The SAFE tool provides estimates of F_{curr} in relation to F-based reference points to determine a species' vulnerability to fishing. The tool uses three parameters: spatial overlap of fishing effort with a species' distribution, catchability (based on size- and behaviour-dependent catch rate and habitat-dependent encounterability) and post capture mortality to determine F_{curr} (Zhou et al. 2012). The SAFE tool relates life-history traits that inform natural mortality, growth rate and intrinsic rate of increase to biological reference points derived from the literature. The result is that F_{curr} can be compared with F-based reference points F_{msm}, F_{lim} and F_{crash}.

The SAFE classified several species as high ($F > F_{lim}$) or extreme ($F > F_{crash}$) vulnerability in the South Pacific Ocean. Seven species were vulnerable to demersal trawl, seven species to midwater trawl and 14 species to demersal longline fishing gears (Figure 33 and Table 15). Teleost species classified as high or extreme vulnerability across all fisheries (Figure 33 and Table 15) in the South Pacific Ocean included silver spinyfin (*Diretmus argenteus*), giant oarfish *(Regalecus glesne),* thorny tinselfish *(Grammicolepis brachiusculus),* Parin's spinyfin *(Diretmichthys parini*), narrownecked oceanic eel *(Derichthys serpentinus),* basketwork eel *(Diastobranchus capensis)* and barbeled dragonfish (*Melanostomias valdiviae).* All of these were data deficient species for which F_{msm}, F_{lim} and F_{crash} could not be calculated because of a lack of biological data to inform the productivity attributes. Out of the 159 species assessed, two additional species (*Ostracion cubicus* and *Triodon macropterus*) were missing data needed to calculate F-based reference points, meaning a total of nine species are not present in Figure 33.

The PSA and SAFE vulnerability scores for 150 teleost species are compared in Figure 33, with a subset of species assessed to be at high or extreme SAFE vulnerability and corresponding PSA vulnerability shown in Table 15. The results indicate good concurrence between the PSA and SAFE results for most species categorised as being at high or extreme vulnerability in the SAFE. However, around half of these species at the upper end of the risk spectrum were data deficient (see Table 15), resulting in higher vulnerability scores in both the PSA and SAFE. Many species classified as high or medium vulnerability by the PSA were ranked as low vulnerability by the SAFE (Table 15 and Figure 33) and many of these are very likely to be false positives (i.e., species assessed to be at high risk that are probably low risk in reality). False positives in the PSA are expected and are a design feature of the method that assigns higher rankings to species with less information. False negatives (i.e., species assessed to be low risk that may be high risk in reality), on the other hand, are often more difficult to identify. Running PSA and SAFE together provides enhanced ability to identify potential false positives and false negatives. There are some examples of species being ranked higher in the SAFE than in the PSA (e.g., *Nemadactylus macropterus* in the assessment for demersal longline gears, which was ranked medium in the PSA and high in the SAFE and may indicate a potential false negative in the PSA). Evidence of potential false positives at the medium and upper end of the PSA vulnerability rankings, include, for example, *Bassanago hirsutus* (PSA high, SAFE low), *Helicolenus percoides* (PSA medium, SAFE low) and *Rexea solandri* (PSA medium, SAFE low) for demersal trawl and midwater trawl gears (Table 15).

For demersal trawl gears, data-robust species assessed by the SAFE to be at medium vulnerability were *Bassanago hirsutus* and *Hoplostethus atlanticus*. For midwater trawl gears, data-robust species assessed by the SAFE to be at medium vulnerability were *Bassanago hirsutus* and *Pseudopentaceros richardsoni*.

For longline gears, data-robust species assessed to be at high vulnerability were *Bassanago hirsutus*, *Helicolenus percoides*, *Epigonus telescopus*, *Nemadactylus macropterus*, *Rexea solandri* and data-robust species assessed to be at extreme vulnerability were *Polyprion oxygeneios* and *Hyperoglyphe antarctica* (Table 15).

Australia intends to update Ecological Risk Assessments for teleosts during 2024 and these results will be presented to SC12.

4.2.5.3 Catch of assessed species in the SPRFMO Convention Area

Table 16 provides details of the top ten species (or groups of species) caught in the SPRFMO Convention Area between 2012 and 2016[11] and their respective vulnerability ranking from both the PSA and SAFE. Of the top ten species, four (*Hyperoglyphe antarctica, Polyprion spp., Nemadactylus macropterus* and *Epigonus telescopus*[12]) were classified as high or extreme vulnerability in the SAFE (all in the assessment for demersal longline gears) (Table 16).

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[11] This corresponds to the Australian and New Zealand effort dataset used in the ERA

[12] Note that this species was caught exclusively by demersal trawl gears during the 2012-2016 period, indicating a probable false positive in the demersal longline SAFE assessment.

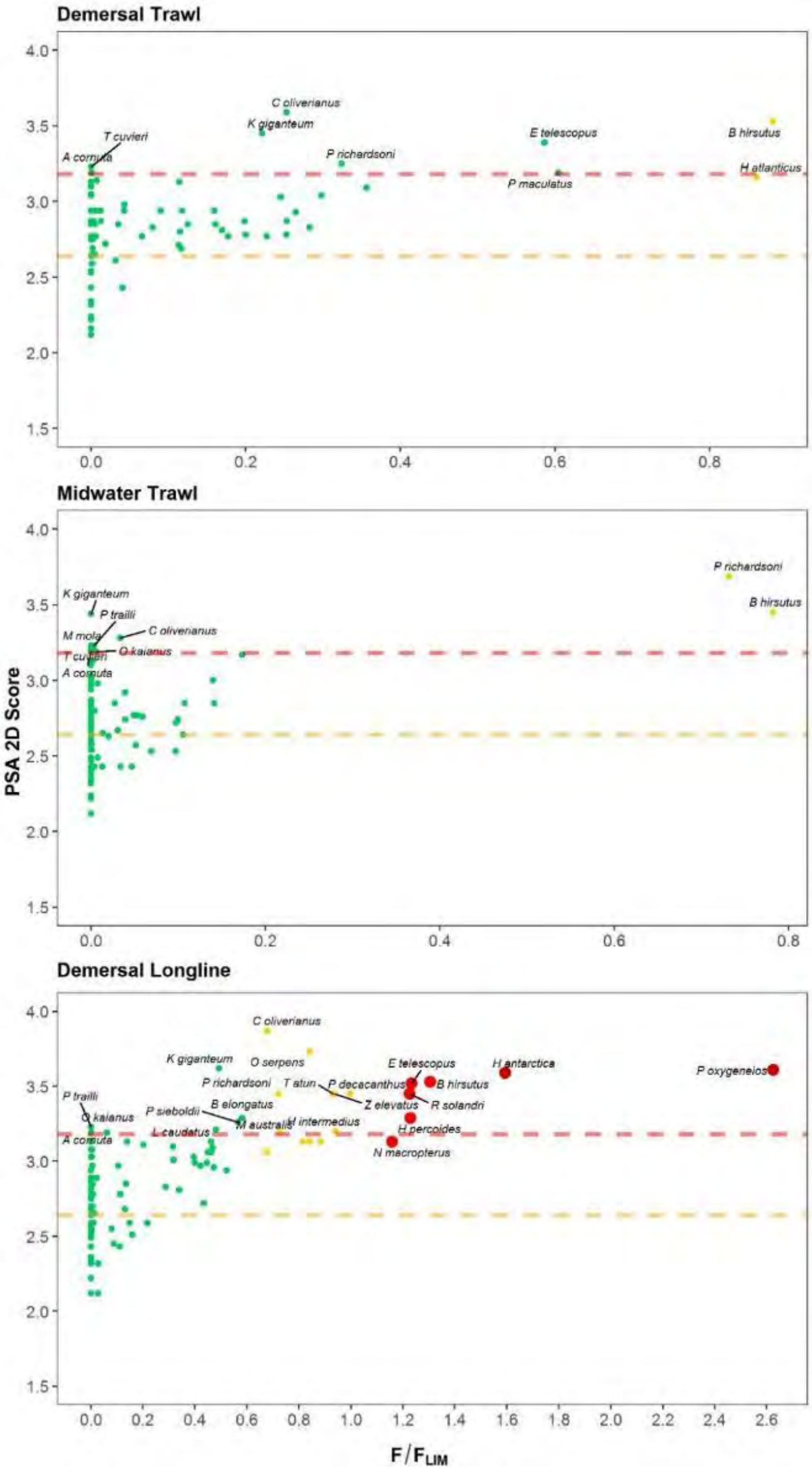

Figure 33: Relationship between SAFE and PSA results for 150 teleost species thought to occur and have the potential to interact with demersal, midwater trawl and demersal longline gears in the SPRFMO Convention Area. Points are coloured dark red, light red, yellow and green to signify species classified as extreme, high, medium and low vulnerability respectively in the SAFE. Dashed red and orange lines represent PSA risk high and medium score boundaries. Nine species could not be shown on the panels as F-based reference points could not be calculated.

Table 15: Matrix of high and extreme vulnerability teleost species from the SAFE and their respective PSA score for each fishery along with 2012-2016 catch totals in the SPRFMO Convention Area. Proportion of catch by gear type for the last 5 years (2014-2018) is also included to indicate the main fishery catching each species.

Teleost species	Data deficient in PSA	2012-2016 fishing activity (kg)	Proportion of catch (last five years 2014-2018) by gear type	Demersal Trawl		Midwater Trawl		Demersal Longline	
				PSA	SAFE	PSA	SAFE	PSA	SAFE
Diretmus argenteus (DD)	Yes	0	N/A	High	Extreme	High	Extreme	High	Extreme
Regalecus glesne (DD)	Yes	6	100% Demersal Trawl	Medium	Extreme	Medium	Extreme	Medium	Extreme
Grammicolepis brachiusculus (DD)	Yes	N/A **a**	N/A	High	Extreme	High	Extreme	High	Extreme
Diretmichthys parini (DD)	Yes	0	N/A	Medium	Extreme	Medium	Extreme	Medium	Extreme
Derichthys serpentinus (DD)	Yes	N/A **a**	N/A	High	Extreme	High	Extreme	High	Extreme
Diastobranchus capensis (DD)	No	295	100% Demersal Trawl	High	Extreme	Medium	Extreme	Medium	Extreme
Melanostomias valdiviae (DD)	Yes	N/A **a**	N/A	High	Extreme	Medium	Extreme	Medium	Extreme
Polyprion oxygeneios	No	12,366[13]	72% Longline 28% Demersal Trawl	Medium	Low	Medium	Low	High	Extreme
Hyperoglyphe antarctica	No	358,260	92% Longline 5% Demersal Trawl 2% Midwater Trawl	Medium	Low	Medium	Low	High	Extreme
Bassanago hirsutus	No	930	100% Longline	High	Medium	High	Medium	High	High
Helicolenus percoides	No	26,238	99% Longline 1% Demersal Trawl	Medium	Low	Medium	Low	High	High
Epigonus telescopus	No	71,484	100% Demersal Trawl	High	Low	Medium	Low	High	High
Rexea solandri	No	2,472	100% Longline	Medium	Low	Medium	Low	High	High
Nemadactylus macropterus	No	162,591	100% Longline	Low	Low	Medium	Low	Medium	High

Notes: DD = Data deficient in SAFE, defined as species for which F-based reference points were unable to be calculated. N/A = Not applicable. **a** Interactions with these species are recorded in the SPRFMO database but there is no catch data associated with them.

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[13] Note that 192,844 kg of '*Polyprion* spp.' is recorded in the SPRFMO database for this period.

Table 16: Matrix of top 10 species (or species groups) by catch volume based on 2012-2016 catch and their respective PSA and SAFE vulnerability score for each gear type assessed in the SPRFMO Convention Area.

Teleost species/group	2012-2016 fishing activity (kg)	Proportion of catch (last five years 2014-2018) by gear type	Specific species	Demersal Trawl		Midwater Trawl		Demersal Longline	
				PSA	SAFE	PSA	SAFE	PSA	SAFE
Hoplostethus atlanticus	5,427,208	100% Demersal Trawl		Medium	Medium	Medium	Low	Medium	Low
*Beryx spp.**	767,106	68% Demersal Trawl 31% Midwater Trawl <1% Longline	*Beryx splendens*	Medium	Low	Low	Low	Medium	Low
			Beryx decadactylus	Medium	Low	Medium	Low	Medium	Low
Hyperoglyphe antarctica	358,260	92% Longline 5% Demersal Trawl 2% Midwater Trawl		Medium	Low	Medium	Low	High	Extreme
Polyprion spp.	274,172	98% Longline 2% Demersal Trawl	*Polyprion americanus*	Medium	Low	Medium	Low	Medium	Low
			Polyprion oxygeneios	Medium	Low	Medium	Low	High	Extreme
Seriola lalandi	171,886	100% Longline		Medium	Low	Medium	Low	Medium	Low
Nemadactylus macropterus	162,591	100% Longline		Low	Low	Medium	Low	Medium	High
*Macrourus spp^*	97,848	99% Demersal Trawl <1% Longline	*Macrourus carinatus*	Medium	Low	Medium	Low	Medium	Low
			Macrourus whitsoni	Medium	Low	Low	Low	Low	Low
			Macruronus novaezelandiae	Medium	Low	Medium	Low	Medium	Low
Pseudopentaceros richardsoni	80,607	79% Demersal Trawl 14% Midwater Trawl 7% Longline		High	Low	High	Medium	High	Medium
Epigonus telescopus	71,484	100% Demersal Trawl		High	Low	Medium	Low	High	High
Neocyttus rhomboidalis	64,373	100% Demersal Trawl		Medium	Low	Medium	Low	Medium	Low

* Catch total is a combination of *Beryx spp., Beryx splendens and Beryx decadactylus* from the SPRMFO database. *Beryx spp*. is assumed to comprise mostly *Beryx splendens*

^ Catch total is a combination of *Macrourus spp*, *Macruronus novaezelandiae*, *Macrouridae*, *Macrourus whitsoni* and *Macrourus holotrachys* from the SPRFMO database

Table 17: Species proposed for further attention and notes on categorisation into Tier 1 or Tier 2 of the SPRFMO stock assessment framework.

Species name	Common Name	Main gear type	SAFE risk for main gear type	PSA risk for main gear type	Catch (kgs) 2012-2016	Catch (kgs) 2014-2018	% Longline (14-18)	% Demersal Trawl (14-18)	% Midwater Trawl (14-18)	Notes
Hoplostethus atlanticus	Orange Roughy	Demersal Trawl	Medium	Medium	5,427,208	5,862,492	0.0%	100.0%	0.0%	Already regarded as a Tier 1/2 species
Epigonus telescopus	Black Deepsea Cardinalfish	Demersal Trawl	Low	High	71,484	74,440	0.0%	100.0%	0.0%	Low SAFE ranking and relatively low catches may indicate this species could be moved to Tier 3 but may require precautionary monitoring and/or management measures. Ability to apply non-standard assessment approaches unlikely.
Pseudopentaceros richardsoni	Pelagic Armourhead	Demersal Trawl	Low	High	80,607	46,061	7.1%	78.7%	14.2%	Medium SAFE ranking for midwater trawl. Relatively low catches may indicate this species could be moved to Tier 3 but may require precautionary monitoring and/or management measures. Ability to apply non-standard assessment approaches unlikely.
Beryx splendens	Alfonsino	Demersal Trawl (also MWT)	Low	Medium	244,018	3,689*	8.9%	91.1%	0.0%	*Additional 807,154 kgs of *Beryx spp.* caught between 2014-2018 Historically taken in relatively significant proportions using midwater trawl gears. Proposed for retention as Tier 1/2 species.
Mora moro	Ribaldo	Demersal Trawl	Low	Medium	52,160	100,945*	10.1%	89.9%	0.0%	*Additional 3,627 kgs of *Moridae spp.* caught between 2014-2018. Low SAFE ranking and relatively low catches may indicate this species could be moved to Tier 3 but may require precautionary monitoring and/or management measures. Ability to apply non-standard assessment approaches unlikely.
Neocyttus rhomboidalis	Spikey Oreodory	Demersal Trawl	Low	Medium	64,373	112,697	0.0%	100.0%	0.0%	Low SAFE ranking and relatively low catches may indicate this species could be moved to Tier 3 but may require precautionary monitoring and/or management measures. Ability to apply non-standard assessment approaches unlikely.
Polyprion oxygeneios	Hapuku	Longline	Extreme	High	12,366	10,408*	72.3%	27.7%	0.0%	*Additional 173,552 kgs of *Polyprion spp*. caught between 2014-2018. ERA rankings and relatively significant catch volumes suggest *Polyprion* spp. should be retained as Tier 2 species.
Hyperoglyphe antarctica	Blue-Eye Trevalla	Longline	Extreme	High	358,260	258,875	92.3%	5.5%	2.2%	ERA rankings and relatively significant catch volumes suggest *H. antarctica* should be retained as Tier 2 species.
Bassanago hirsutus	Deepsea Conger	Longline	High	High	930	930	100.0%	0.0%	0.0%	Negligible catches but ranked as high vulnerability to longline. Proposed to be moved to Tier 3 but may require monitoring.

Species name	**Common Name**	**Main gear type**	**SAFE risk for main gear type**	**PSA risk for main gear type**	**Catch (kgs) 2012-2016**	**Catch (kgs) 2014-2018**	**% Longline (14-18)**	**% Demersal Trawl (14-18)**	**% Midwater Trawl (14-18)**	**Notes**
Helicolenus percoides	Reef Ocean Perch	Longline	High	High	26,238	20,057	98.6%	1.4%	0.0%	Relatively low catch volumes. Proposed to be moved to Tier 3 but may require monitoring.
Epigonus telescopus	Black Deepsea Cardinalfish	Longline	High*	High	71,484	74,440	0.0%	100.0%	0.0%	*Ranked as high vulnerability in longline but caught exclusively in trawl during 2014-2018 period. May require monitoring.
Rexea solandri	Gemfish	Longline	High	High	2,472	2,222	100.0%	0.0%	0.0%	Relatively low catch volumes. Proposed to be moved to Tier 3 but may require monitoring.
Nemadactylus macropterus	Jackass Morwong	Longline	High	Medium	162,591	124,450*	100.0%	0.0%	0.0%	*Additional 45,656 kgs of *Nemadactylus spp*. caught between 2014-2018. Historically significant as a target species in LL fishery. Proposed to be retained at Tier 2 although ability to apply non-standard assessment approaches may be unlikely.
Seriola lalandi	Yellowtail Kingfish	Longline	Low	Medium	171,886	153,737	100.0%	0.0%	0.0%	Low SAFE ranking but of significance as a retained species. Ability to assess using non-standard assessment may be unlikely; thus, species could be moved to Tier 3 but may require catch triggers and monitoring.
Etelis coruscans	Flame Snapper	Longline	Low	Medium	41,039	61,528	100.0%	0.0%	0.0%	Low SAFE ranking but of significance as a retained species. Ability to assess using non-standard assessment may be unlikely; thus, species could be moved to Tier 3 but may require catch triggers and monitoring.
Polyprion americanus	Bass Groper	Longline	Low	Medium	68,962	76,739*	99.9%	0.1%	0.0%	*Additional 173,552 kgs of *Polyprion spp*. caught between 2014-2018. Other comments as per *P. oxygeneios*.
Lethrinus miniatus	Redthroat Emperor	Longline	Low	Low	58,330	83,734	100.0%	0.0%	0.0%	Low SAFE ranking but of significance as a retained species. Ability to assess using non-standard assessment may be unlikely; thus, species could be moved to Tier 3 but may require catch triggers and monitoring.

4.2.5.4 Discussion of teleost ERA results

The results of the SPRFMO teleosts ERA indicate that a number of demersal teleost species are potentially vulnerable to demersal trawl, midwater trawl and demersal longline fishing gears in the SPRFMO Convention Area. The results, when combined with information on catches and understanding of species' biological and life history characteristics, have been used to categorise species into the SPRFMO assessment framework. The intention is to continue using these results to aid prioritisation of species for additional data collection, research, assessment or management measures.

The results from the SAFE assessment for demersal and midwater trawl gears were somewhat surprising due to the low number of data-robust species being assessed at high vulnerability compared to demersal longline gears. Furthermore, low productivity species such as *Hoplostethus atlanticus* (orange roughy) that are targeted by the trawl fisheries and that we therefore might expect to be at the upper end of the vulnerability spectrum were assessed to be at medium vulnerability in both the PSA and SAFE. This is driven by a combination of the productivity and susceptibility attributes and how these correlate to the overall PSA and SAFE scores. To use *Hoplostethus atlanticus* as an example, out of all data-robust species, it ranked highest in terms of overall susceptibility in the PSA (i.e., AxExSxPCM), indicating that the productivity score is driving the overall vulnerability ranking down. Analysis of its individual productivity attributes reveal that the method is ranking *Hoplostethus atlanticus* as a moderately productive species. This is due to the influence of the individual productivity attributes for which *Hoplostethus atlanticus* is given a low vulnerability score (i.e., fecundity, average maximum size, average size at maturity and reproductive strategy are scored a 1), despite being given a high vulnerability score for the remaining productivity attributes used in this PSA (i.e., average age at maturity, average maximum age and trophic level are scored a 3).

The assumption that each individual productivity attribute provides a theoretically equal contribution to the overall productivity score has been challenged by Hordyk and Carruthers (2018), with their study showing a complex non-linear relationship between individual attributes and over-parameterisation caused by irrelevant or correlated attributes. In a statistical exploration of productivity attributes Griffiths et al. (2017a) showed a number of productivity attributes were redundant for species assessed in a purse seine fishery in the Eastern Pacific Ocean, with a clear correlation between attributes such as age at maturity and maximum age. They postulated that the use of these redundant attributes would create an implicit weighting and positive bias in productivity scores, leading to an overestimation of species productivity and underestimation of the effects of fishing.

Consequently, the example of *Hoplostethus atlanticus*, despite being somewhat 'surprising', is not unexpected as the original Hobday et al. (2011) attributes and risk cut-off scores were based on a large database of teleosts and chondrichthyans with a very broad productivity range, with an intention to allow assessment and differentiation of the relative vulnerability of very low productivity (e.g., deepwater chondrichthyans) and very high productivity (e.g., small pelagic) species.

Such an example may highlight a key limitation of ERA and suggests that: 1) where possible, species' vulnerability rankings should be considered in the context of catches by gear type and our understanding of species' biological and life history attributes; 2) relative vulnerability (within both the PSA and SAFE) is more informative than absolute vulnerability based on the limitations of the methodology when applied in this context; and 3) species overall vulnerability rankings in this assessment will likely be more sensitive to susceptibility attributes, in particular availability and encounterability, than to productivity attributes.

The results for trawl gears indicate that careful attention should be given to those species assessed to be at medium vulnerability in the SAFE assessment (i.e., not just those assessed as high or extreme vulnerability). Species ranked as medium vulnerability in the SAFE include *Hoplostethus atlanticus* and *Bassanago hirsutus* for demersal trawl, and *Pseudopentaceros richardsoni* and *Bassanago hirsutus* for midwater trawl. In the context of available SPRFMO catch data, <1 t of catch has been reported for *Bassanago hirsutus* (deepsea conger) since 1990, and consequently this species may not warrant further attention. Conversely, ~83 t was reported for *Pseudopentaceros richardsoni* using predominantly demersal trawl gears between 2012 and 2016, and 46 t was reported as caught between 2014 and 2018, which may indicate that further attention is warranted. This example highlights key challenge of interpreting these ERA results in that there are many other species or species groupings that are not assessed to be at high vulnerability to trawl gears but may be caught in relatively high volumes, such as *Beryx* spp., *Macrourus* spp. and *Oreosomatidae*, that may warrant additional attention and where more quantitative assessment and/or measures may be necessary to avoid risks of overexploitation.

In summary, for demersal and midwater trawl gears, the results of the Georgeson et al. (2019) assessment in conjunction with information on SPRFMO catch levels and existing stock assessments suggest that current efforts to assess and manage *Hoplostethus atlanticus* are appropriate. Despite *Beryx splendens* not being assessed to be highly vulnerable to trawl gears in either the PSA or SAFE, we suggest that further research into stock structure delineation (see SC7-DW09) and more quantitative assessment may be appropriate given the high level of catches relative to other demersal teleosts and the fact that they are a target species.

For demersal longline gears, the results indicate a relatively high number of species assessed to be at the upper end of the PSA and SAFE vulnerability spectrum compared to the trawl gears. For data robust species, this is likely being driven by relatively high scores for two susceptibility attributes: availability and encounterability. The authors of this study did not have access to the confidential fine-scale spatial data to investigate the contribution of the availability attribute, but for the encounterability attribute—which is informed by the level of overlap between the gear depths and core depth range of each species—it is likely that a shallower minimum depth for demersal longline gears relative to trawl gears is contributing to the higher number of species assessed to be at the upper end of the vulnerability spectrum. This is because the gear depth data that informs scoring of this attribute will include the core depth range of more species that live in shallower habitats. This could be explored further and confirmed in future analyses.

Our results suggest that there are several species assessed to be vulnerable to longline gears that should be prioritised for further research and/or assessment (see, e.g., SC-07-DW-09). Of these, *Hyperoglyphe antarctica*, *Polyprion* spp. and *Nemadactylus* spp. are of particular interest as they comprise key target stocks and are assessed to be at high or extreme vulnerability to longline gears. Several species are caught in relatively large volumes in the demersal longline fishery that may warrant further attention based on knowledge of catches, productivity, targeting characteristics and/or other information, including *Seriola lalandi*, *Lethrinus miniatus* and *Etelis coruscans*.

For other species caught in the demersal longline fisheries, including those assessed as medium vulnerability in the SAFE assessment, catches may be deemed to be so low that there is unlikely to be a measurable influence on biomass.

4.2.5.5 Outcomes from the teleosts ERA

In response to the ERA for SPRFMO teleosts, the 7th meeting of the Scientific Committee (SC-07; SPRFMO 2019) agreed that species listed in Table 17 could be considered for additional management measures and/or research, enhanced data collection, precautionary catch triggers and monitoring, or stock structure delineation studies, and that attempts are continued to categorise these species into Tier 1 or Tier 2 of the SPRFMO assessment framework. SC-07 also noted that species listed at Appendix B have been proposed for categorisation into Tier 3 of the SPRFMO assessment framework (i.e., no further assessment required).

4.3 INTERACTIONS WITH MARINE MAMMALS, REPTILES, SEABIRDS AND OTHER SPECIES OF CONCERN

4.3.1 Importance of interactions with marine mammals, seabirds, reptiles and other species of concern

Some marine mammals, seabirds, reptiles and other species of concern are either experiencing reductions in population size and face a high risk of extinction in the wild or are likely to be threatened in the near future (IUCN 2022). Because many of these species have extensive at-sea distributions, incidental mortality (bycatch) in pelagic and demersal longline and trawl fisheries can pose a significant species-level threat. For example, fisheries bycatch has been identified as one of the major threats to seabirds (Dias et al. 2019), which are one of the most threatened groups of birds globally (Croxall et al. 2012). Vessels participating in SPRFMO bottom line and trawl fisheries sometimes catch mammals, seabirds, reptiles and other species of concern. The objective of CMM03-2023 and CMM 03a-2023 requires an ecosystem approach to managing bottom fishing that ensures the long-term conservation of non-target and associated or dependent species (defined in the measure as marine mammals, seabirds, reptiles (turtles) (as referenced in Article 1, para f (iv) of the Convention) and other species of concern (as defined in Annex 14 of CMM 02-2023 (Data standards) and presented in Table 18). It requires vessels undertaking bottom fishing to implement existing CMMs on seabird bycatch mitigation (CMM 09-2017) and data standards (CMM 02-2023). It also seeks specific advice from the Scientific Committee on interactions of bottom fisheries with marine mammals, seabirds, reptiles and other species of concern and potential management actions. The Scientific Committee's considerations and advice may include risk assessments, identification of important bird areas or other information relating to the nontarget or associated, or dependent species caught as bycatch by bottom fisheries.

Table 18: Taxa specified as "other species of concern" for the purpose of data collection (as of January 2017) by Annex 14 of CMM02-2022.

Scientific name	English name	3-alpha (FAO) code
Carcharhinus longimanus	Oceanic whitetip shark	OCS
Carcharodon carcharias	Great white shark	WSH
Cetorhinus maximus	Basking shark	BSK
Lamna nasus	Porbeagle shark	POR
Manta spp.	Manta rays	MNT
Mobula spp.	Mobula nei	RMV
Rhincodon typus	Whale shark	RHN

4.3.2 Summary of reported interactions

Fishers and observers are required to report interactions with marine mammals, seabirds, reptiles and other species of concern in accordance with CMM02-2022 on Standards for the Collection, Reporting, Verification and Exchange of Data (J.2.d). Such interactions appear to be rare in SPRFMO bottom fisheries; there have been only 16 reported instances of seabird captures, one marine mammal (subsequently determined to be a decomposing carcass), two reptiles and 21 sharks and rays (Table 19, see also Appendix C for disaggregated data) since 2008. Observers report a high proportion of these interactions and many are recorded as having the animal being released alive. The prognosis of such releases is unknown.

It is likely that Table 19 underestimates the total number of interactions with marine mammals, seabirds, reptiles and other species of concern, particularly for bottom line fisheries, because fishers may not report all interactions and observer coverage in both Australian and New Zealand line fisheries is only ~10%. Additionally, not all interactions are observable by normal observer protocols; this is sometimes referred to as “cryptic mortality”. For example, a proportion of seabird interactions with trawl vessels are warp strikes, where birds are hit by or fly into the trawl warps and can be injured or killed. Rarely do such incidents result in recovery of the specimen onboard where they might be recorded as bycatch. Estimates of the cryptic multipliers, which allow the total number of incidents to be estimated from observed interactions, used in the New Zealand seabird risk assessment varied from 3 to 89, depending on the type of birds and the trawl fishery (Richard et al. 2020). Seabirds caught on longline hooks and drowned during the set may also come off the hook before the haul.

Table 19: Summary (after detailed checking and correction) of seabirds, marine mammals, reptiles, and other species of concern reported or observed captured in bottom fisheries in the SPRFMO Area in 2007–2021, together with their IUCN threat classification categories. Reports from fishers’ logbooks (2007–2021) and observers (Australia 2007–2010 and 2016–2021, New Zealand 2013–2021) combined. More details by reported event are shown in Appendix C.

Common name	Scientific name	No. captures	IUCN category
Great-winged petrel	*Pterodroma macroptera gouldi*	4	Least Concern
Flesh-footed shearwater	*Puffinus carneipes*	3	Near Threatened
White-chinned petrel	*Procellaria aequinoctialis*	1	Vulnerable
Black petrel	*Procellaria parkinsoni*	1	Vulnerable
NZ white-faced storm petrel	*Pelagodroma marina maoriana*	1	Least Concern #
Gould’s petrel	*Pterodroma leucoptera*	1	Vulnerable
Fairy Prion	*Pachyptila turtur*	1	Least Concern #
Petrels & shearwaters nei	Procellariidae	3	NA
Black-browed or Campbell Island albatross	*Thalassarche melanophris or T. impavida*	1	Least Concern or Vulnerable #
Green turtle	*Chelonia mydas*	1	Endangered
Sea snakes nei	Elapidae	1	NA
Great white shark	*Carcharodon carcharias*	4	Vulnerable
Oceanic whitetip shark	*Carcharhinus longimanus*	3	Critically
Basking shark	*Cetorhinus maximus*	1	Endangered
Porbeagle shark	*Lamna nasus*	1	Vulnerable
Requiem sharks nei	*Carcharhinidae*	3	NA
Rays, stingrays, mantas nei	*Rajiformes*	9	NA

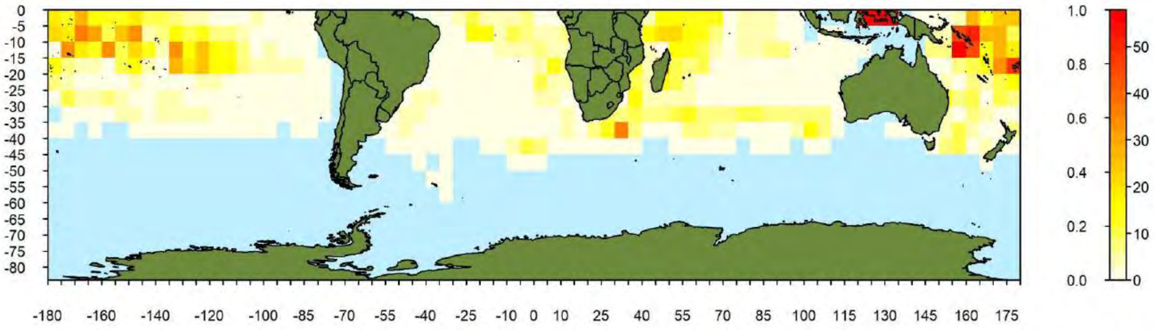
IUCN threat classification based on a broader definition of the species than assumed in this table.

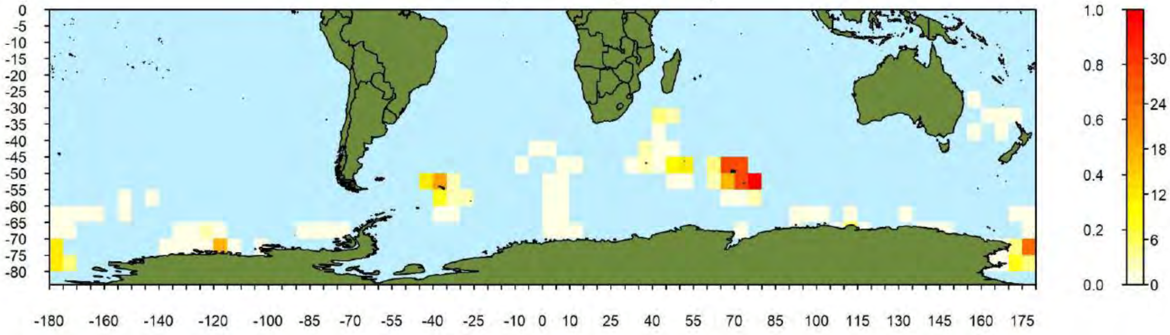
Deepwater trawling is generally not considered to pose as high a risk to seabirds given the steep angle at which the trawl warps enter the water, and the limited processing typically carried out on board (Richard et al. 2020). The small number of reported and observed captures suggest interaction rates of only a handful of individuals each year. This does not necessarily mean that the captures are inconsequential. Some marine mammals, seabirds, reptiles and other species of concern face a high risk of extinction in the wild, and even a low number of captures can present a substantial species-level threat. For example, at least three of the observed seabird captures were species classified by the IUCN as Vulnerable, and one capture was of a black (Parkinson's) petrel, a species known to be at high risk from fisheries in New Zealand's EEZ. Some observer identifications of black petrel have turned out to be other species (white-chinned petrel or great-winged petrel) when photographs have been viewed by experts. No photographs of the black petrel in Table 19 were available to confirm the identification and there remains some doubt about the actual species captured and released.

New Zealand has been working on a spatially explicit fisheries risk assessment (SEFRA) for seabirds since 2013 (Richard and Abraham 2013; Sharp et al. 2013). The initial implementations of this risk assessment included commercial fisheries within New Zealand's EEZ, and the approach has been applied to include commercial pelagic longline fishing in the Southern Hemisphere. Effort data from SPRFMO bottom fisheries will be included in the southern hemisphere risk assessment for seabirds due for publication in 2023. Pelagic longline fisheries were included first because of engagement between New Zealand and the "tuna" RFMOs, in particular the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). Pelagic longline fisheries are much larger than trawl and bottom longline fisheries; Francis and Hoyle (2019) estimated fishing effort by method throughout the southern hemisphere and their results suggest hundreds of millions of hooks set each year in pelagic longline fisheries compared with tens of millions in bottom longline fisheries (of which only a small fraction of hooks is within the SPRFMO Convention area). It is probably reasonable to assume that pelagic longlines pose a higher risk for seabirds than bottom longlines due to the relative size of the respective fisheries, though it should be noted that pelagic longline fisheries tend to fish in warmer waters with lower seabird numbers compared to bottom longline fisheries. Abraham et al. (2017) estimated that pelagic longlines in the southern hemisphere captured 6 275 seabirds each year with a 95% credible interval (c.i.) of 4 918 – 8 054 birds. Abraham et al. (2019) refined the approach to incorporate data from Japan, South Africa, Australia and New Zealand, updated effort data, seabird tracking data and separate catchability estimates for each fleet, and preliminary results suggested annual fatalities of 41 078 (95% c.i.: 39 432 – 42 746), excluding cryptic mortality. Estimated annual captures of seabirds using data from SPRFMO bottom fisheries will be available in 2023 calculated using New Zealand observer data; these estimates will be on a species level, and it will be possible to estimate the contribution of risk from SPRFMO fisheries to total risk for each taxon. It should be noted that future iterations of the Southern Hemisphere risk assessment will seek to include observer data from other nations to increase accuracy by allowing for the calculation of fleet specific catchability parameters.

Notwithstanding the likely low risk posed by SPRFMO bottom fisheries, the *Seabird Maps and Information for Fisheries* tool (https://www.fisheryandseabird.info/) was applied to identify seabird taxa that overlap areas of either trawl or longline fisheries, and hence being at potential risk of impact. The list obtained from the tool was expanded to account for new knowledge on seabird distribution (e.g., the more widespread foraging distribution of black petrel), recent changes in taxonomy (the addition of grey-faced petrel at the species level) and to reflect the taxonomy used by the ACAP (considering shy and white-capped albatross separately). Some species were excluded based on marginal overlap (less than 1% of the species' range overlapping less than 10% of the combined fishery area). Based on knowledge of the of seabird interactions with other fisheries, such as domestic New Zealand and Australian trawl and longline fisheries, and global bycatch assessments, the species were categorised (at genus-level) into one of three categories; those known to be susceptible to bycatch in trawl and longline fisheries with bycatch being a conservation concern (highly vulnerable species), those known to be bycaught and/or attracted to vessels by light, leading to vessel strike, but where bycatch may not be the major conservation concern for the species (medium vulnerability), and all remaining species (lower vulnerability). Twenty-six species were classified as highly vulnerable, and includes species of very high concern, such as the Antipodean albatross, which is classified as Endangered and was recently listed on Appendix I of the Convention of Migratory Species. It also includes 20 species listed on Annex I of the Agreement on the Conservation of Albatrosses and Petrels (https://acap.aq/acap-agreement/206-agreement-on-the-conservation-of-albatrosses-and-petrels/file). Appendix D details the results of this work.

At the time of its development, CMM09-2017 measures were close to global best practice for mitigating interactions with seabirds and it is encouraging that the numbers of seabirds reported by fishers and observers is low. However, ACAP has recommended that the measures are updated to ensure they remain aligned with the latest and best available science (ACAP 2022). Given that SPRFMO fisheries overlap the foraging distributions of so many highly vulnerable seabirds, it is important to continue observation and monitoring to ensure the measure is complied with and updated as new information on best practice mitigation appears.





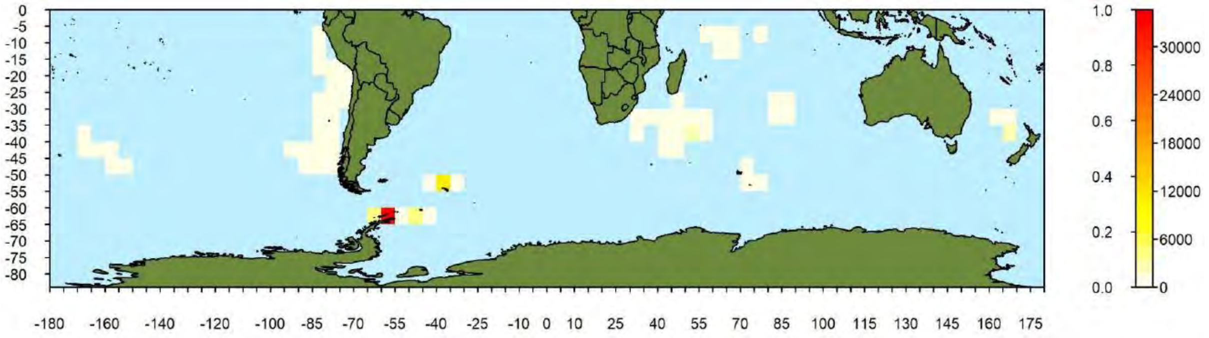


Figure 34: Southern Hemisphere reported fishing intensity in 2014–2016 for surface longline (top plot, hooks km^{-2}), bottom longline (middle plot, hooks km^{-2}) and trawl (bottom plot, tows km^{-2}). Colour legends are shown in relative (left) and absolute values (right). Summarised from Francis and Hoyle (2019).

We are not aware of similarly comprehensive and quantitative estimates of captures of marine mammals, reptiles, or the shark and ray species identified as other species of concern in the South Pacific Ocean. The observed interaction rates for marine mammals and reptiles in SPRFMO bottom fisheries are very low (no marine mammals and two reptiles observed captured in bottom fisheries in the SPRFMO Area in the period 2007–2019) and thought to pose low risk. The risk posed by the relatively few captures of sharks and rays which are classified by SPRFMO as "other species of concern" is covered in the risk assessment for chondrichthyans (see next section).

4.3.3 Ecological risk assessment for SPRFMO deepwater chondrichthyans

Risks to deepwater chondrichthyans (sharks, rays and chimaeras) from fishing are poorly understood, particularly in areas beyond national jurisdiction. Georgeson et al. (2020) adapted PSA and SAFE tools to assess the vulnerability of 173 deepwater chondrichthyans to various fishing gears in the Southern Indian and South Pacific Oceans. One hundred and twelve species were included for the SPRFMO Convention Area analyses. While a number of these species are caught as bycatch while targeting other species (and sometimes retained), the assessment is included in this section due to the life history characteristics (low productivity, late age at maturity, low fecundity etc.) meaning that many deepwater chondrichthyan species could potentially be highly vulnerable to fishing pressure and could be considered to be 'species of concern'. These have not been updated for the 2023 BFIA.

As for the Georgeson et al. (2019) teleosts risk assessment, the primary objective of the Georgeson et al. (2020) chondrichthyans risk assessment was to assess the relative vulnerability of species so that those at the upper end of the vulnerability spectrum could be prioritised for additional attention. The results should not be considered as absolute estimates of risk.

4.3.3.1 Productivity-Susceptibility Analysis (PSA)

As per the teleosts risk assessment (Georgeson et al. 2019) described above, PSA results are not provided or discussed in detail here due to various methodological limitations and because they are, by design, extremely precautionary, resulting in many probable false positives (species assessed to be at risk that are not at risk in reality). Nonetheless, in the assessment for SPRFMO chondrichthyans there was good concordance between PSA and SAFE results at the upper end of the vulnerability spectrum.

4.3.3.2 Sustainability Assessment for Fishing Effects (SAFE)

In the SPRFMO Convention Area, there were a total of 20, 4 and 17 species classified by the SAFE method as high ($F>F_{lim}$) or extreme ($F>F_{crash}$) vulnerability to demersal trawl, midwater trawl and demersal longline fisheries respectively. Of the 112 species assessed in the SPRFMO Convention Area, four (*Echinorhinus cookei, Oxynotus bruniensis, Mitsukurina owstoni* and *Squalus fernandezianus*) were missing data needed to calculate the reference points F_{msm}, F_{lim} and F_{crash}.

Chondrichthyan species classified as high or extreme risk across all fisheries (

Table **20**) in the SPRFMO Convention Area were *Echinorhinus cookei, Mitsukurina owstoni, Oxynotus bruniensis* and *Squalus fernandezianus*. An additional seven species were classified as high or extreme vulnerability across all fisheries with the exception of midwater trawl in the SPRFMO Convention Area being *Dalatias licha, Squalus acanthias, Deania calcea, Centrophorus harrissoni, Hydrolagus bemisi, Centrophorus squamosus* and *Chimaera carophila*.

The PSA and SAFE vulnerability scores for all species in the SPRFMO Convention Area are compared in Figure 35. The results indicate good concurrence between the PSA and SAFE results for most species categorised as being at high or extreme vulnerability in the SAFE. There were three species (*Zameus squamulosus, Parmaturus macmillani* and *Chimaera carophila*) that were classified as medium vulnerability in the PSA but high or extreme vulnerability in the SAFE, which may indicate potential false negatives for the PSA method. Nonetheless, many species classified as high or medium vulnerability by the PSA were ranked as low vulnerability by the SAFE (indicating likely false positives in the PSA) (

Table **20**).

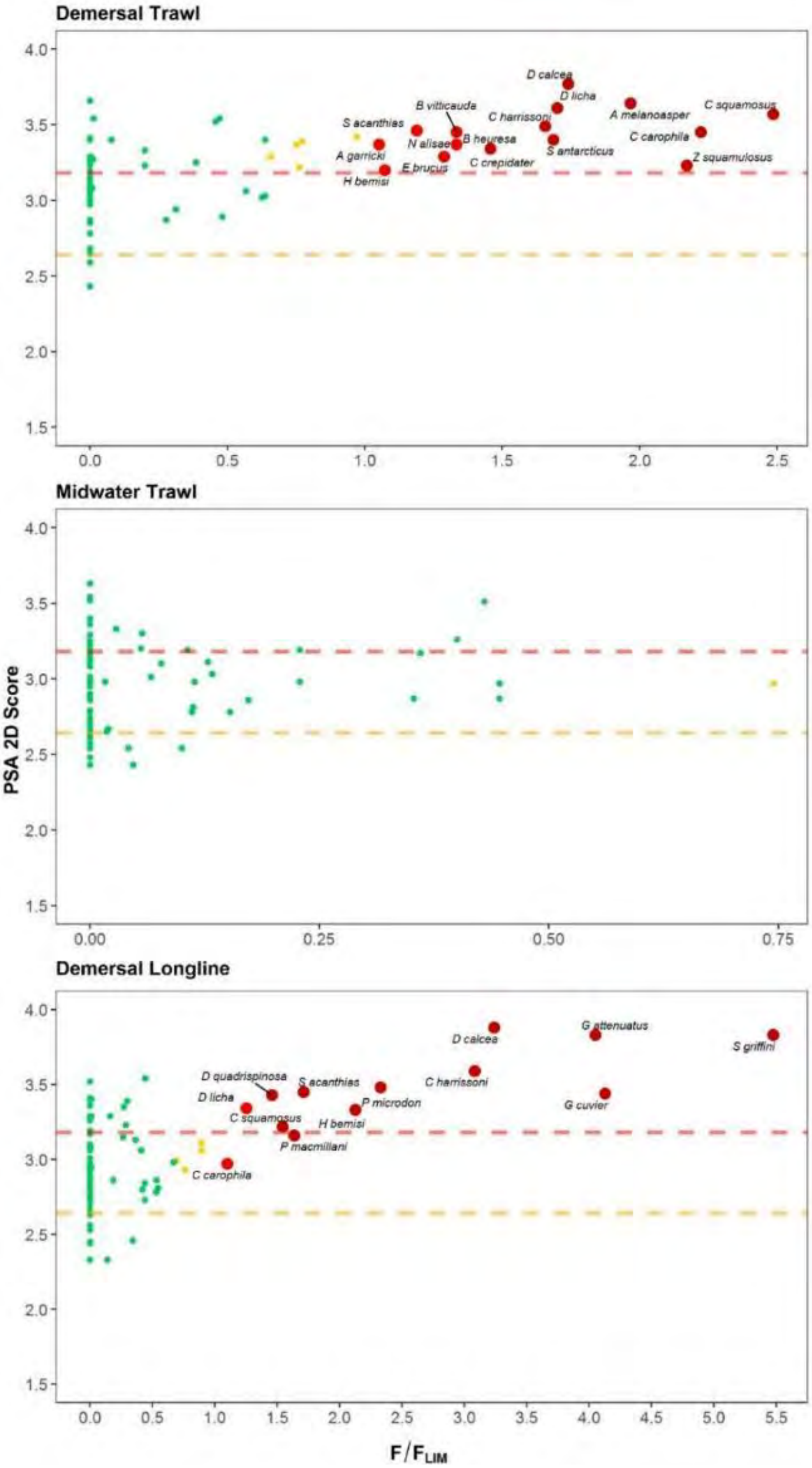


Figure 35: Relationship between SAFE and PSA results for 112 chondrichthyan species with the potential to interact with demersal longline, demersal trawl and midwater trawl fisheries in the SPRFMO Convention Area. Points are coloured dark red, light red, orange and green to signify species classified as extreme, high, medium and low vulnerability, respectively, in the SAFE. Dashed red and orange lines represent PSA high and medium vulnerability score boundaries from the PSA. Four species are not shown on the panels because their *F*-based reference points could not be calculated.

Table 20: Matrix of high (and extreme) vulnerability species from the SAFE and their respective PSA score for each fishery in the SPRFMO Convention Area. Note that it is important to view these rankings in the context of the discussion herein and because the ERA was undertaken to prioritise species requiring additional attention. They should not be regarded as absolute estimates of risk and/or vulnerability.

South Pacific Ocean Species	Demersal longline		Demersal trawl		Midwater trawl	
	PSA	SAFE	PSA	SAFE	PSA	SAFE
Squalus fernandezianus	High	Extreme	High	Extreme	High	Extreme
Deania calcea	High	Extreme	High	Extreme	High	Low
Gollum attenuatus	High	Extreme	High	Low	High	Low
Squalus griffini	High	Extreme	High	Medium	High	Low
Centrophorus harrissoni	High	Extreme	High	Extreme	High	Low
Oxynotus bruniensis	High	Extreme	High	Extreme	High	Extreme
Mitsukurina owstoni	High	Extreme	High	Extreme	High	Extreme
Echinorhinus cookei	High	Extreme	High	Extreme	High	Extreme
Pseudotriakis microdon	High	Extreme	High	Medium	Medium	Low
Squalus acanthias	High	Extreme	High	Extreme	Medium	Low
Deania quadrispinosa	High	Extreme	High	Medium	Medium	Low
Galeocerdo cuvier	High	Extreme	Medium	Low	Medium	Low
Dalatias licha	High	High	High	Extreme	Medium	Low
Hydrolagus bemisi	High	Extreme	High	High	Medium	Low
Centrophorus squamosus	High	Extreme	High	Extreme	Medium	Low
Parmaturus macmillani	Medium	Extreme	Medium	Low	Medium	Low
Chimaera carophila	Medium	High	High	Extreme	Low	Medium
Apristurus melanoasper	High	Low	High	Extreme	Medium	Low
Brochiraja vitticauda	Medium	Low	High	High	Medium	Low
Notoraja alisae	Medium	Low	High	High	Medium	Low
Brochiraja heuresa	Medium	Low	High	High	Medium	Low
Apristurus garricki	Medium	Medium	High	High	Medium	Low
Somniosus antarcticus	Medium	Medium	High	Extreme	High	Low
Centroselachus crepidater	Medium	Low	High	Extreme	Medium	Low
Echinorhinus brucus	Medium	Low	High	High	Medium	Low
Zameus squamulosus	Low	Low	High	Extreme	Low	Low

4.3.3.3 *Discussion of chondrichthyans ERA results*

The results of the PSA and SAFE analyses highlight that some chondrichthyans in the SPRFMO Convention Area are likely to be vulnerable to fishing pressure due to their life-history traits (i.e., long-lived, slow growing and low fecundity), which compromises their ability to recover from fishing-induced depletion. There is a deficit of information on chondrichthyans globally, with over 50% of shark and ray species listed as data deficient on the IUCN Red List due to the taxonomic resolution of fishery catch data being too low to identify species-level trends in abundance (Cashion et al. 2019). Given the limited fisheries and biological data on deepwater chondrichthyans in the South Pacific Ocean (Duffy et al. 2017), data-poor methods such as ERA provide a useful tool for evaluating vulnerability of these species to fisheries interactions based on their biological productivity and susceptibility to the main fisheries operating across their geographic range (Zhou and Griffiths 2008; Patrick et al. 2010; Hobday et al. 2011). This approach allows those species that are at highest vulnerability to be identified and the risk either mitigated or investigated further through data collection and research prioritisation (Griffiths et al. 2017b).

A key challenge when considering the results of the Georgeson et al. (2020) assessment is the availability and quality of supplementary information that can be used to critically review results in the context of the fishery or fisheries that interact with species or groups of species. In particular, information on catch and effort over time and space can be valuable in making inferences about the likely true vulnerability of species to certain gears. Catch and effort information at a suitable species resolution were only available for a subset of the fisheries assessed in the analysis.

In the SPRFMO Convention Area, deepwater chondrichthyans are caught mostly in demersal trawl fisheries targeting orange roughy and in demersal longline fisheries targeting species such as bluenose/blue-eye trevalla (*Hyperoglyphe antarctica)*, hapuku (*Polyprion oxygeneios*) and bass groper (*Polyprion americanus*) (Duffy et al. 2017), but these catches are made in relatively low volumes. Recorded total chondrichthyan catches in the New Zealand demersal trawl fishery estimated from at-sea observer data ranged from 7.7 tonnes in 2014 to 228.1 tonnes in 2016 (Duffy et al. 2017), with two species (*Deania calcea* and *Dalatias licha*) classified at extreme vulnerability to demersal trawl in our SAFE analysis contributing to a total 47% of the catch between 2012 and 2016. Observers estimate the catch weight by species for almost 100% of New Zealand bottom trawl tows. However, they were only able to identify to species level 83–94% of chondrichthyans by weight (varying between years) leaving some scope for further species at high or extreme vulnerability to have been caught in these fisheries. Commercial fishers' logbook data from the same fishery had a much greater proportion of unspecified 'deepwater dogfish' recorded (67%) compared with just 9% for at-sea observers, meaning that the observer data are preferred (Duffy et al. 2017).

Deepwater chondrichthyans were also caught in New Zealand's line fisheries, including *Dalatias licha*, which made up 8% of the total chondrichthyan catch reported by at-sea observers between 2012 and 2016 (Duffy et al. 2017). Observers estimate the catch weight by species for only about 10–20% of New Zealand bottom line sets, necessitating more reliance on commercial fishers' logbooks. Other species including *Squalus acanthias* and *Deania calcea*, which were classified at extreme vulnerability in the SAFE analysis, have been recorded as caught in the longline fishery (SPRFMO 2018). However, as identified by Duffy et al. (2017), some of these identifications (especially the commonly-reported *Squalus acanthias*) are probably errors and catches by species are therefore likely to be poorly estimated. This supposition is reinforced by 105 tonnes of unidentified deepwater sharks recorded as caught between 2012 and 2016 in the SPRFMO database. Issues with species identification, reporting and the resolution at which historical data have been collected make it very difficult to make inferences about the historical contribution of fishing to overall catches of deepwater chondrichthyans species in the SPRFMO Convention Area.

Within-species comparison of PSA and SAFE results demonstrated good concurrence between those listed at high or extreme vulnerability by the SAFE; however, the PSA estimated far more species to be at high or medium relative vulnerability than the SAFE, which classified them as low. A greater number of false positives in the PSA is to be expected (Hobday et al. 2011; Zhou et al. 2016) and in this assessment is largely driven by the PSA assuming a minimum score of 1 for the *Availability* attribute even if there is zero overlap between the species and the gears, while the SAFE gives a true zero for susceptibility (i.e., no overlap means no vulnerability and the susceptibility/*F*-estimate is zero). The number of possible false positives was less than it would have been if data on productivity attributes from congeneric species (related species from the same genus) was not used to reduce the number of species classified as data deficient (i.e., those missing three or more attributes). A bias in the vulnerability score can occur if the imputed attributes from congeneric species are incorrect but, given the limited knowledge of deepwater chondrichthyan species' biology and life history, this approach was regarded as adequate and expert-informed substitution of missing data has been used previously. Interestingly, three species were assessed to be at a high or extreme vulnerability by the SAFE that were ranked as medium relative vulnerability by the PSA. These discrepancies in vulnerability ranking, which are possibly false negatives of the PSA, were unexpected and were likely driven by the inability of the PSA to be a reliable indicator of biological risk for species within these intermediate PSA vulnerability scores. In other words, the vulnerability scores from our PSA are unlikely to be ordered correctly with respect to risk of overexploitation. Between-species comparison of PSA and SAFE vulnerability classifications indicated that differentiation was driven more by susceptibility attributes than productivity attributes. The influence of the susceptibility attributes in our results highlights the limitation of the PSA in assuming a linear and additive relationship between the productivity and susceptibility scores in the calculation of relative vulnerability scores. The assumption that each individual productivity and susceptibility attribute contributes equally to each axis has also been previously challenged.

While there were clear uncertainties and limitation in the Georgeson et al. (2019) ERA, this should not prevent a precautionary approach being taken by SPRFMO to prioritise species at high or extreme vulnerability for further research, data collection and/or further assessment to estimate bycatch limits or sustainable yields. When coupled with information on the characteristics of fisheries (including, importantly, information on catches), such methods can be used to provide a semi-quantitative underpinning for these actions. It is clear that information on the identification, distribution, stock structure, biology and life history of deepwater chondrichthyans is lacking (Gallagher et al. 2012) and that at-sea identification protocols need to be improved in high seas fisheries to increase the accuracy of logbook and at-sea observer reporting (Duffy et al. 2017; Cashion et al. 2019; SIOFA 2019). Research on post capture mortality and gear selectivity of deepwater chondrichthyans would be useful to inform mitigation strategies to reduce or manage risk that is associated with the species susceptibility.

4.3.3.4 Outcomes from the chondrichthyans ERA

The seventh meeting of the SPRFMO Scientific Committee noted that other RFMO/As, such as the Southern Indian Ocean Fisheries Agreement, have implemented measures prohibiting targeted fishing for deepwater chondrichthyans, which it agreed could be similarly implemented by SPRFMO to discourage such practices in the absence of scientifically based assessment and management. It also recommended that identification guides be developed and used to increase taxonomic resolution and improve data collection, which can feed into future assessments and estimates of sustainable yields. The SPRFMO Commission agreed in 2020 to increase the data collection requirements in respect of deepwater sharks.

4.4 FISHERIES INTERACTIONS WITH BENTHIC HABITATS AND VMES

4.4.1 General approach to assessing benthic impacts and VMEs

All bottom-contacting fisheries impact benthic systems and modify benthic communities, although the intensity of such impacts varies substantially between fishing gears and the type of benthic fauna that the fishing gear contacts. Mobile fishing gears such as trawling generally have a more intense impact than static gears such as bottom longline (Chuenpagdee et al. 2003) (see also Table 21). Groups of species, communities or habitats that may be vulnerable to the impacts of bottom fishing activities due to slow growth, late age at maturity, long life expectancy or low or unpredictable recruitment are termed VMEs. Assessing the impacts of bottom fisheries on benthic habitats (and in particular VMEs) has been the focus of much global and regional research. The assessment of benthic impacts presented here builds on this research by developing a workflow to assess the impacts of bottom fishing on VMEs. This workflow includes determining: (1) the spatial distribution of VME indicator taxa and bottom fishing effort; (2) changes in the status of VME indicator taxa due to the impacts of historical fishing; and (3) evaluating the performance of management measures, including spatial management and move-on rules, taking into consideration the spatial scale at which managers may deem it necessary to prevent SAIs on VMEs, and the uncertainty associated with the data informing the assessment (Figure 36). This process was guided through one of New Zealand's standing science working groups, the South Pacific Fishery Assessment Working Group (SPACWG), which provided a forum to discuss the assessment approach collegially among scientific, policy and management representatives of Australia and New Zealand, environmental non-government organisations and fishing industry representatives. For example, discussions at the SPACWG guided decisions on the development of abundance metrics from habitat suitability models, the development of naturalness layers, the sensitivity analyses to be applied and the appropriate presentation of research outputs.

Table 21: Ranking of expected habitat impact for each fishing gear class on either physical or biological habitats on a scale of 1 (very low) to 5 (very high) (modified after Chuenpagdee et al. 2003). Gear classes commonly used in SPRFMO bottom fisheries in bold (benthopelagic trawl was not considered by Chuenpagdee et al. (2003) but we consider its impact to be intermediate between pots and traps and bottom trawl).

Gear Class	Physical habitat	Biological habitat
Gillnet – midwater	1	1
Hook and line	1	1
Longline – pelagic	1	1
Purse seine	1	1
Trawl – true midwater	1	1
Longline – bottom	**2**	**2**
Gillnet – bottom	3	2
Pots and traps	3	2
Trawl – benthopelagic	**–**	**–**
Trawl – bottom	**5**	**5**
Dredge	5	5

The main fishing methods in use in SPRFMO bottom fisheries are bottom trawl (targeting mainly orange roughy), midwater trawl (targeting benthopelagic species like alfonsino close to the seabed) and bottom longline (targeting bluenose/blue-eye trevalla, wreckfishes (*Polyprion* spp.), and other species). Of these, bottom trawling has the most intense impact and is also the most frequently deployed and widespread fishing method in SPRFMO bottom fisheries. In recognition of this, the SPRFMO interim management measures (agreed in 2007 before the establishment of SPRFMO) and formal measures established since (starting with CMM2.03 in 2014 up to the current CMM03-2023) restrict bottom trawling more tightly than other methods. The spatial measures included in CMM 03-2019 through to CMM 03-2023 for managing the impacts of bottom trawling were developed using a decision support tool (Zonation) with the intention to protect VMEs (based on habitat suitability maps for VME indicator taxa taking into account 'naturalness' condition) while providing for the utilisation of high value areas for fisheries (based on a value to the New Zealand fishing industry trawl catch data supplied by the fishing industry). The result was guidance on the identification of areas to be closed to fishing (with the intention to prevent SAIs on VMEs) and areas to be opened to fishing (to provide for a viable fishery). The key metric of the likely performance of the spatial management measures was determined by calculating the proportion of suitable habitat or abundance protected for each VME indicator taxon that occur outside the areas open to fishing, and the proportion of high value areas for fishing that occur within open areas. Recognising that the habitat suitability models that underpin the spatial management areas have associated uncertainty, CMM03-2019 through to

CMM03-2023 includes a VME encounter protocol within areas open to fishing to provide for a rapid response to large catches of VME indicator taxa (relative to rates of historical bycatch).

Since the implementation of the spatial management measures included in CMM03-2019 additional data has become available allowing updates to the habitat suitability models. Additionally, alternative analytical approaches for describing the current status of VME indicator taxa after the effects of bottom fishing ('naturalness' condition of VMEs) and for translating habitat suitability models into estimates of VME indicator taxa abundance while calculating metrics of the likely performance of the spatial management measures have been developed. These advances allow potentially improved estimates of the performance of the spatial management measures as a basis for an updated benthic impact assessment.

Six thousand new records across the whole range of modelled VME indicator taxa have become available since the first habitat suitability models were developed, and prior to the 2020 update of the BFIA these records were used alongside the original data to update the constituent and ensemble habitat suitability models. This BFIA incorporates the updated models, which have improved predictive power into the assessment of the performance of the spatial management measures.

This BFIA uses two approaches to account for the interaction between fishing gear and biota (mortality) and the recovery after impact when describing the current status of VME indicator taxa after the effects of historic bottom trawling. The first approach uses an estimate of "naturalness" to produce a spatial representation of the current status of each taxon after the effects of all historical trawling (i.e., it accounts for depletion caused by the passing of fishing gear). The second approach uses relative benthic status (RBS), that includes a dynamic component to estimate the long-term relative abundance of biota as a fraction of the rate of impact (depletion per trawl), recovery rate and exposure to trawling, with a further sensitivity added to account for future trawling and recovery potential.

Alternate estimates describing the performance of spatial management areas, including those implemented in CMM03-2023 and those proposed for adoption by Commission in 2024 and described in COMM10-Inf03, were made using two alternative approaches; (1) Receiver Operator Characteristics (ROC) curves that sum habitat suitability scores above cut-off thresholds; and power curves estimated using information on the observed cover or abundance of VME indicator taxa within grid cells for which HSI predictions were available. SC9 noted in paragraph 78 of its report that these metrics are representative of the metrics spectrum presented in the 2020 BFIA, and they are used here.

The following sections describe each of the components of the impact assessment in detail, including differences in alternative analytical approaches. Sensitivities of the final results to different analytical approaches are summarized in tables, with the performance metrics calculated at the spatial scale of Fisheries Management Areas as required by para 39 of CMM03-2023.

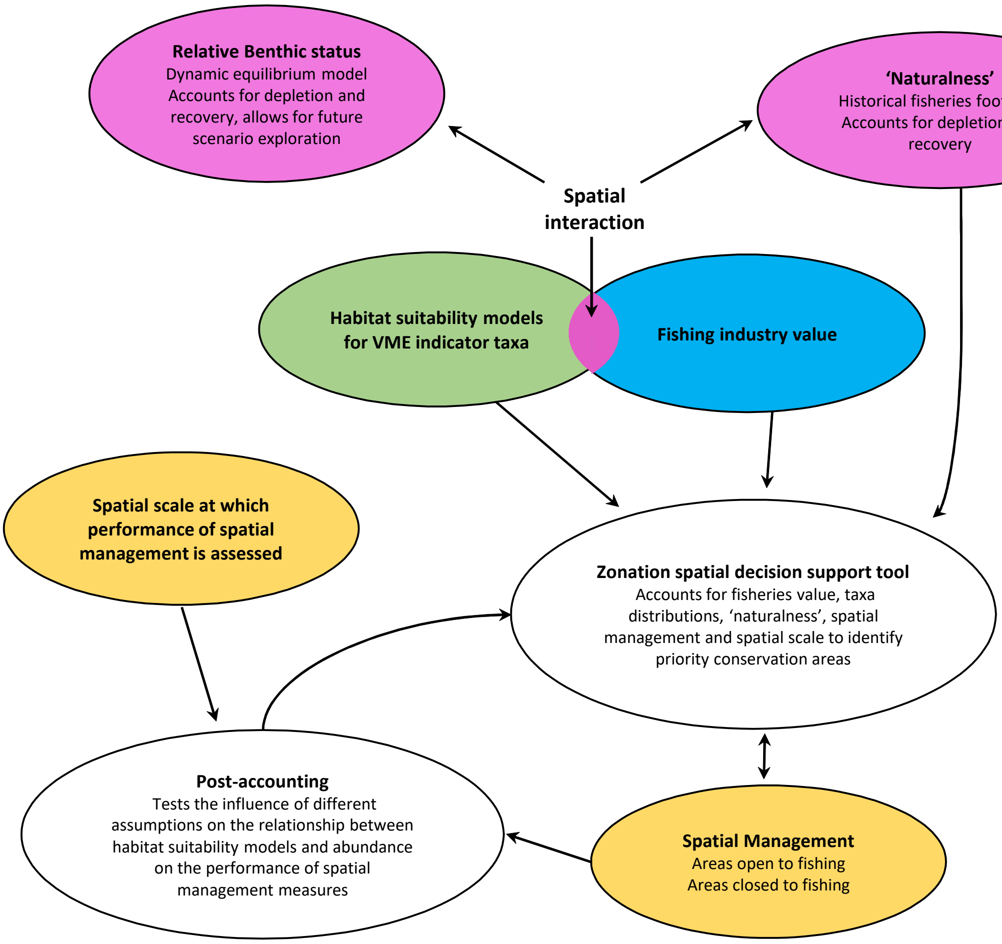


Figure 36: Schematic representation of the workflow used to assess the likely current and future state of VME indicator taxa and assess the likely performance of current spatial management arrangements.

4.4.1 International guidance on benthic impacts assessment

The impetus for RFMO/As to prevent SAIs on VMEs by bottom fisheries originated with United Nations General Assembly Resolution 61/105, which calls upon RFMO/As:

> *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*;

This and subsequent UNGA resolutions did not define VMEs, but referred to them as "*vulnerable marine ecosystems, including seamounts, hydrothermal vents and cold-water corals*", nor did they define SAIs. Subsequently, the FAO Deep-Sea Guidelines adopted in August 2008 have provided more specific guidance on the characteristics which could be considered to define VMEs and SAIs, and provide examples of potentially vulnerable species groups, communities and habitats, as well as features that potentially support them (numbering from the guidelines, FAO 2009):

3.2 Vulnerable marine ecosystems

14. *Vulnerability is related to the likelihood that a population, community, or habitat will experience substantial alteration from short-term or chronic disturbance, and the likelihood that it would recover and in what time frame. These are, in turn, related to the characteristics of the ecosystems themselves, especially biological and structural aspects. VME features may be physically or functionally fragile. The most vulnerable ecosystems are those that are both easily disturbed and very slow to recover, or may never recover.*
15. *The vulnerability of populations, communities and habitats must be assessed relative to specific threats. Some features, particularly those that are physically fragile or inherently rare, may be vulnerable to most forms of disturbance, but the vulnerability of some populations, communities and habitats may vary greatly depending on the type of fishing gear used or the kind of disturbance experienced.*
16. *The risks to a marine ecosystem are determined by its vulnerability, the probability of a threat occurring and the mitigation means applied to the threat.*

3.3 Significant adverse impacts

17. *Significant adverse impacts are those that compromise ecosystem integrity (i.e., ecosystem structure or function) in a manner that: (i) impairs the ability of affected populations to replace themselves; (ii) degrades the long-term natural productivity of habitats; or (iii) causes, on more than a temporary basis, significant loss of species richness, habitat or community types. Impacts should be evaluated individually, in combination and cumulatively.*
18. *When determining the scale and significance of an impact, the following six factors should be considered:*
    - *i. the intensity or severity of the impact at the specific site being affected;*
    - *ii. the spatial extent of the impact relative to the availability of the habitat type affected;*
    - *iii the sensitivity/vulnerability of the ecosystem to the impact;*
    - *iv. the ability of an ecosystem to recover from harm, and the rate of such recovery;*
    - *v. the extent to which ecosystem functions may be altered by the impact; and*
    - *vi. the timing and duration of the impact relative to the period in which a species needs the habitat during one or more of its life-history stages.*
19. *Temporary impacts are those that are limited in duration and that allow the particular ecosystem to recover over an acceptable time frame. Such time frames should be decided on a case-by-case basis and should be in the order of 5-20 years, taking into account the specific features of the populations and ecosystems.*
20. *In determining whether an impact is temporary, both the duration and the frequency at which an impact is repeated should be considered. If the interval between the expected disturbance of a habitat is shorter than the recovery time, the impact should be considered more than temporary. In circumstances of limited information, States and RFMO/As should apply the precautionary approach in their determinations regarding the nature and duration of impacts.*

5.2 Identifying vulnerable marine ecosystems and assessing significant adverse impacts

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.*

45. 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.

Annex 1. Examples of potentially vulnerable species groups, communities and habitats, as well as features that potentially support them

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 may 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 (eg, 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).*

4.4.2 Potentially impacted benthic fauna, especially Vulnerable Marine Ecosystems

4.4.2.1 Vulnerable Marine Ecosystem taxa and indicators

VMEs are groups of species, communities or habitats that may be vulnerable to impacts of fishing activities. Some VME-forming taxa may be retained in fishing gear during the course of fishing activities and therefore serve as an indicator that a VME may be present within the area (i.e., VME indicator taxa). However, the detection of a VME indicator taxon or component is not sufficient to identify a VME and additional evaluation taking into consideration the FAO criteria for VMEs is required.

For the encounter protocol and move-on rule to work effectively, it is necessary to assume that the presence or abundance of VME specimens present in bycatch provides a reasonable indicator of the abundance of VME organisms occurring on the sea floor. Because not all VME material encountered by fishing gear is retained, and catchability will be different for different taxa, the effectiveness of the move on rule will depend on taxon-specific catchability, but attempts to estimate catchability using paired camera and trawl deployments were largely unsuccessful (SC10-DW04). In 2022 the IWG advised that "*if VME catchability for a particular taxon is very close to zero, then move-on rules based on bycatch are likely to be inappropriate for that taxon*" (para 132d of COMM11-DOC07).

For the encounter protocol and move-on rule to work effectively, it is important that observers and fishers are able to identify VME indicator taxa so that they can determine if an encounter has occurred. In practice, this means that observers and fishers need to be able to identify the range of benthic organisms that comprise VME indicator taxa (stony corals, black corals, true soft corals, sea fan octocorals, sea pens, anemones, hydrocorals, armless stars and sea lilies). The list of taxa in Annex 5 of the CMM03-2023, which is the operational component of the encounter protocol, was derived from VME indicator taxa defined for the southwest Pacific Ocean and was the basis for NZ's national management arrangements in SPRFMO prior to CMM03-2019 coming into force (Parker et al. 2009). The list of taxa identified by Parker et al. (2009) included 10 VME indicator taxa, designated variously at the taxonomic levels of phylum, class, order or family, was subsequently updated in 2021 to include Zoantharia, Hydrozoa and Bryozoa following a review of VME indicator taxa presented in SC7-DW13.

Annex 5 of CMM03-2023 is defined at a coarse taxonomic level to enable the identification of benthic bycatch by observers and fishers onboard fishing vessels without the aid of complex morphological characteristics. The Scientific Committee also maintains a list of VME indicator taxa at a finer taxonomic level (based on reviews of benthic bycatch from within the SPRFMO Convention Area against FAO VME criteria, as presented in SC8-DW11 and SC9-DW11). This is a list of known VME indicator taxa within the Convention Area and is intended to support Scientific Committee work programmes and inform management decisions (e.g., the development of identification guides for VME indicator taxa; designating and mapping the spatial extent of VMEs; evaluating the relationship between the density/biomass of VMEs and the diversity of associated species; formulating inferences from habitat suitability models based on higher-level taxonomic groups; and reviews of fishing events that have triggered the encounter protocol).

The list of VME indicator taxa currently included in Annex 5 of CMM03-2023, along with qualifying taxa, respective weight and biodiversity thresholds, and the reference for associated habitat suitability models are presented in Table 22.

Table 22: Matrix indicating taxa identified by Parker et al. (2009) as VME indicators, qualifying taxa, associated weight and biodiversity thresholds as stipulated in CMM03-2023, and references to current habitat suitability models.

FAO code	VME indicator taxon	Common Name	Qualifying taxa	Weight Threshold	Biodiversity Threshold	Habitat suitability models
PFR	Porifera (Phylum)	Sponges	All taxa of the classes Demospongiae and Hexactinellidae	25	5	Separate models for Demospongiae and Hexactinellida (Stephenson et al. 2021)
CSS	Scleractinia (Order)	Stony corals	All taxa within the following genera: Solenosmilia; Goniocorella; Oculina; Enallopsammia; Madrepora; Lophelia	60	5	Separate models for Enallopsammia rostrata, Madrepora oculata, Solenosmilia variabilis, Goniocorella dumosa (Stephenson et al. 2021)
AQZ	Antipatharia (Order)	Black corals	All taxa	5	1	Modelled as a single group (Stephenson et al. 2021)
ALZ	Alcyonacea (Order)	True soft corals	All taxa excluding Gorgonian Alcyonacea	-	1	Modelled as a single group (Stephenson et al. 2021)
GGW	Gorgonian Alcyonacea (Informal group)	Sea fans octocorals	All taxa within the following suborders: Holaxonia; Calcaxonia; Scleraxonia	15	1	Modelled as a single group (Stephenson et al. 2021)
NTW	Pennatulacea (Order)	Sea pens	All taxa		1	Modelled as a single group (Stephenson et al. 2021)
ATX	Actiniaria (Order)	Anemones	All taxa	35	5	Modelled as a single group (Stephenson et al. 2022a)
ZOT	Zoantharia (Order)	Hexacorals	All taxa	10	1	Modelled as a single group (Stephenson et al. 2022a)
HQZ	Hydrozoa (Class)	Hydrozoans	All taxa within the orders Anthoathecata and Leptothecata, excluding Stylasteridae	-	1	Modelled as a single group (Stephenson et al. 2022a)
AXT	Stylasteridae (Family)	Hydrocorals	All taxa	-	1	Modelled as a single group (Stephenson et al. 2021)
BHZ	Bryozoa (Phyllum)	Bryozoans	All taxa within the orders Cheilostomatida and Ctenostomatida	-	1	Modelled as a single group (Stephenson et al. 2022a)
BHZ	Brisingida (Order)	Armless stars	All taxa	-	1	Modelled as a single group (Stephenson et al. 2022a)
CWD	Crinoidea (Class)	Sea lillies and feather stars	All taxa	-	1	Modelled as a single group (Stephenson et al. 2022a)

4.4.2.2 Predicted distribution of VME indicator taxa

The available information on biomass, depth, and location of VME indicator taxa is too sparse to enable direct mapping of these taxa within the SPRFMO Convention Area, so habitat suitability models have been used to predict the niche distribution of key taxonomic groups based on the data that are available. This statistical approach relates field observations to environmental predictor variables, yielding predictions of a habitat suitability index (HSI, ranging from 0 to 1) for given taxa and the underlying environmental drivers of their geographic distribution (Anderson et al. 2016a; 2016b; Rowden et al. 2017; Stephenson et al. 2021). The spatial management measures implemented under CMM03-2019, and subsequently included in CMM03-2020, CMM03-2021, CMM03-2022 and CMM03-2023, were designed using ensemble habitat suitability models developed by Georgian et al. (2019).

Georgian et al. (2019) used a suite of broad-scale environmental variables to predict the distributions of each taxon, upscaled to higher-resolution regional bathymetry using a similar approach to that described by Davies and Guinotte (2011). Depth is an extremely important variable and depths for each cell were derived from the bathymetry grid for the New Zealand region derived by Mackay et al. (2015). Additional seafloor terrain metrics were derived from this bathymetry using the Benthic Terrain Modeler in ArcGIS 10.3.1.1 (Wright et al. 2012). A range of water chemistry and productivity variables were included, all gridded to 1 km^2 (Table 23). Variable selection and fitting procedures are described in Georgian et al. (2019). Ensemble models were constructed from the weighted average of model predictions of HSI from models using Boosted Regression Trees (BRT), Maximum Entropy (Maxent), and Random Forests (RF). Predictions were on a grid of 1 km^2 cells for depths between 200 and 3000 m for four species of framework-building scleractinian (stony) corals, *Enallopsammia rostrata*, *Goniocorella dumosa*, *Madrepora oculata*, and *Solenosmilia variabilis*. Sponges were modelled as two groups, glass sponges (Hexactinellida) and demosponges (Demospongiae). Black corals (Antipatharia), Soft corals (Alcyonacea), seafan octocorals (Gorgonian Alcyonacea) and seapens (Pennatulacea) were each modelled as a single group.

The 2020 BFIA (Delegations of Australia and New Zealand 2020) used the Georgian et al. (2019) models to evaluate the performance of the spatial management measures included in CMM03-2020. Stephenson et al. (2021) used the same approach as Georgian et al. (2019) to update the Georgian et al. (2019) models and Stephenson et al. (2022) developed ensemble models for previously unmodelled VME indicator taxa, including anemones (Actiniaria), hexacorals (Zoantharia), hydrozoans (Hydrozoa), hydrocorals (Stylasteridae), bryozoans (Bryozoa) armless stars (Brisingida) and sea lillies and feather stars (Crinoidea), each modelled as a single group.

For each taxon modelled by Stephenson et al. (2021) and Stephenson et al. (2022), habitat suitability (HSI), a spatially explicit measure of uncertainty (measured as the standard deviation of the mean (SD), calculated for each grid cell using 1000 bootstrapped layers) (Figure 37 to Figure 52) and environmental coverage (Smith et al. 2013) was calculated (Figure 53 and 54). Environmental coverage indicates which parts of the environmental space contain many sighting records (across all taxa), and therefore the likelihood that the predicted relationship between the environment and taxa is more certain. Metrics of environmental coverage indicated that there is poor coverage of environmental data in the deepest waters, but that the coverage is adequate in depths where fishing takes place.

Validation was performed for all models by calculating the mean area under the curve metric (AUC) and other performance statistics. AUC indexes a model’s ability to correctly rank occurrences above background locations; a random model has a theoretical AUC of 0.5, AUC >0.7 indicates adequate performance, and AUC >0.8 indicates excellent performance (Hosmer Jr et al. 2013). In these tests, AUC was for ensemble models consistently achieve AUC in the range 0.89 to 0.99, indicating excellent performance at classifying records as presence or (informed) pseudo-absence (Table 24). Full descriptions of the modelling approach, which has previously been endorsed by the SPRFMO SC (SC8 and SC10 reports) is provided in Georgian et al. (2019), Stephenson et al. (2021) and Stephenson et al. (2022). Models are available for all VME indicator taxa included in Annex 5 of CMM03-2023 (Table 22).

Table 23: Environmental variables considered for use in habitat suitability models by Georgeson et al. (2019) and in this assessment (particulate organic carbon export was updated). Variables highlighted in green were used as model predictors in both Georgeson et al. (2019) and the new models for this assessment.

Variable	Units	Native Resolution	Source
Seafloor Characteristics			
Depth	m	$1\ km^2$	Mackay et al. (2015)
Percent gravel	%	–	NIWA
Percent mud	%	–	NIWA
Ruggedness[2]	–	–	Derived from bathymetry
Slope[2]	degrees	–	Derived from bathymetry
Slope SD[2]	–	–	Derived from bathymetry
Aspect	degrees	–	Derived from bathymetry
Range[2]	–	–	Derived from bathymetry
Standard deviation[2]	–	–	Derived from bathymetry
Profile curvature	–	–	Derived from bathymetry
Plan curvature	–	–	Derived from bathymetry
Curvature	–	–	Derived from bathymetry
Bathymetric Position Index – fine	–	–	Derived from bathymetry
Bathymetric Position Index – broad	–	–	Derived from bathymetry
Seamounts	–	–	Rowden et al. (2008), Yesson et al. (2011)
Water Chemistry			
Apparent oxygen utilization	$ml\ l^{-1}$	1°	Garcia et al. (2013a)
Aragonite saturation state	–	0.5°	Bostock et al. (2013)
Calcite saturation state	–	0.5°	Bostock et al. (2013)
Dissolved oxygen	$ml\ l^{-1}$	1°	Garcia et al. (2013a)
Nitrate	$\mu mol\ l^{-1}$	1°	Garcia et al. (2013b)
Oxygen saturation	%	1°	Garcia et al. (2013a)
Phosphate	$\mu mol\ l^{-1}$	1°	Garcia et al. (2013b)
Salinity	–	0.25°	Zweng et al. (2013)
Sigma theta (in-situ density of seawater)	$kg\ m^{-3}$	0.25°	Derived from temperature and depth
Silicate	$\mu mol\ l^{-1}$	1°	Garcia et al. (2013b)
Temperature	°C	0.25°	Locarnini et al. (2013)
Productivity			
Particulate organic carbon export	$mg\ C\ m^{-2}\ d^{-1}$	0.08°	Pinkerton (unpublished)
Vertically Generalized Production Model[1]	$mg\ C\ m^{-2}\ d^{-1}$	0.167°	Oregon State University[3]
Eppley-VGPM[1]	$mg\ C\ m^{-2}\ d^{-1}$	0.167°	Oregon State University[3]
Carbon Productivity Model-2[1]	$mg\ C\ m^{-2}\ d^{-1}$	0.167°	Oregon State University[3]

[1] -Surface data derived from MODIS–Aqua (NASA) as the mean, minimum, maximum, and standard deviation from mid-2002–2016.

[2] -Terrain metrics calculated using window sizes of 3, 5, 7, and 15 cells.

[3] -Data obtained from http://www.science.oregonstate.edu/ocean.productivity.

Table 24: Performance metrics for the new models tuned using only the data available to Georgian et al. (2019) and tested using the new, entirely independent data (Stephenson et al. 2022a). Performance metrics are AUC = mean area under the curve, TSS[14] = true skill statistic, SEN = sensitivity (a measure of true positives), SPEC = specificity (a measure of true negatives). The new models tuned using all available data would be expected to perform better.

	Random forest				Boosted regression tree				MaxEnt				Ensemble models			
	AUC	TSS	SEN	SPEC	AUC	TSS	SEN	SPEC	AUC	TSS	SEN	SPEC	AUC	TSS	SEN	SPEC
Demospongiae	0.97	0.91	0.98	0.93	0.95	0.8	0.94	0.86	0.7	0.27	0.51	0.76	0.99	0.85	0.96	0.89
Hexactinellida	0.97	0.87	0.97	0.89	0.96	0.78	0.92	0.86	0.82	0.51	0.69	0.82	0.98	0.79	0.92	0.87
Enallopsammia rostrata	0.96	0.9	0.95	0.96	0.94	0.82	0.94	0.89	0.91	0.72	0.87	0.85	0.96	0.85	0.93	0.92
Goniocorella dumosa	0.96	0.85	0.96	0.89	0.92	0.76	0.94	0.82	0.76	0.47	0.67	0.81	0.97	0.77	0.95	0.81
Madrepora oculata	0.99	0.95	0.95	1.00	0.98	0.92	0.95	0.98	0.97	0.85	0.88	0.98	0.97	0.92	0.93	0.99
Solenosmilia variabilis	0.99	0.92	0.99	0.93	0.96	0.79	0.91	0.88	0.96	0.81	0.92	0.89	0.96	0.84	0.94	0.9
Antipatharia	0.98	0.88	0.95	0.93	0.96	0.79	0.9	0.88	0.87	0.61	0.83	0.77	0.97	0.79	0.87	0.92
Non-gorgonian Alcyonacea	0.97	0.87	0.96	0.91	0.87	0.62	0.9	0.72	0.86	0.58	0.88	0.7	0.92	0.74	0.91	0.83
Gorgonian Alcyonacea	0.76	0.39	0.65	0.74	0.76	0.38	0.58	0.8	0.75	0.4	0.74	0.66	0.89	0.4	0.73	0.67
Pennatulacea	0.98	0.87	0.96	0.91	0.94	0.75	0.89	0.86	0.87	0.56	0.78	0.78	0.97	0.79	0.93	0.86
Actiniaria	1.00	0.99	1.00	1.00	0.99	0.90	0.95	0.95	0.84	0.55	0.75	0.81	0.99	0.89	0.92	0.97
Zoantharia	0.98	0.87	0.95	0.92	0.90	0.64	0.87	0.77	0.88	0.63	0.90	0.73	0.94	0.71	0.87	0.84
Hydrozoa	0.98	0.87	0.97	0.90	0.94	0.75	0.94	0.81	0.80	0.46	0.74	0.72	0.95	0.77	0.95	0.83
Stylasteridae	0.98	0.9	0.96	0.94	0.96	0.81	0.92	0.89	0.87	0.59	0.85	0.75	0.96	0.82	0.93	0.88
Bryozoa	0.98	0.87	0.97	0.90	0.92	0.69	0.88	0.81	0.81	0.49	0.73	0.76	0.94	0.74	0.93	0.81
Brisingida	0.98	0.86	0.97	0.89	0.92	0.70	0.87	0.83	0.83	0.55	0.82	0.72	0.94	0.73	0.85	0.88
Crinoidea	0.98	0.87	0.98	0.88	0.93	0.74	0.92	0.82	0.85	0.56	0.75	0.80	0.95	0.77	0.92	0.84

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[14] TSS and AUC both measure the ability of a model to discriminate between presences and absences. TSS scales from -1 to +1; values of +1 show perfect agreement, 0 indicates no better than random, and < 0 indicates systematically incorrect prediction Allouche, O., Tsoar, A., Kadmon, R. (2006) Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). *Journal of Applied Ecology*, 43(6): 1223-1232. https://doi.org/10.1111/j.1365-2664.2006.01214.x. TSS values >0.6 are considered useful to excellent. AUC is a highly effective, threshold-independent measure of accuracy; a random model has a theoretical AUC of 0.5, AUC > 0.7 indicates adequate performance, and AUC > 0.8 indicates excellent performance Hosmer Jr, D.W., Lemeshow, S., Sturdivant, R.X. (2013) *Applied logistic regression*. John Wiley & Sons. TSS is a threshold-dependent measure of accuracy, but is not sensitive to prevalence Allouche, O., Tsoar, A., Kadmon, R. (2006) Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). *Journal of Applied Ecology*, 43(6): 1223-1232. https://doi.org/10.1111/j.1365-2664.2006.01214.x, Komac, B., Esteban, P., Trapero, L., Caritg, R. (2016) Modelization of the Current and Future Habitat Suitability of Rhododendron ferrugineum Using Potential Snow Accumulation. *PLoS ONE*, 11(1): e0147324. 10.1371/journal.pone.0147324.

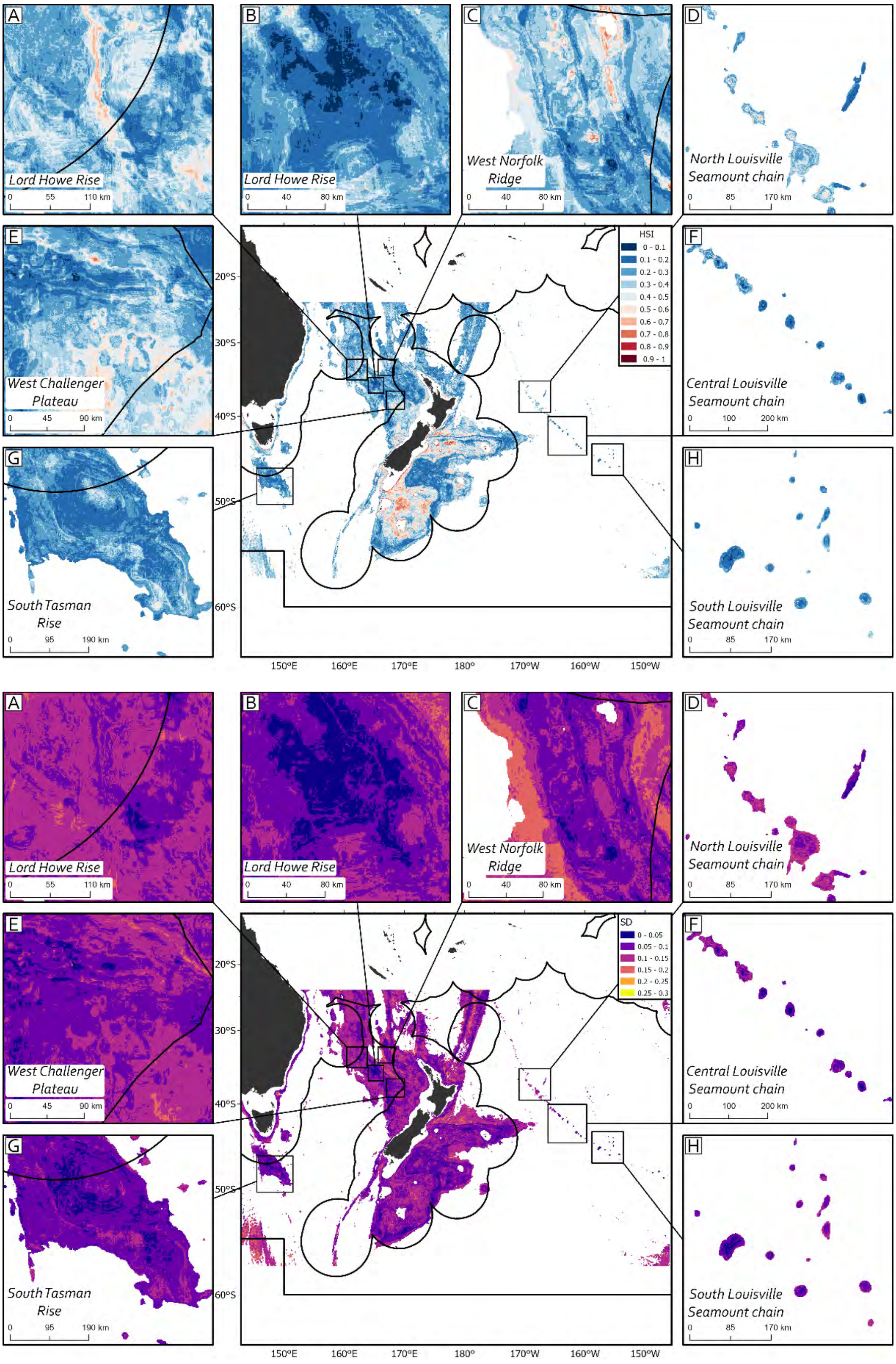

Figure 37: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Demospongiae from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

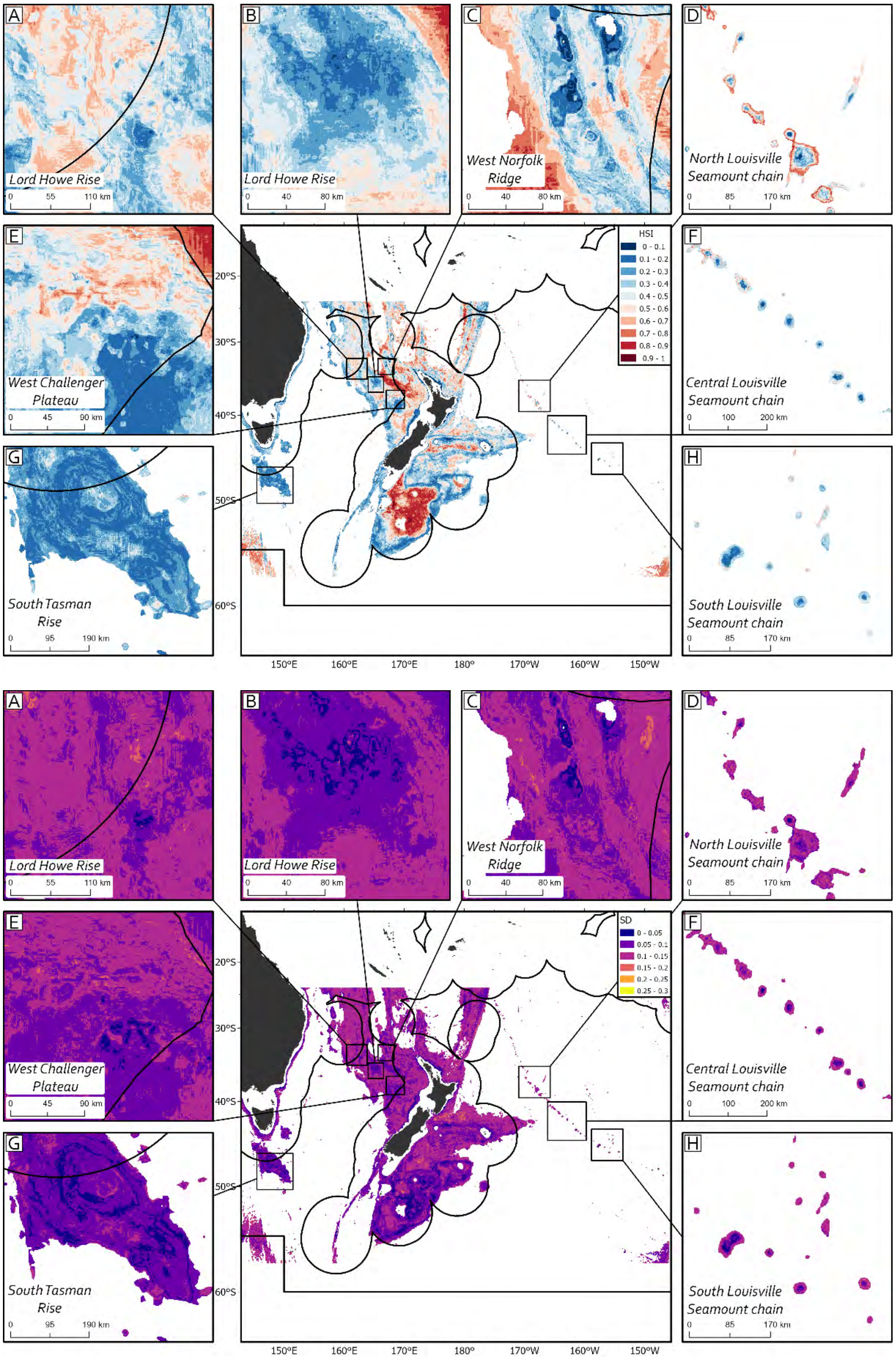

Figure 38: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Hexactinellida from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

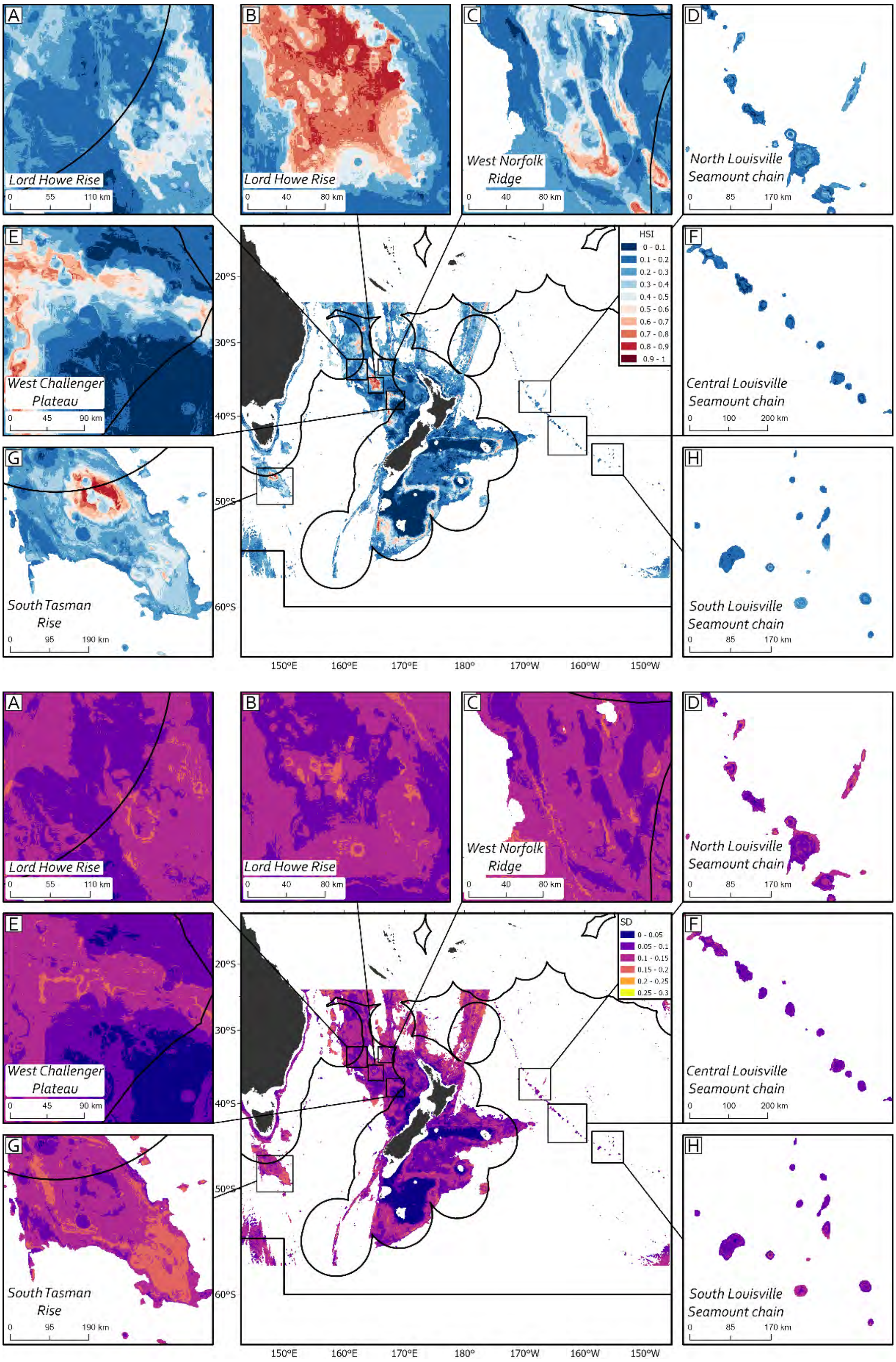

Figure 39: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for *Enallopsammia rostrata* from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

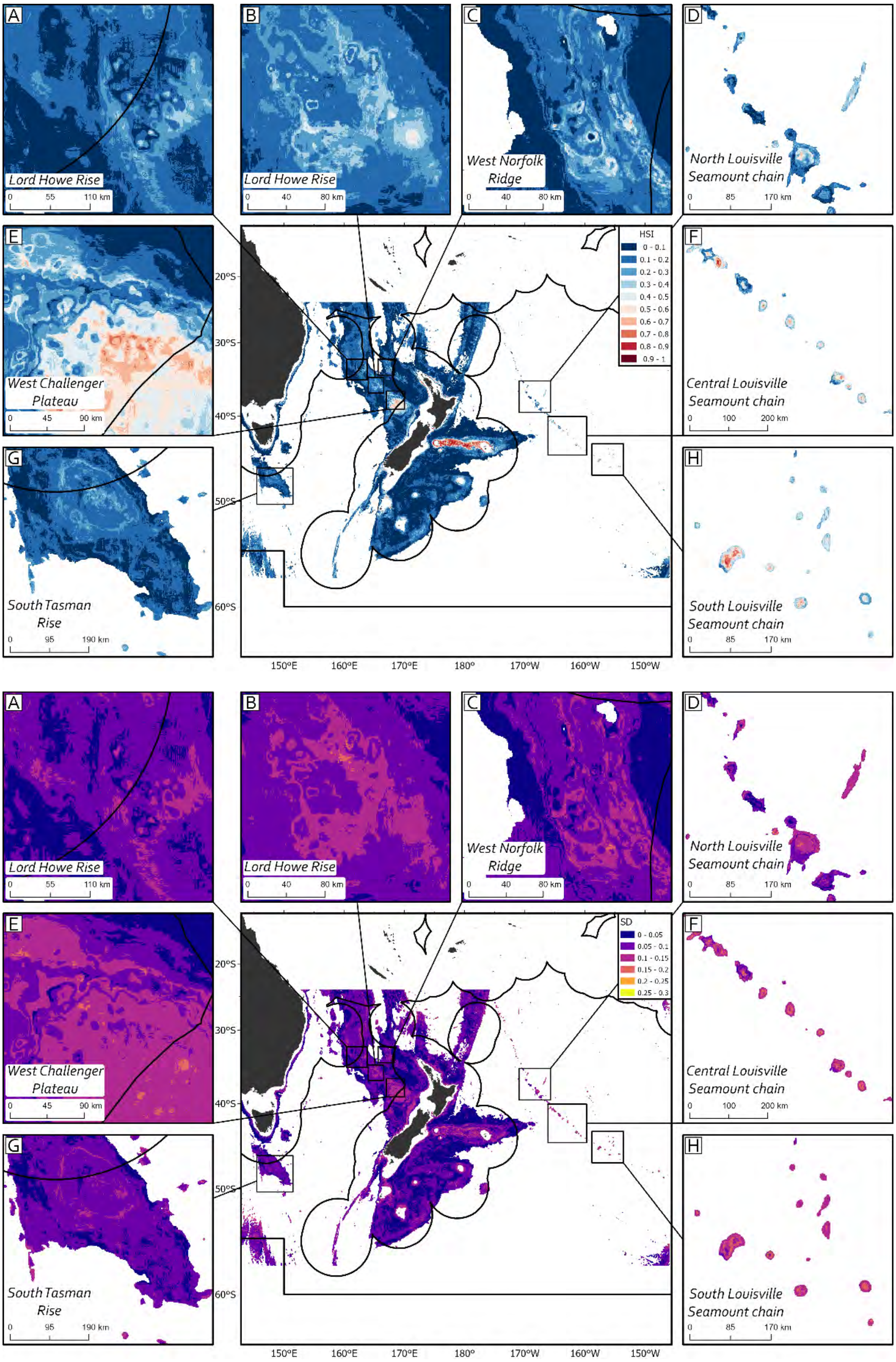

Figure 40: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for *Goniocorella dumosa* from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

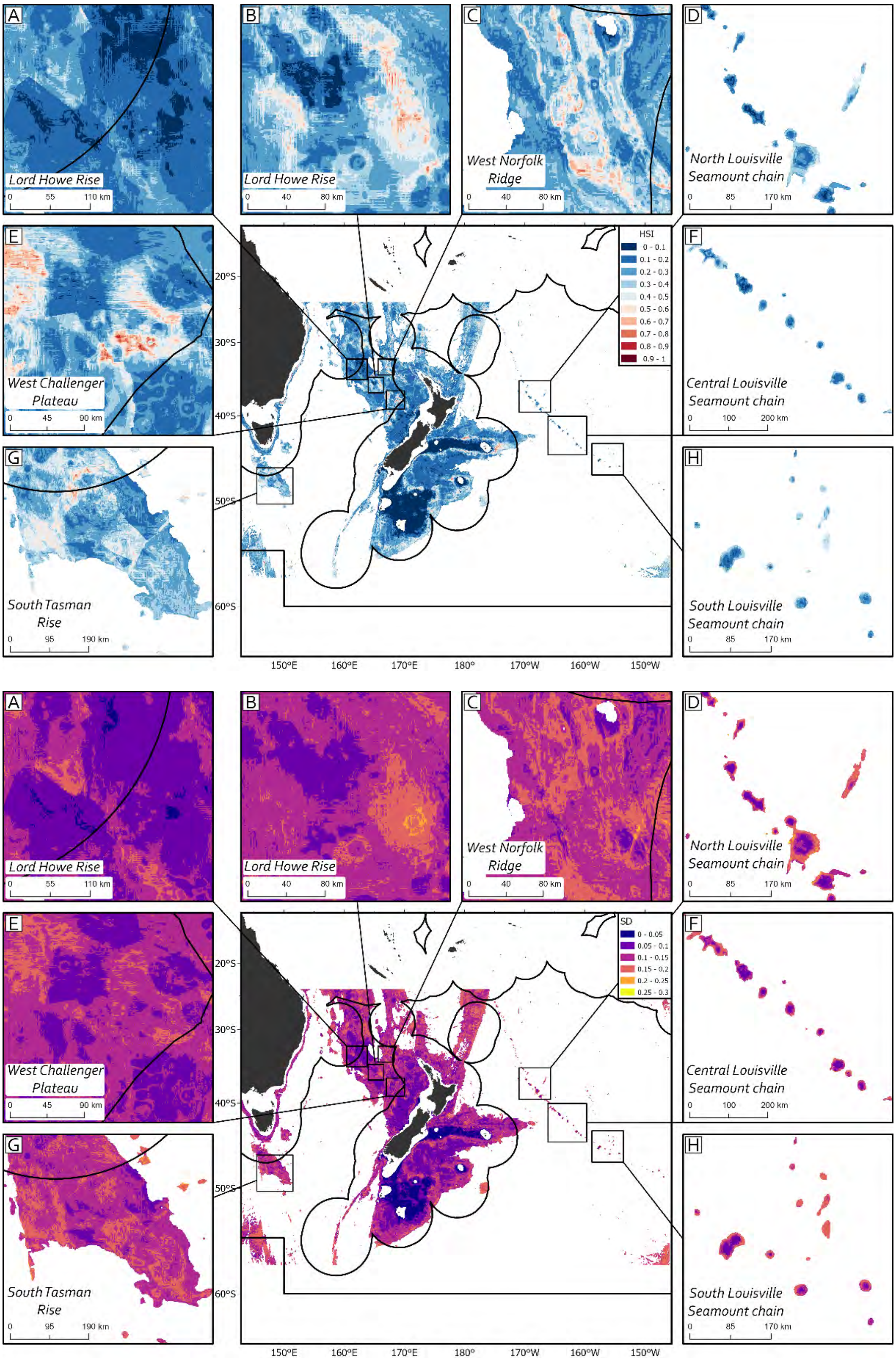

Figure 41: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for *Mandrepora oculata* from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

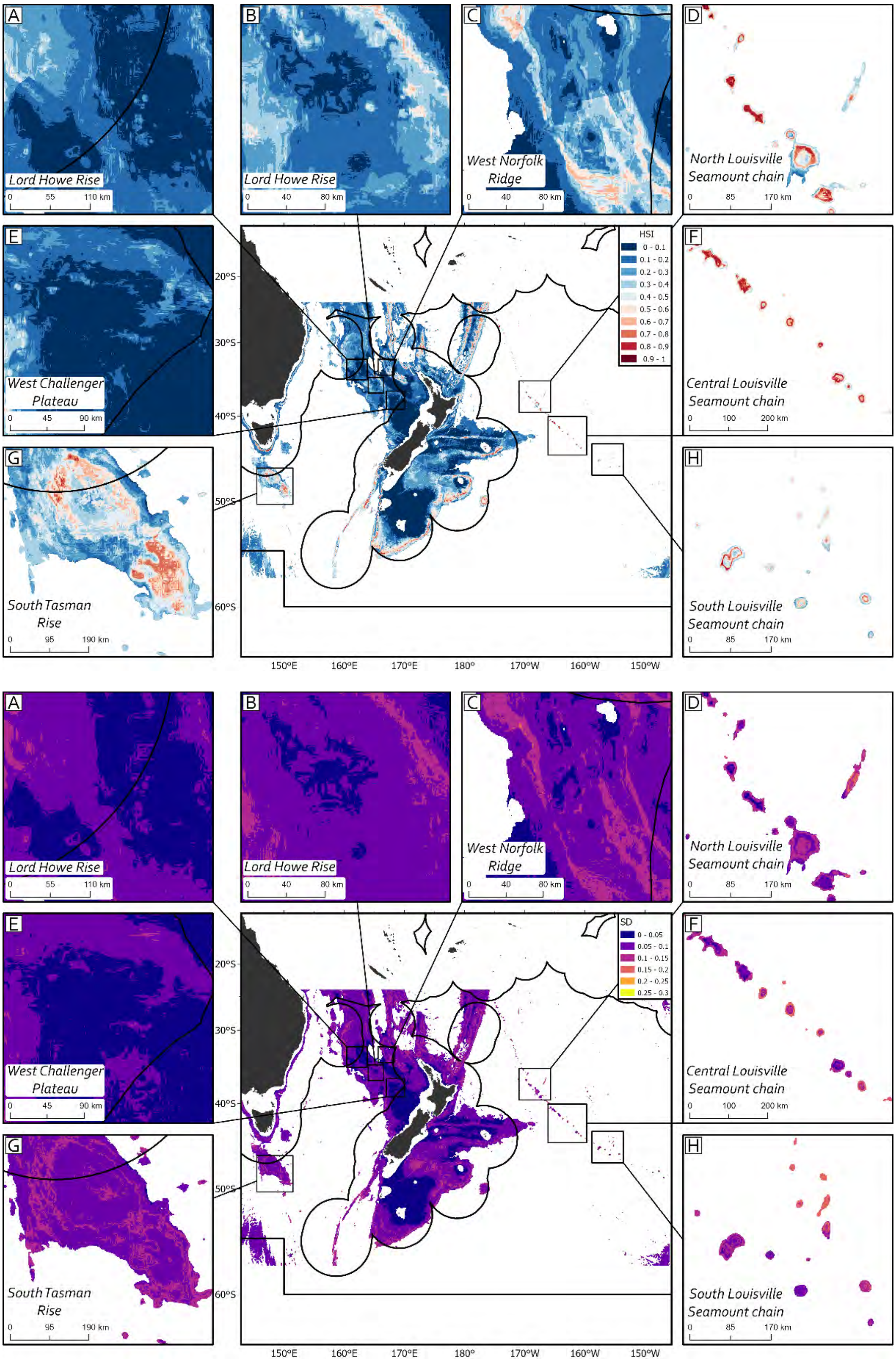

Figure 42: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for *Solenosmilia viriabilis* from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

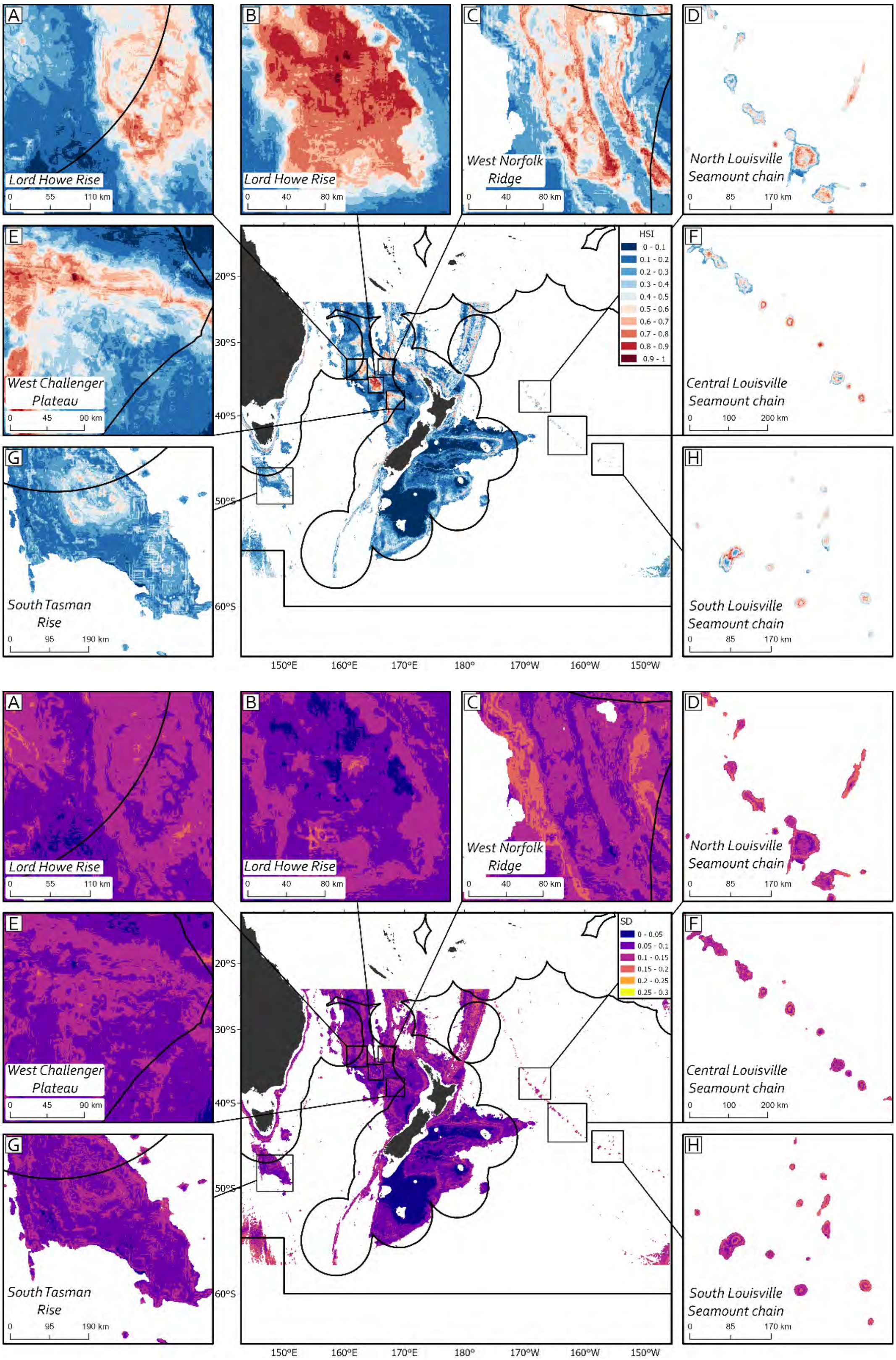

Figure 43: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Antipatharia from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

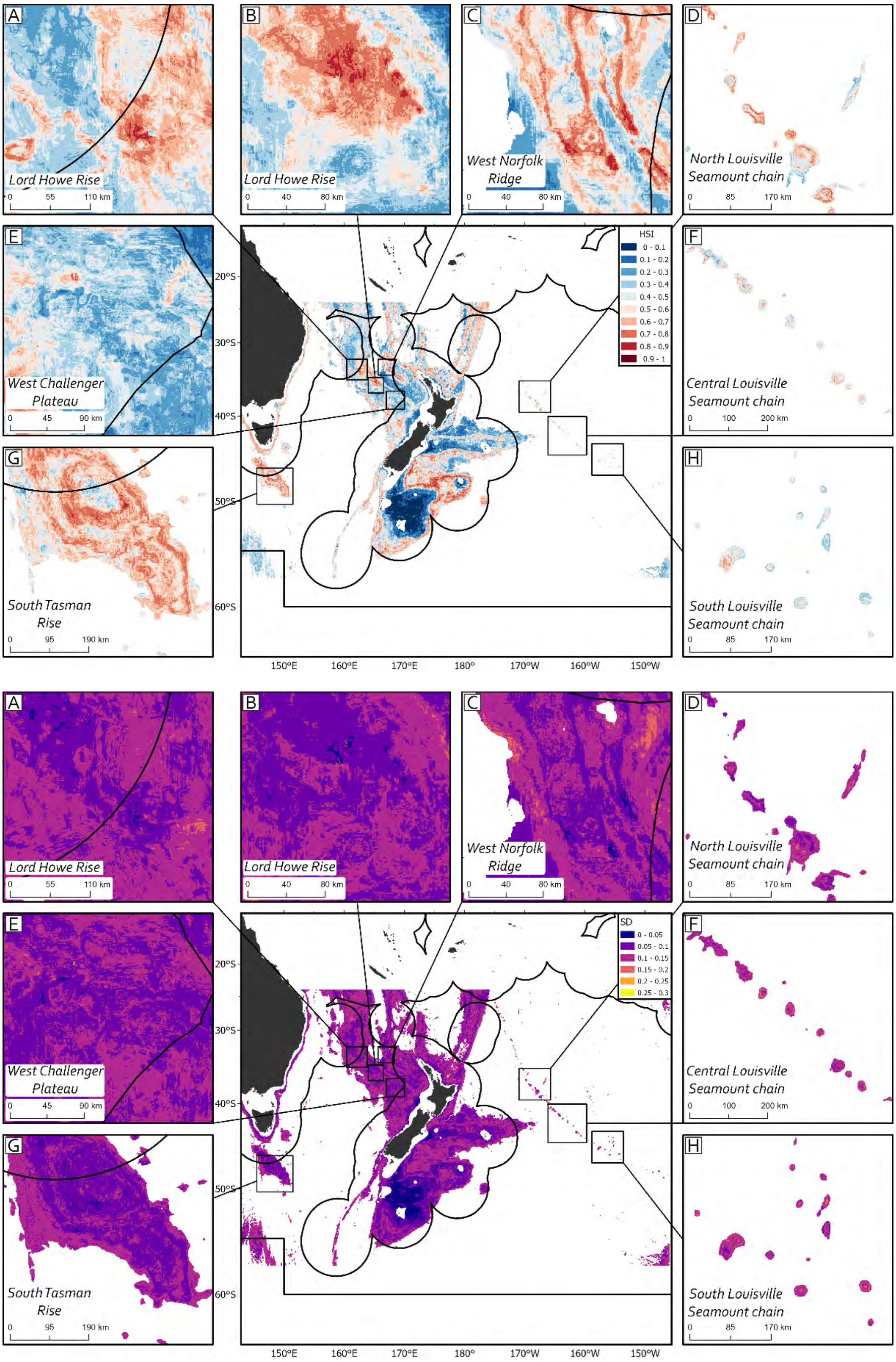

Figure 44: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Gorgonian Alcyonacea from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

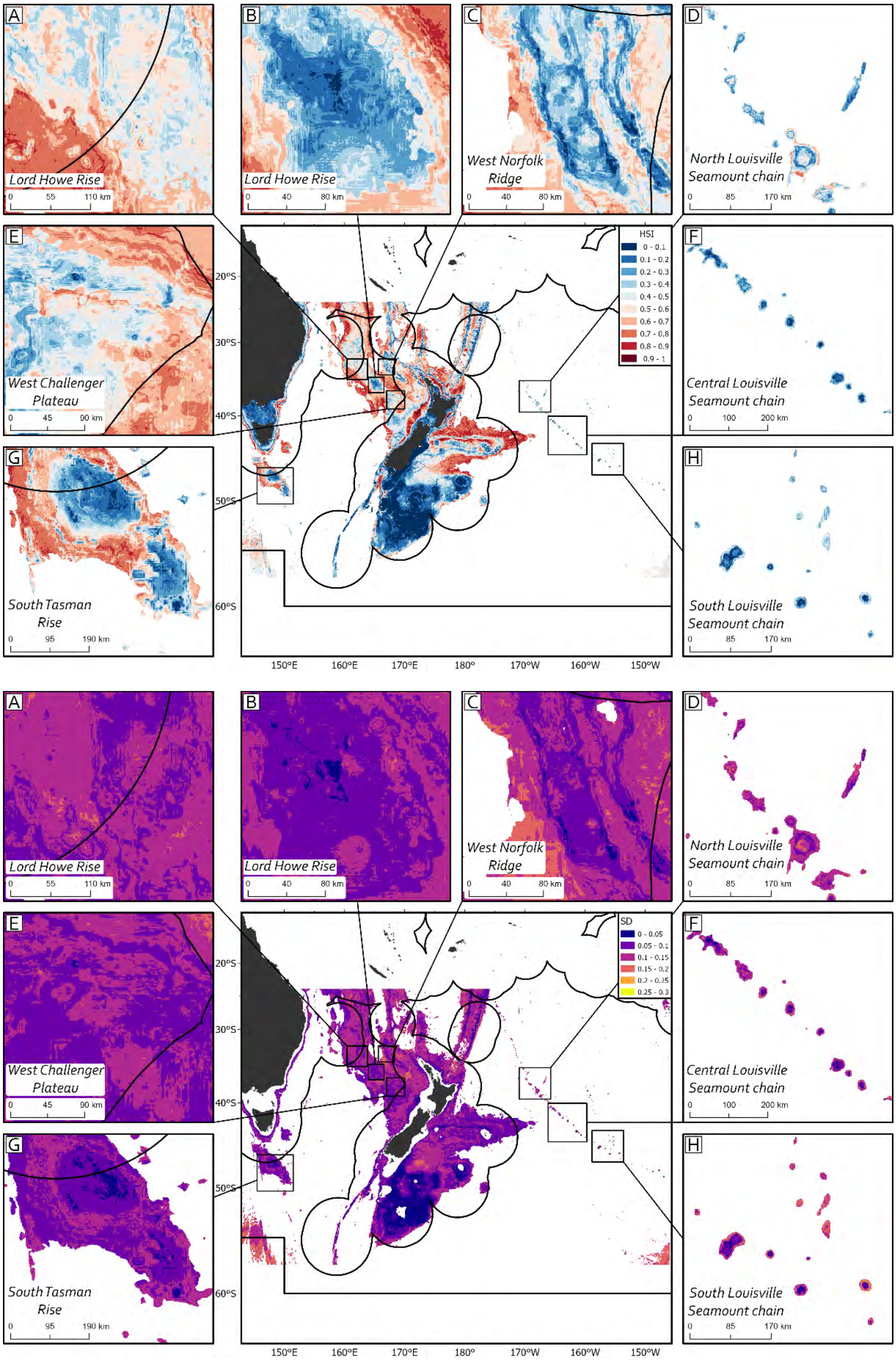

Figure 45: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Pennatulacea from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

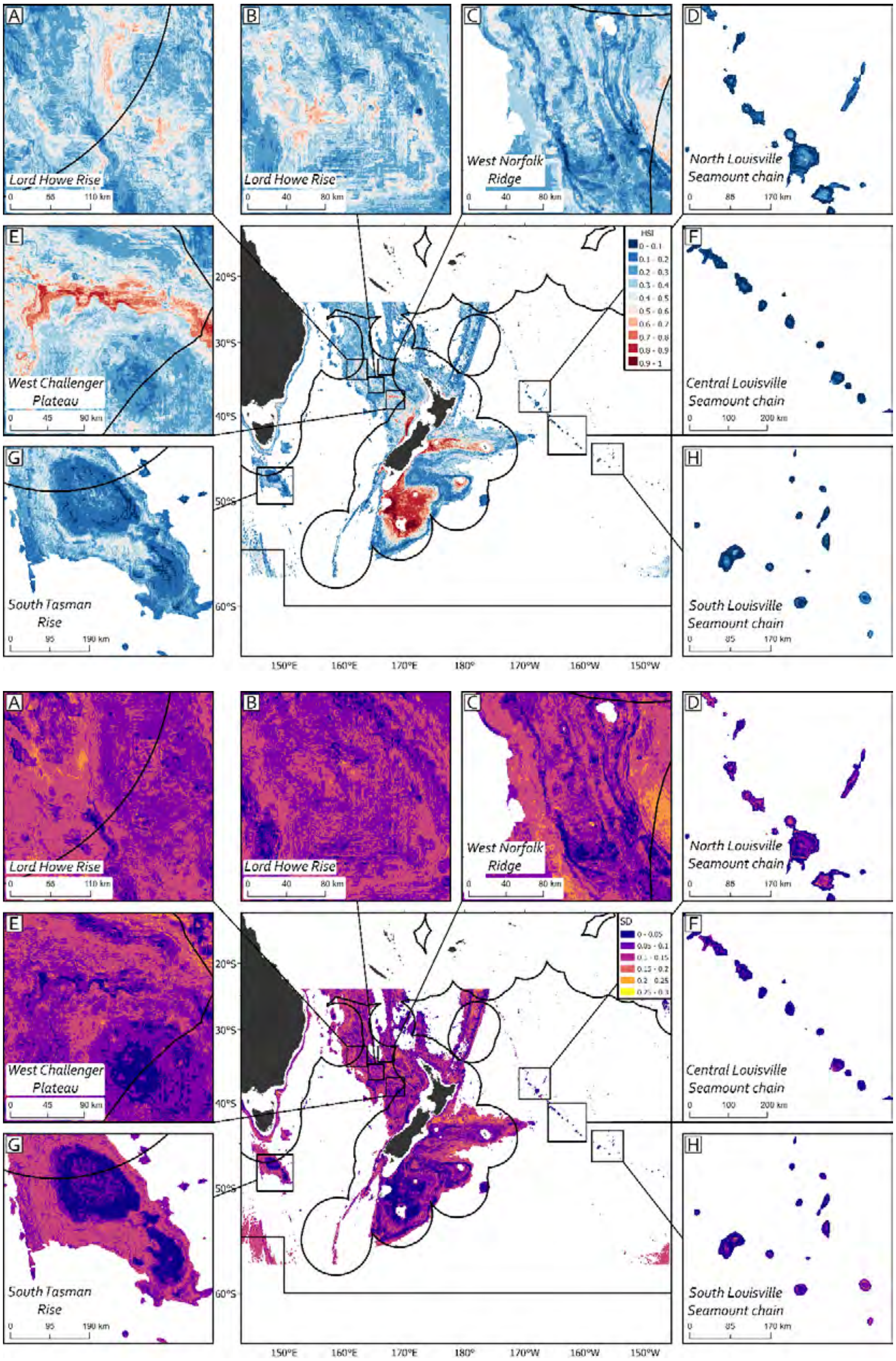

Figure 46: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Actinaria from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

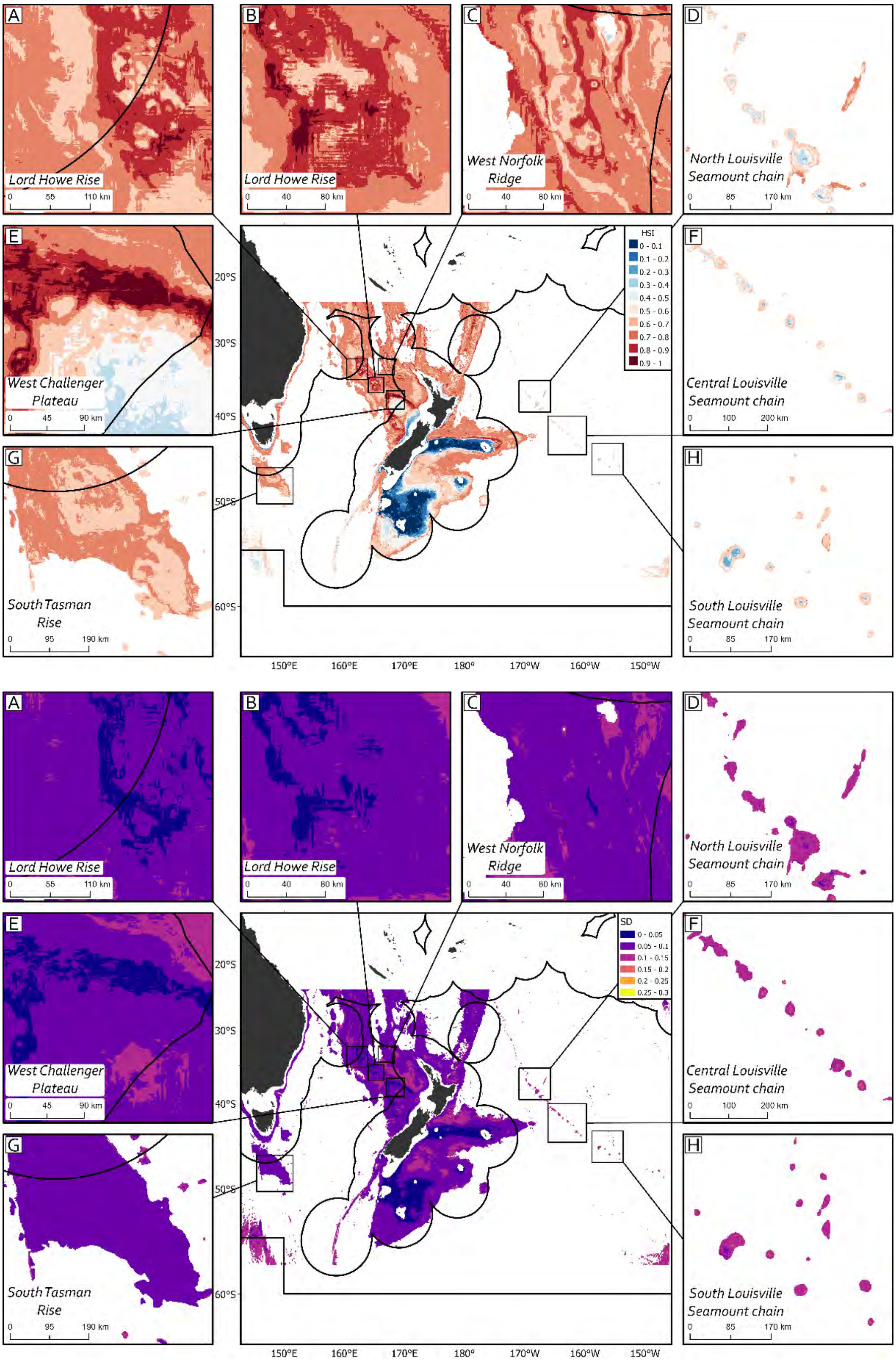

Figure 47: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Zoantharia from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

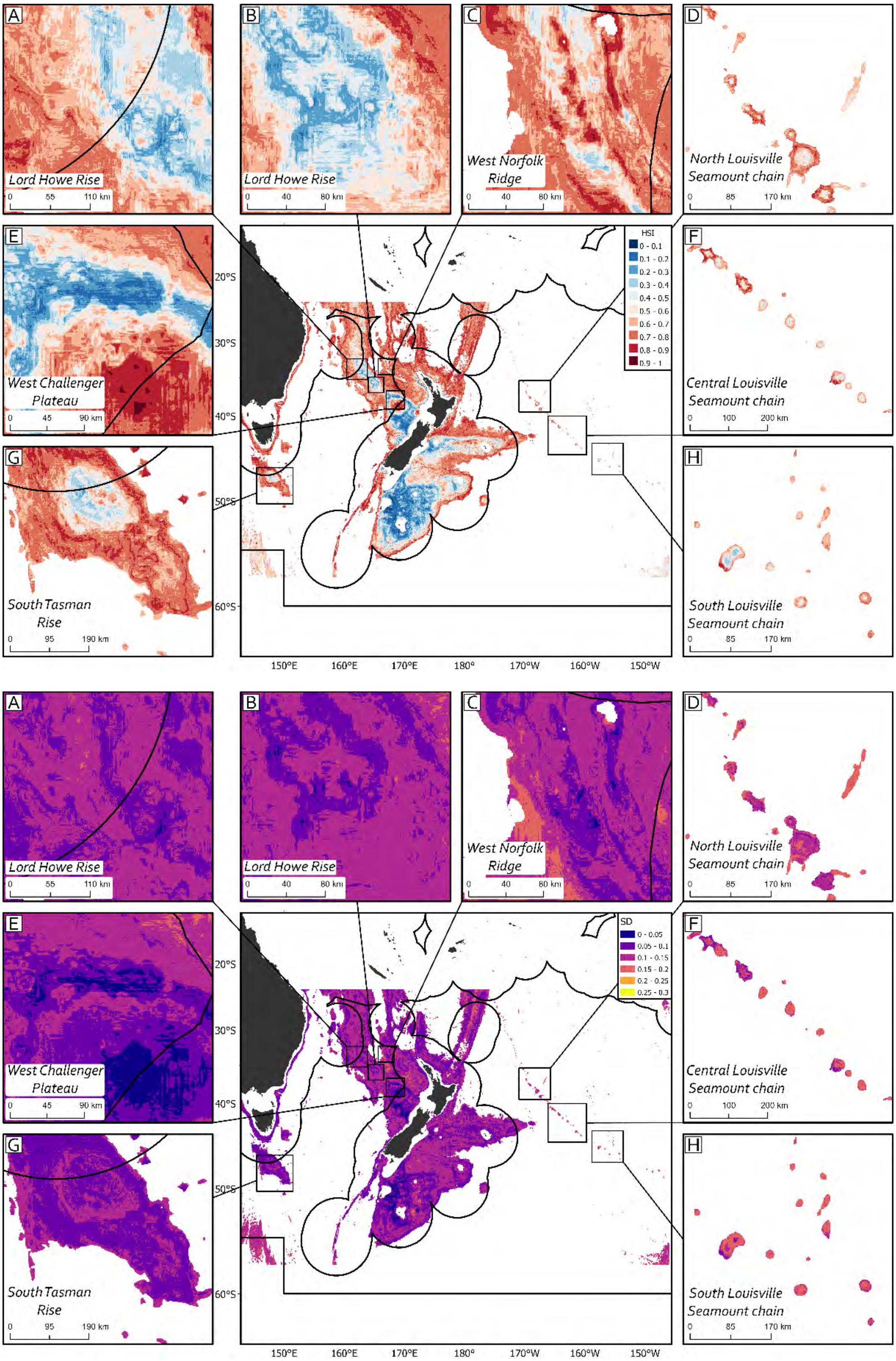

Figure 48: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Hydrozoa from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

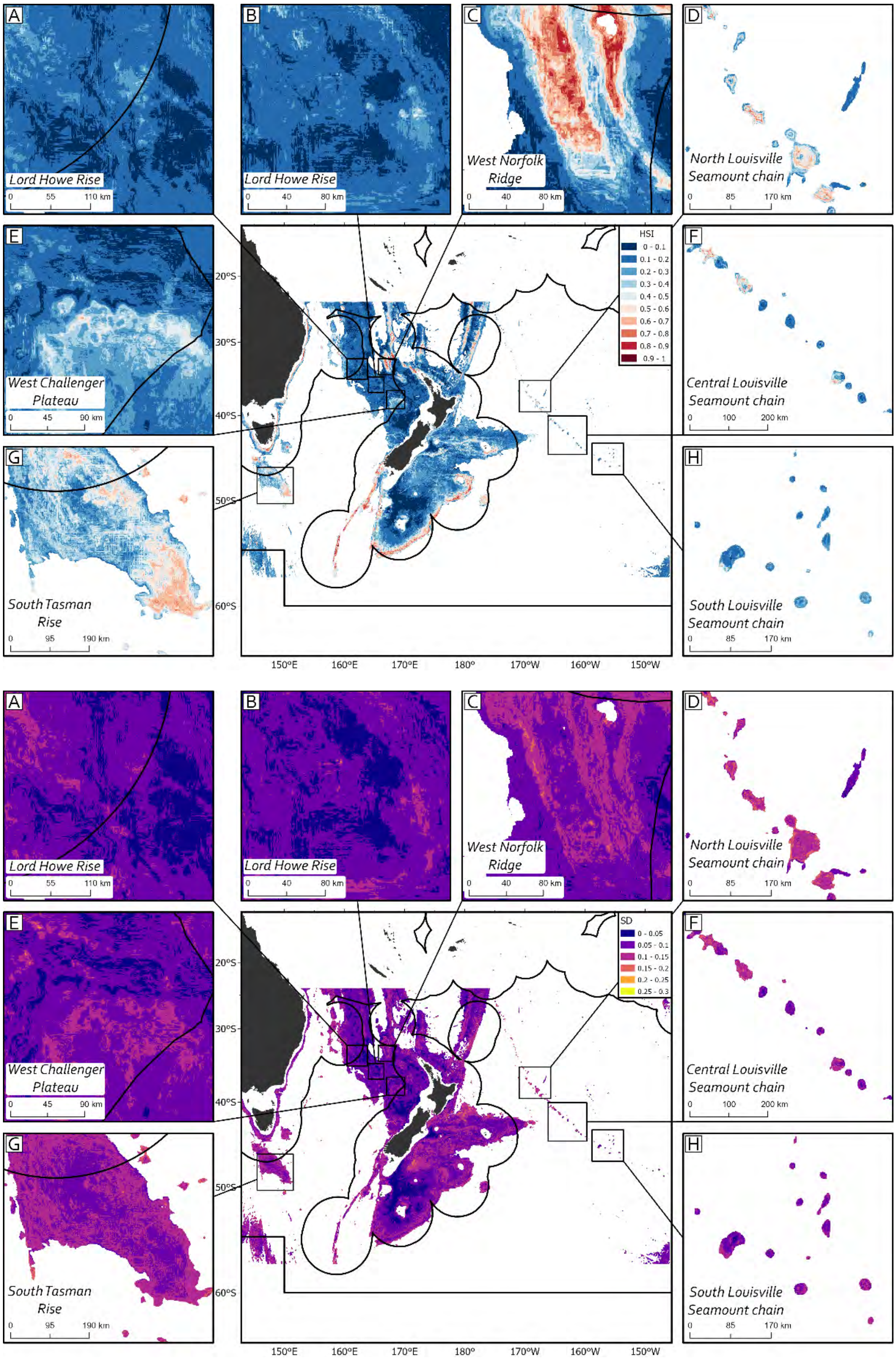

Figure 49: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Stylasteridae from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

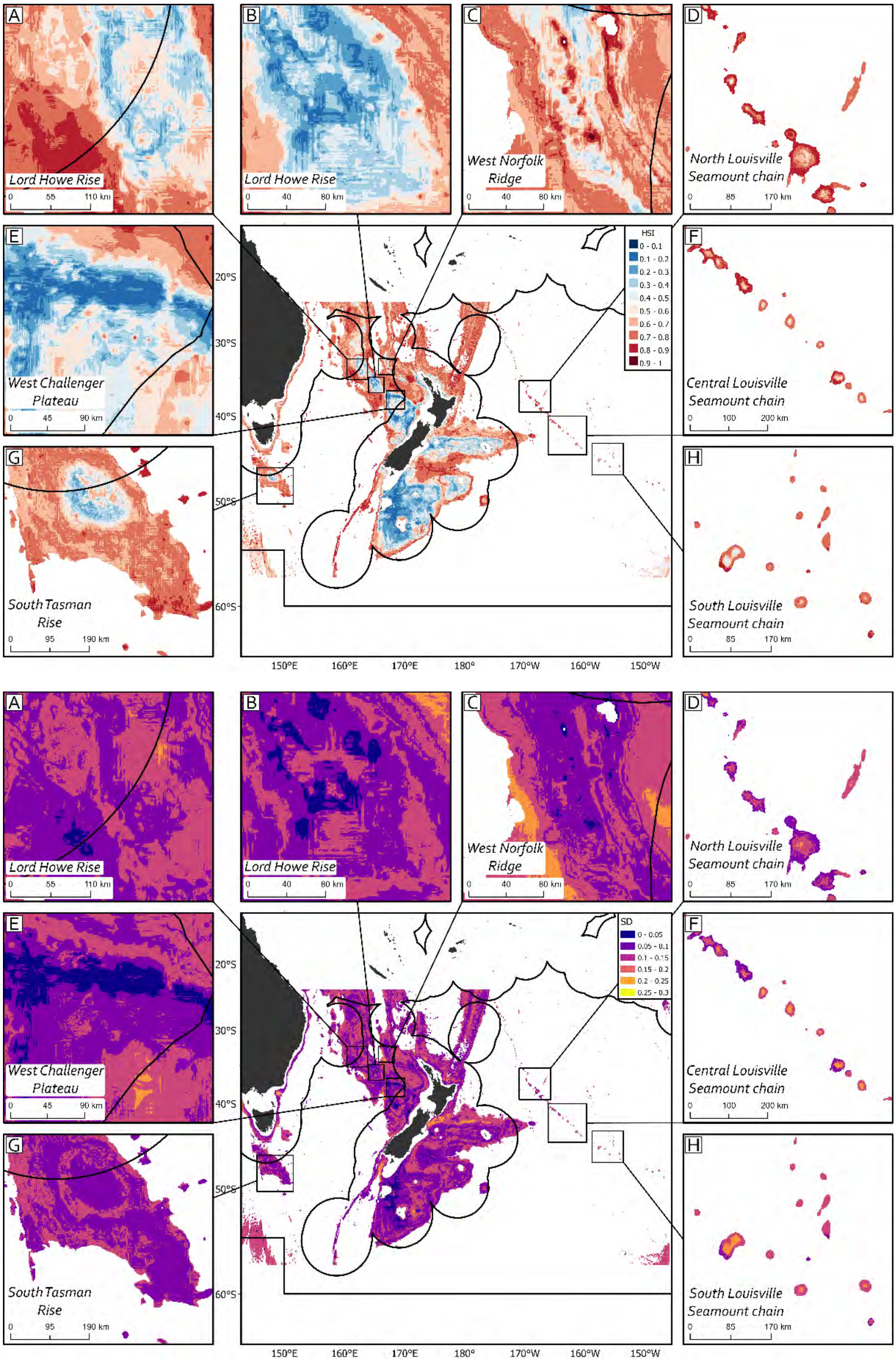

Figure 50: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Bryozoa from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

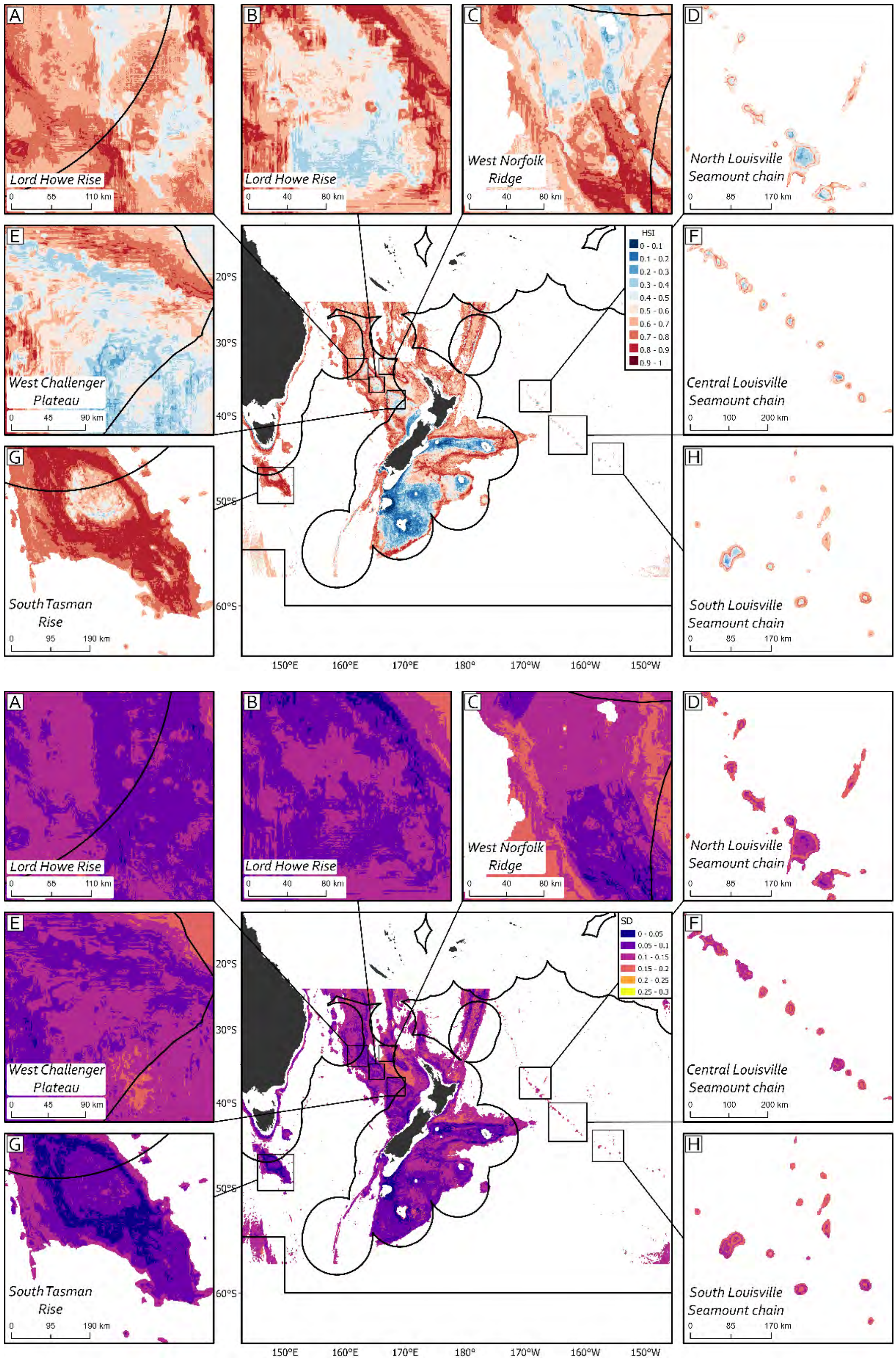

Figure 51: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Brisingida from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

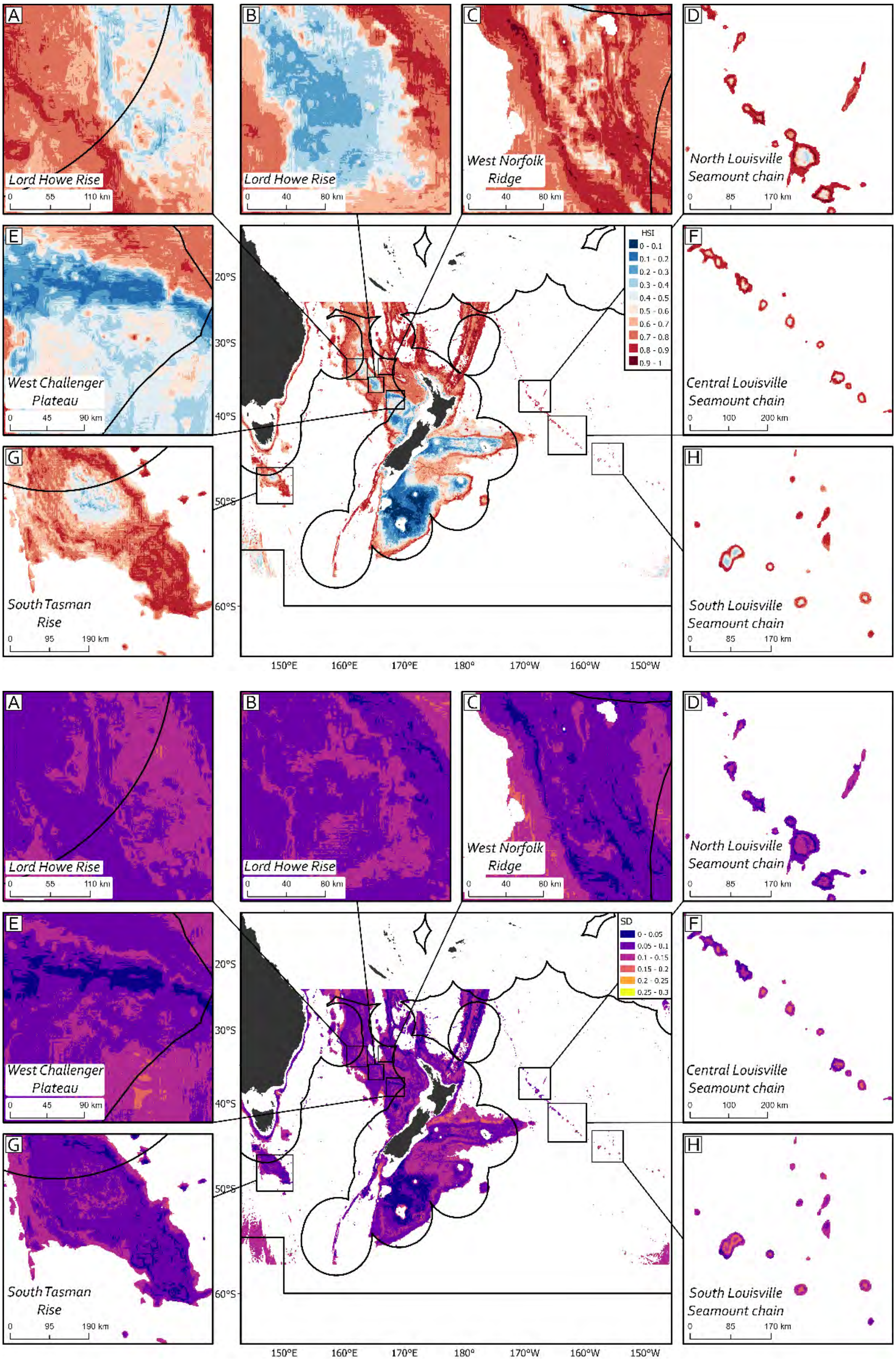

Figure 52: Mean predicted ensemble model habitat suitability index (HSI) (upper plot) and standard deviation (SD)(lower plot) for Crinoidea from ensemble habitat suitability models. Inset maps of the high seas in the study area: (a) West Lord Howe Rise; (b) East Lord Howe Rise; (c)West Norfolk Ridge; (d) North Louisville Seamount Chain; (e) West Challenger Plateau; (f) Central Louisville Seamount Chain; (g) South Tasman Rise; and (h) South Louisville Seamount Chain.

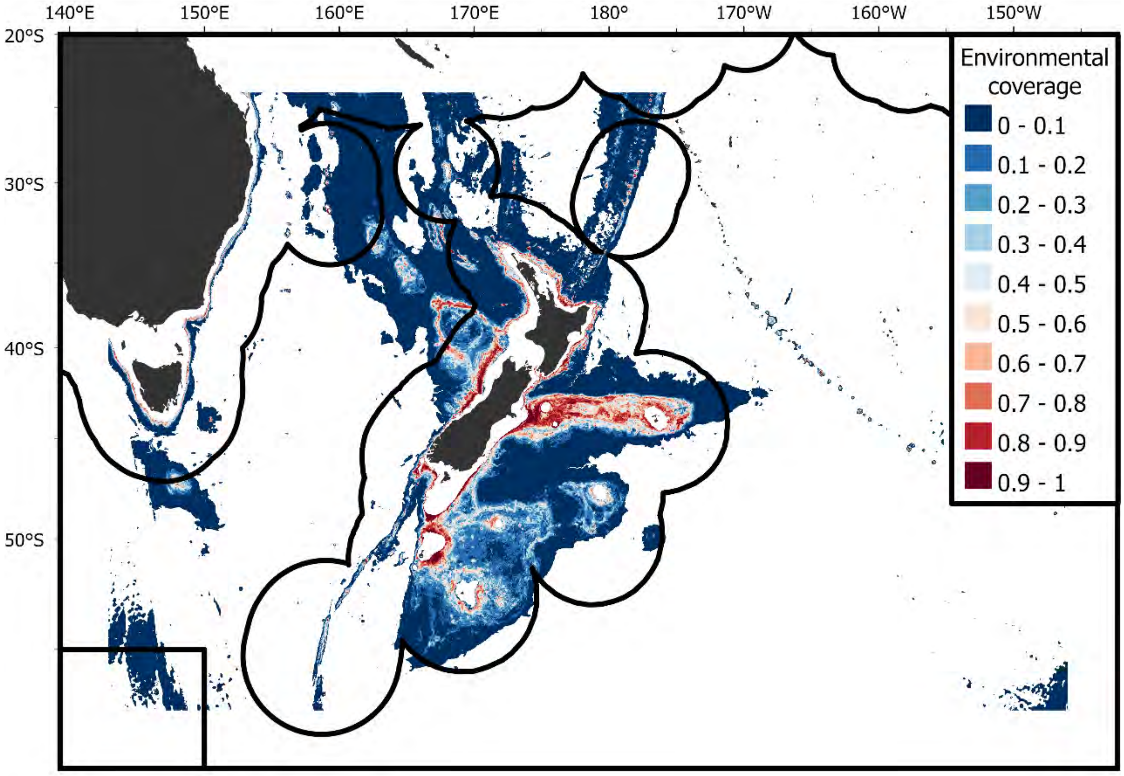

Figure 53: Environmental coverage (from low to high), i.e., spatial extent and level of detail of environmental data for HSI models for Actiniaria, Brisingida, Bryozoa, Crinoidea, Hydrozoa and Zoantharia (Stephenson et al. 2022a).

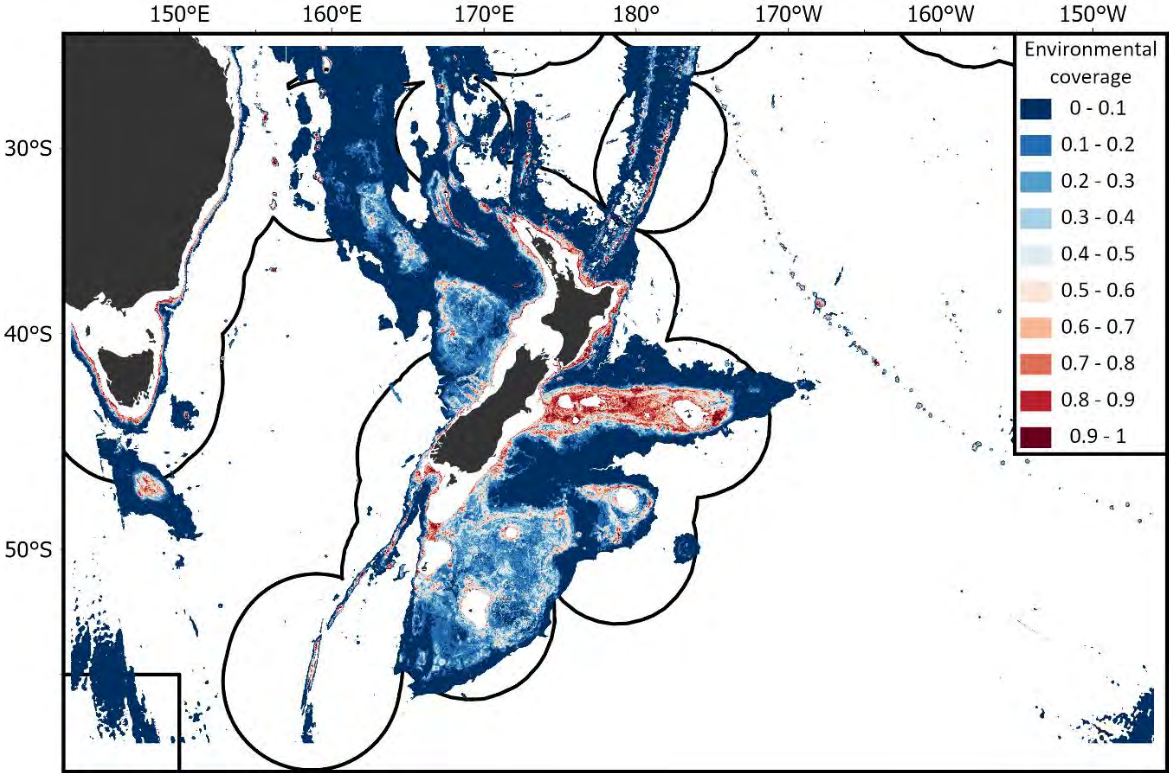

Figure 54: Environmental coverage (from low to high), i.e., spatial extent and level of detail of environmental data for HSI models for Antipatharia, Demospongiae, *Enallopsammia rostrata*, *Goniocorella dumosa*, Gorgonians, Hexactinellida, *Mandrepora oculata*, Pennatulacea, *Solenosmilia variabilis*, Stylasteridae (Stephenson et al. 2021).

4.5 RISK ASSESSMENT FOR BENTHIC HABITATS, BIODIVERSITY AND VMES

The risk assessments documented here were conducted for the 2020 BFIA (Delegations of Australia and New Zealand 2020), including data up to 2019. Fishing effort has been very low since 2019 (e.g., Table 4, Table 7, Table 8, Table 11, Table 12), particularly for bottom trawling, and fishing is not expanding into new areas (e.g., Figure 8 compared to equivalent figure in the 2020 BFIA). Consequently, the previous estimates of RBS presented within the 2020 BFIA will over-estimate impact and under-estimate RBS, given the very low level of bottom trawling that has occurred in the interim (and noting that RBS includes projections of future fishing impact, not merely a reflection of current status). Further, the 'future scenario' RBS estimates in the2020 BFIA (also reproduced here) assumed that bottom trawling effort could increase to catch estimated future catch limits for orange roughy; however, orange roughy catch limits have instead been reduced for a number of FMAs under CMM 03a-2023. Consequently, the RBS estimates presented here are likely to be conservative in that they overestimate future fishing activity and underestimate benthic status. Changes to orange roughy catch limits adopted in 2023 are shown in Table 6; if effort levels consistent with these newly adopted catch limits are the new status quo, then the extent to which the RBS results labelled 'current' will over-estimate impact and under-estimate equilibrium status in each FMA will be roughly proportional to the extent to which catch limits have been reduced.

Updating the projected effort levels to more accurately estimate the effect of changing fishing effort levels on VME intact status and RBS, is a high priority.

Predicted HSI distributions are now available for an additional six VME indicator taxa (Stephenson et al. 2021; Stephenson et al. 2022a), but it has not been possible to update the impact assessment to include these taxa. These additional taxa will be incorporated into future work to produce updated estimates of status and RBS for all VME indicator taxa when the BFIA is fully updated.

Research is currently underway to *Explore thresholds for "significant" adverse impact (SAI) for VMEs at different spatial scales, and understanding knowledge gaps and uncertainties.* This will allow the evaluation of the risk that cumulative fishing impacts may exceed the SAI level, for each taxon and within each FMA, and also at other spatial scales.

4.5.1 Spatial footprint and intensity of fisheries

The fishing footprint and cumulative location-specific impact on VME indicator taxa (giving rise to 'naturalness') was calculated following the methods outlined in Mormede et al. (2017). All available New Zealand and Australian recorded fishing events using bottom-contacting methods were obtained and assembled, the resulting dataset covering the 30-year period from 1989–2019. Data were groomed to remove or correct erroneous values and unwanted records (e.g., overly long trawls/sets, locations in too-deep water or outside of the evaluated area).

The data available included three fishing methods: bottom trawling, midwater trawling, and bottom longlining. Most of the New Zealand trawls were recorded as bottom trawls, but this distinction between trawl methods was only available for the recent Australian data (2019). The total number of recorded midwater trawls for the whole assessment period was 775 (about 1% of the total, Table 25).

The start and end locations of all sets and trawls were jittered by 0.5 minutes (using a uniform random distribution) to spatially separate records overlying due to rounding of reported positions to the nearest minute of arc. Tow positions were also adjusted using trawl geometry and depth so as to represent the position of the trawl on the seafloor rather than the vessel position.

Following Mormede et al. (2017), trawl and longline records were split into approximately 100 m long segments. For trawls the calculated tow distance, and hence the number of these segments, was based on speed and duration rather than start and end positions to account for trawls that vary off a direct course between the recorded start and end position (technically, all of them). The width assigned to each trawl segment varied, and was set according to the fishing method, bottom type, and nationality (the Australian trawlers have typically used smaller trawls) based on figures tabulated in Mormede et al. (2017) and unpublished notes from a 2017 SPRFMO trawl impact workshop (Table 26).

Because the extent and duration of bottom trawl gear contact with the seafloor depends on whether they are conducted on slopes of underwater topographical features, bottom trawls were designated as Underwater Topographical Feature (UTF) tows if the start position was within 3 n. miles of a hill, 5 n. miles of a knoll, or 8 n. miles of a seamount, and if trawl duration was less than 0.5 h; tows not meeting these criteria were designated SLOPE tows. The position of UTF trawls with end position equal to start position, or with missing end position, were adjusted back in the direction of the nearest UTF peak. Segment widths were further adjusted for UTF and midwater tows, to account for the lesser impact from the various components of the trawl (doors, sweeps/bridles, ground gear) due to the reduced period of seafloor contact by some components of the gear during the tow. For example, tows using midwater trawls to target benthopelagic species only rarely touch the bottom and only for very short time periods, and bottom trawl tows on UTFs are generally undertaken with the doors off the bottom. UTF segment widths were reduced by a ratio of 0.24/0.82 and midwater segment widths by a ratio of 0.001/0.82 (based on values in Mormede et al. (2017) and from the trawl impact workshop in July 2017).

Table 25: Number of fishing events used in the analyses; by year, method, and nationality.

	Number of trawls			Number of longlines		
Year	**AUS**	**NZL**	**Total**	**AUS**	**NZL**	**Total**
1989	0	9	9	0	0	0
1990	0	254	254	0	0	0
1991	0	37	37	0	0	0
1992	0	150	150	0	2	2
1993	0	2 872	2 872	0	64	64
1994	0	3 960	3 960	0	0	0
1995	0	5 667	5 667	0	0	0
1996	52	4 219	4 271	0	6	6
1997	646	2 478	3 124	0	19	19
1998	1 504	2 002	3 506	0	5	5
1999	1 190	2 849	4 039	0	15	15
2000	930	1 960	2 890	5	8	13
2001	396	2 156	2 552	21	0	21
2002	554	3 517	4 071	22	0	22
2003	332	3 499	3 831	7	26	33
2004	251	2 741	2 992	3	102	105
2005	207	2 472	2 679	0	295	295
2006	874	1 413	2 287	28	669	697
2007	203	629	832	18	427	445
2008	0	239	239	85	245	330
2009	0	649	649	48	210	258
2010	0	1 183	1 183	49	66	115

2011	171	1 153	1 324	52	60	112
2012	393	713	1 106	58	131	189
2013	244	876	1 120	80	260	340
2014	102	403	505	49	307	356
2015	18	933	951	79	199	278
2016	49	980	1 029	90	135	225
2017	73	1 452	1 525	91	192	283
2018	0	1 041	1 041	111	172	283
2019	108	269	377	84	392	476

Table 26: Nominal swept widths (m) applied to trawls by fishing type and nationality

	Australia	New Zealand
Slope tows	100	135
Feature tows	85	115
Midwater tows	30	30

The effective width of the area impacted by bottom longlines is largely determined by the lateral movement of the backbone during retrieval and that has been shown to vary according to depth. Segment widths were estimated according to a calculation derived from Welsford et al. (2013) and Darby (2010), and based on the depth of the set:

Width=exp(2.4892514 - 0.0011380* Depth)

Impact widths thus estimated were mostly between 6 m and 10 m but were up to 12 m for some shallower sets (Figure 55). Fishing footprints for each fishing method were derived from the segment data by assigning each segment to a cell of a standard 1x1 km grid in Mercator 41 projection with an extent defined by the Evaluated Area. The total footprint in each cell was calculated by adding the areas of all segments with midpoints within the cell, assuming random overlap between segments (after Mormede et al. 2017). Using this procedure, the total accumulated footprint from bottom trawling inside the evaluated area in 1989–2019 was calculated to be 17 643.4 km^2. By comparison, the equivalent footprint from midwater trawling was 0.22 km^2 and the equivalent footprint from bottom longlining was 96.96 km^2. The very small footprint of midwater trawls stems from the trawl impact workshop conclusion that, on average, only 30% of midwater trawls contact the seafloor and that contact happens only twice per tow, for an average of 25 seconds each time.

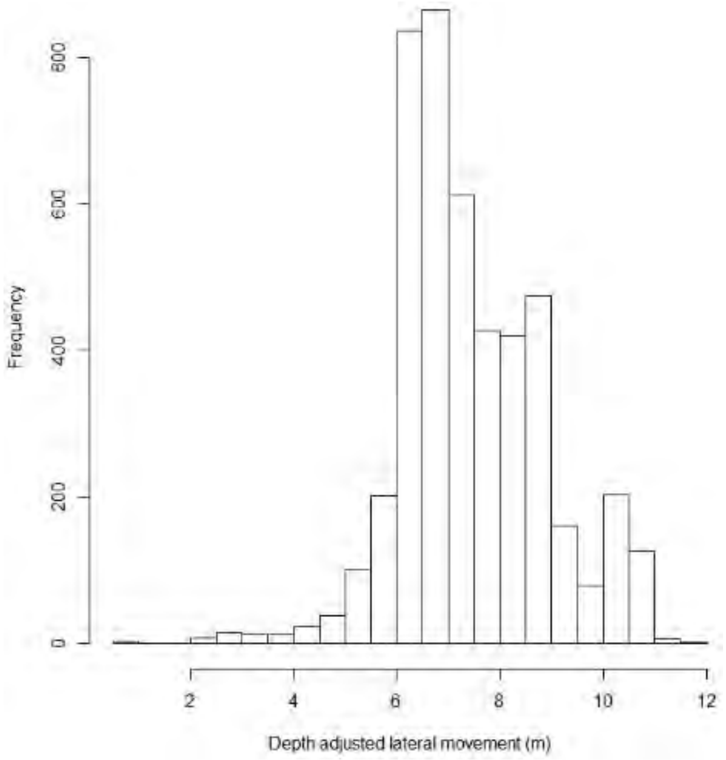

Figure 55: Distribution of estimated, depth-adjusted longline impact widths.

The footprints as a percentage of the total high-seas seafloor area within the Evaluated Area, and the Fisheries Management Areas for orange roughy as defined by Clark et al. (2016), were also calculated (Figure 56).

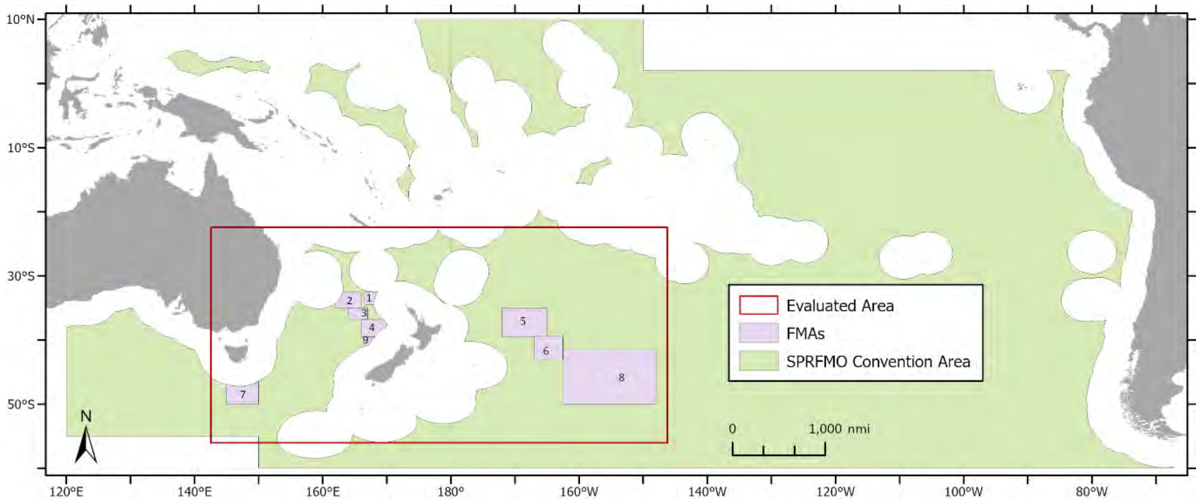

Figure 56: SPRFMO Convention Area (light green) including the extent of the evaluated area under SC9-DW-10 (red boundaries) with all numbered Fishing Management Areas (FMAs) defined under SPRFMO CMM03-2023 (purple polygons). FMAs numbered as 1) West Norfolk, 2) North Lord Howe Rise, 3) South Lord Howe Rise, 4) Northwest Challenger, 5) North Louisville Ridge, 6) Central Louisville Ridge, 7) South Tasman Rise, 8) South Louisville Ridge, and 9) Westpac Bank. Fisheries Management Areas (FMAs) after Clark et al. 2016 used to assess the likely performance of spatial management areas in force under

CMM03-2023. (noting the FMAs do not cover the whole Evaluated Area; Table 33 shows the proportion of each taxon estimated to be outside the FMAs).

The bottom trawl footprint dominates in all these percentages, and is estimated to have contacted 0.13% of the total seafloor in the high-seas of the Evaluated Area, but 1.9% when restricted to the depths used in the habitat suitability models (200–3000 m), and 6.6% when further restricted to fishable depths (<1400 m). The percentages are highest in the fishable depths of Central Louisville where they reach 46.7% (Table 27).

In some regions, particularly those dominated by seamounts where tow lines may be narrowly defined (e.g., the LSC), there is potential for overestimation of these percentages, if the jittered positions of the original fishing locations overrepresent their real variability around the rounded values recorded. This issue may be investigated in future by examination of more recent data with higher spatial resolution.

Table 27: Percentage of seafloor contacted within the high seas parts of the Evaluated Area and areas of the Fisheries Management Areas, by fishing gear type. –, zero footprint for a method in an area.

	All depths			Model depths (200-3000 m)			Fishable depths (<1400 m)		
Regions	**BT**	**MW**	**BLL**	**BT**	**MW**	**BLL**	**BT**	**MW**	**BLL**
Evaluated Area	0.129	0.00000158	0.00071	1.897	0.0000232	0.01043	6.586	0.000804	0.03619
ORY stock areas (FMAs) (Clark et al 2016)									
Lord Howe Rise (1)	3.855	0.00002787	0.00001	3.855	0.0000279	0.00001	5.755	0.00004	–
Lord Howe Rise (2)	0.835	0.00020733	0.00269	1.209	0.0003002	0.00390	1.707	0.00042	0.00550
NW Challenger Plateau	13.866	0.00003482	0.01813	14.363	0.0000361	0.01878	20.717	0.00005	0.02707
West Norfolk Ridge	1.389	0.00001921	0.07262	1.372	0.0000159	0.06880	2.420	0.00003	0.13358
North Louisville Ridge	0.338	0.00000122	0.00056	7.440	0.0000225	0.01320	22.721	0.00006	0.04874
Central Louisville Ridge	0.675	0.00000083	–	12.476	0.0000045	–	46.727	0.00001	–
South Louisville Ridge	0.052	0.00000009	–	6.648	0.0000124	–	21.321	0.00005	–
Three Kings Ridge	0.140	0.00000444	0.00830	0.320	0.0000103	0.01875	2.295	0.00007	0.13211
South Tasman Rise	0.307	0.00000054	0.00005	0.705	0.0000013	0.00012	2.998	0.00001	0.00053

4.5.2 Current state of impacted taxa

Knowledge of the likely current status of impacted benthic taxa is an important input to Zonation prioritisation analyses if there is a preference to prioritise protection of locations where the fauna is likely to be in good condition. The calculation of naturalness, a spatial representation of the current status of a taxon after the effects of all historical trawling, requires at a minimum an estimate of the mortality (i.e., depletion) caused by the passing of fishing gear, and ideally also an estimate of its ability to recover. Depletion (d) and recovery rate (R) values were obtained from (or based on) values published in three studies (Welsford et al. 2013; Mormede et al. 2017; Pitcher et al. 2017) (Table 28).

Table 28: Trawl and longline fishing depletion (d) and recovery (R) rates for the ten taxa modelled, with sensitivities for the uncertainties in these values (low and high) as used in the calculation of naturalness.

	Depletion (trawl)			Depletion (longline)			Recovery		
Taxon	d	d (low)	d (high)	d	d (low)	d (high)	R	R (low)	R (high)
Demospongiae	0.38	0.30	0.46	0.14	0.11	0.17	0.24	0.18	0.30
Hexactinellida	0.38	0.30	0.46	0.14	0.11	0.17	0.24	0.18	0.30
Enallopsammia rostrata	0.67	0.52	0.82	0.03	0.02	0.04	0.20	0.15	0.25
Goniocorella dumosa	0.67	0.52	0.82	0.03	0.02	0.04	0.20	0.15	0.25
Madrepora oculata	0.67	0.52	0.82	0.03	0.02	0.04	0.20	0.15	0.25
Solenosmilia variabilis	0.67	0.52	0.82	0.03	0.02	0.04	0.20	0.15	0.25
Gorgonian Alcyonacea	0.50	0.39	0.61	0.27	0.21	0.33	0.27	0.20	0.34
Antipatharia	0.50	0.39	0.61	0.27	0.21	0.33	0.33	0.25	0.41
Pennatulacea	0.34	0.26	0.42	0.03	0.02	0.04	0.39	0.29	0.49
Stylasteridae	0.41	0.32	0.50	0.03	0.02	0.04	0.33	0.25	0.41

Uncertainty around these values was estimated as follows: overall variability in d and R values was calculated using Median Absolute Deviations (MADs) for all available taxa in the original Pitcher et al. (2017) data, then weighted mean values of d and R for all available taxa were sampled using the uncertainty provided by the MADs, with n=24 000, to estimate the distribution of d/R ratios across all taxa. The mean of the relative MAD values for each taxon (MAD/weighted mean) were then calculated, weighted by number of data points available for each group and these, when halved, provide a range of d/R ratios that approximately covers the inter-quartile range of the full sampling of sensitivities – so that a sensible range of values is d ±0.443/2 = ±0.2215 R ±0.507/2 = ±0.2535. This provides low and high values of d and R that can be used to produce appropriate pessimistic and optimistic estimates of naturalness.

Three different approaches to assessing taxon-specific naturalness within fished areas of SPRFMO were considered:

1. **Mormede-Sharp-Roux-Parker (MSRP)** (Mormede et al. 2017). This method calculates an impact index, a measure of what proportion of vulnerable benthic taxa are damaged or destroyed by contact with bottom fishing gear, within individual grid cells. The footprint of each individual tow is segmented, and segments are assigned to grid cells based on the location of their midpoint. The cumulative footprint is estimated for individual cells assuming random overlap between segments, and the proportion of each cell contacted is determined. Taxon-specific depletion values are used to estimate the proportion of benthic taxa that are damaged or destroyed per cell based on both the fragility of the organism and the proportion of the cell contacted. This method does not allow for any recovery over time, so will under-estimate current naturalness.

2. **Relative benthic status (RBS)** (Pitcher et al. 2017). This method estimates the status of benthos using the formula for the equilibrium of the Schaefer (1954) population model and requires grids of total fishing effort (as Swept Area Ratios (SAR), essentially total annual footprints combined without assuming any overlap), depletion rates as in the MSRP method, and taxon-specific recovery rates. This method accounts for future impacts as well as past impacts, so may under-estimate current naturalness in some areas.

3. **Schaefer ("S30")**. This is a similar approach to RBS in that it takes into account both depletion and recovery, but is based directly on the Schaefer (1954) stock production model, with status being calculated iteratively, by year. Depletion (d), recovery (R) and average annual SAR are applied iteratively for the 30 years of recorded fishing, so that future impacts are not included. Status after 30 years estimates current-day naturalness, although there may be underestimation of naturalness if fishing intensity was greater in the early part of the 30-year time period than in more recent years.

The "S30" method was selected over MSRP and RBS as it was considered to best represent current-day naturalness, taking into account both depletion and recovery. Naturalness is presented as the relative status of the taxon in each cell, with a value of zero meaning complete depletion of the taxon and a value of 1 meaning no depletion of the taxon. Estimates of naturalness for the two sponge taxa are identical as they were assumed to have the same d and R values, and the same is true for the four stony coral taxa. These taxa are used to illustrate the variability in naturalness among the ten VME indicator taxa of interest, as they represent those with the most extreme d and R values (the corals being more vulnerable and the sponges less vulnerable), and between the pessimistic and optimistic d and R sensitivities (Figure 57). In the optimistic case for sponge taxa, the Challenger Plateau region is strongly dominated by values near to 1, indicating a high level of naturalness, with just small areas of more intensely fished cells where naturalness values are closer to zero. Conversely, in the pessimistic case for stony corals, naturalness over a large region of the Challenger Plateau fishery area is 0.4 or lower, with areas of high naturalness restricted to the margins of the area where fishing intensity is lowest.

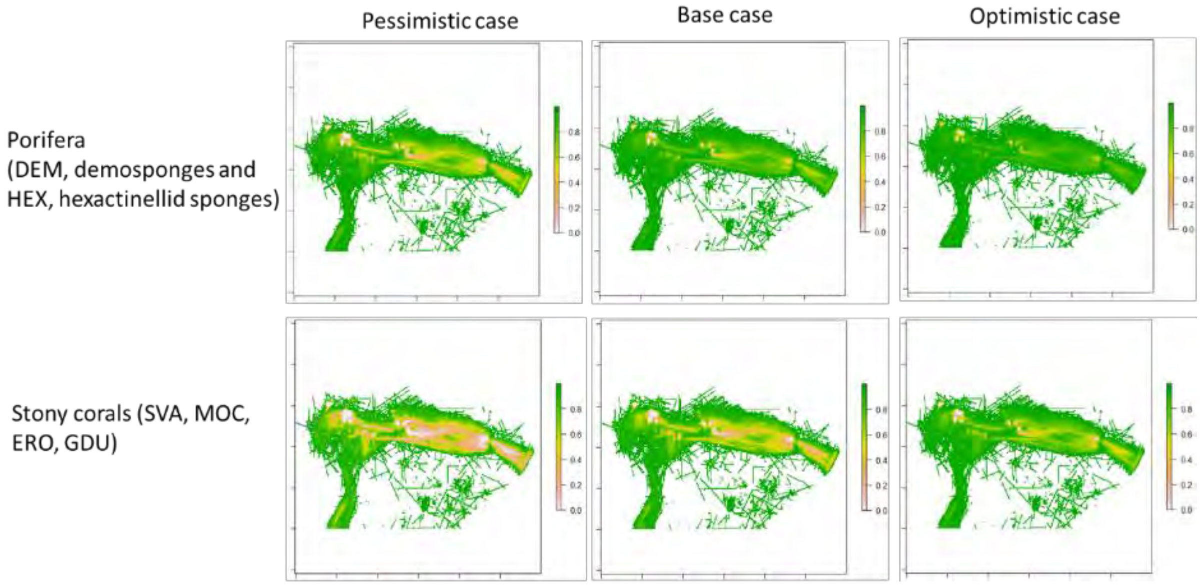

Figure 57: The representation of the current status of taxa after the effects of all historical trawling (i.e., 'naturalness estimated by "S30" for Demosponges/Hexactinellid sponges (top) and stony corals (*Madrepora oculata*/*Solenosmilia variabilis*/*Goniocorella dumosa*/*Enallopsammia rostrata*) (bottom) for the Challanger Plateau area within the Evaluated Area. Plots on the left are the result of the more pessimistic d and R values, plots in the middle column are for the base estimates of d and R, and the right-hand plots are for the most optimistic estimates of d and R (see Table 28).

4.5.3 Future state of impacted taxa

RBS is quantitative method based on the Schaefer (1954)-type population model, as commonly used for stock assessments, with an additional term to describe the direct impacts of trawling on seabed benthos, consistent with previous dynamic-modelling approaches to seabed assessment (Ellis et al. 2014; Pitcher et al. 2015; Pitcher et al. 2017). To enable application to the typically data-limited circumstances of seabed assessment, RBS is a simpler approach, such that in habitats subject to chronic trawling, the long-term relative abundance of biota as a fraction of carrying capacity can be estimated by the equilibrium solution of the Schaefer model. Estimating RBS requires maps of fishing intensity and habitat distributions, and parameters for trawl impact and recovery rates (see Section 4.5.2). The status of trawled habitats and their RBS value depend on impact rate (depletion per trawl), recovery rate and exposure to trawling (Pitcher et al. 2017). Impact in RBS shares similarities with the Mormede et al. (2017) method, but also accounts for future trawling and recovery potential.

4.5.3.1 Methods

The status of VME indicator taxa was estimated using the quantitative RBS method (Pitcher et al. 2017). The equation for RBS is based on the equilibrium solution of the Schaefer model, such that in habitats subject to chronic trawling, the long-term relative abundance of biota (B), as a fraction of carrying capacity (K) is estimated by:

$$B/K = 1 - F\ D/R \text{ where } F<R/D\text{, otherwise } B/K=0$$

where B/K represents “relative benthic status” (RBS) of the seabed in the range 0–1, R is the proportional recovery rate per year, which varies according to taxa, D is the depletion rate per trawl, which depends on gear-type and taxa, and F is trawling intensity as swept-area ratio (SAR: the annual total area swept by trawl gear within a given grid-cell of seabed, divided by the area of that grid-cell). The ratio D/R represents sensitivity to trawling—the time interval between trawls (years) that would cause local extinction of the biota (RBS=0)—and R/D is the corresponding critical annual trawl intensity F at which a given sensitivity will have RBS=0 (Fcrit). For RBS, SAR should be determined for grid cells of size ~1×1 km; a scale at which the distribution of most individual trawls has been shown to be random (although this may not hold for the highly targeted fishing on some features).

The assessment of absolute status for benthic biota requires information on distributions of abundance because different taxa may have different initial un-trawled abundance distributions and different exposure to trawling. Hence, absolute status will differ from relative status. To provide an absolute status assessment, the SPRFMO predicted HSI distributions (Section 4.4.2.2) were used with various adjustments for uncertainty (sections 4.4.2.2 and 4.5.2 and relationships between observed abundance and predicted HSI (section 4.8.3.1). Absolute status (*B*) was estimated by multiplying the predicted grid-cell distribution profiles (*K*) by the respective grid-cell RBS (i.e., *B*/*K*) for each taxon (i.e., *B*=*K*×*B*/*K*). The ‘absolute’ region-wide status was estimated by the sum of grid-cell *B* values and dividing by the sum of grid-cell *K* values, thus providing a status estimate in the range 0–1 that indicates the remaining proportion of total initial abundance in the assessed region.

As with the post-accounting estimates of the performance of spatial measures (Section 4.6.5), there are many possible permutations for the RBS. In this case, the following combinations were estimated:

1. Three fishing effort scenarios: historical; recent/current; future
2. 10 VME indicator taxa
3. Taxa distribution adjustments:
   a) ROC 0-linear thresholded HSI (section 4.6.7) (i.e., HSI=0 below ROC threshold for suitable habitat) and CV down-weighted;

b) Power_mean transformed HSI (Table 44 in section 4.8.3.1) (i.e., assuming a power relationship

4. Taxa sensitivity (depletion/Recovery): low-, mean- and high- range Sensitivity (Table 28 in section 4.5.2)
5. Reporting areas: FMAs with no trawling effort allowed outside BTMAs as implemented under CMM03-2023 and as proposed for the 70% scenario presented in COMM10-Inf3.

The historical fishing effort scenario used the historical effort as annual average swept-area ratio by grid-cell for bottom trawl and for longline (see Section 4.5.1).

The recent/current fishing effort scenario adjusted the historical average to recent stanzas of effort for trawl (2010-2019, about half the historical average overall) and for long-line (2013-2019, about double) (see Figure 58) as well as confining trawl effort to within the spatial BTMAs. In practice, the change in trawl effort over time has differed between the Tasman Sea and the Louisville Seamount Chain and the 2010-2019 average annual SAR for the Tasman and LSC (912.1 km² and 35.1 km² respectively) was used to scale the recent/current trawl effort within BTMAs. For 2013-2019, the average number of long-line operations has been 320 per year with a footprint of 0.026 km² per operation, giving an annual SAR of 8.4 km². Trawl effort (within BTMAs) and long-line effort were retained within previously fished cells. The South Tasman Rise is currently closed (since 2007) and received no trawl effort in the recent/current fishing effort scenario.

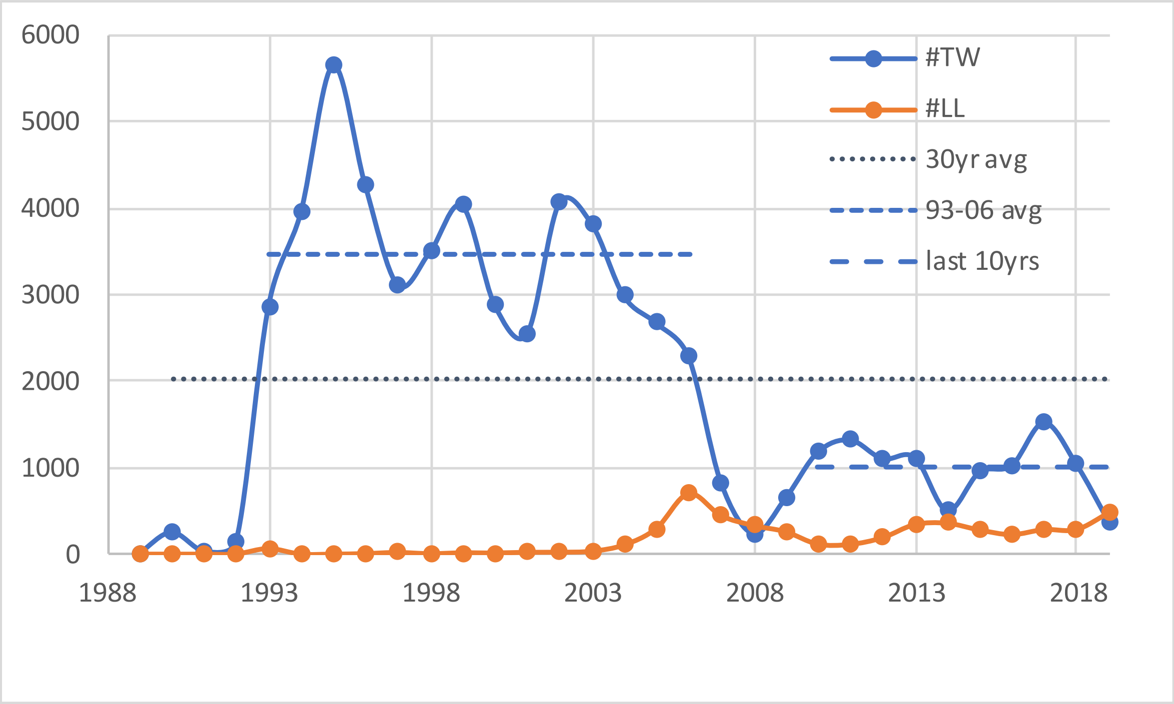

Figure 58: Annual numbers of bottom trawl (TW) and long-line (LL) operations in SPRFMO.

The future fishing effort scenario considered the limits imposed by CMM03-2021 and the mean long-term yields derived from recent orange roughy stock assessments, which are catch limits rather than effort limits. Where the recent catch history is greater than catch limits, it was assumed that effort must reduce going forward so that catch meets the limits (assuming the catch limits and catch rates in the fishery do not change). However, where the recent catch history is less than catch limits, future effort is not constrained from increasing to catch that limit. To fully understand the ongoing risks to VMEs, the future scenario should explore the limit of effort permitted under current management, recognizing that there has been a subsequent reduction in catch limits, as implemented in CMM03-2023. The future effort adjustments are given in Table 29; the inverse of the 'under-catch' ratio is the future-effort adjustment relative to the recent/current scenario. For the future scenarios, trawl effort for the Tasman Sea, Westpac Bank and LSC were scaled separately. For the South Tasman Rise, which is currently closed but could be re-opened, the future effort was downscaled from historical effort based on the recent/historical ratio for the entire Tasman. Future trawl effort (within BTMAs) and long-line effort were retained within previously fished cells only.

It should be noted that in the reduced effort scenarios, RBS will estimate the ultimate equilibrium status. This means any previously trawled areas that are trawled with less effort will be assumed to recover to a higher status, and areas now closed will be assumed to recover completely. However, where there have been substantial historical impacts, recovery will take a very long time (up to many decades to centuries) for most taxa to recover from the historical impacts to the RBS levels indicated in such scenarios.

Table 29: Approximation of recent annual trawl catches (t) for the Tasman Sea (excluding Westpac Bank), Westpac Bank, and Louisville Seamount Chain and total regional catches for longline with current catch limits or mean long term yields estimated by recent orange roughy stock assessments. The hypothetical under-catch is indicated by recent average annual catch divided by the catch limit in CMM03-2021 or mean long term yield estimated by recent stock assessments. Note that catch totals for the Tasman Sea may contain relatively small amounts of species other than orange roughy but that exclusion of these catches would not substantially change the hypothetical under-catch ratio.

Year	Tasman	Westpac	LSC	Longline
2010	879	5	584	
2011	852	5	285	
2012	681	8	288	
2013	732	3	565	257
2014	236	54	758	198
2015	732	118	462	303
2016	732	234	73	272
2017	642	129	420	280
2018	584	569	81	194
2019	257	111	139	256
Average	632.7	123.6	365.5	251.4
Catch limit or yield estimate	852	258	1140	973
Under-catch	0.743	0.479	0.321	0.258

4.5.3.2 Results

The status of fished habitats depends on their depletion (d) rate, recovery (R) rate and exposure to fishing and its intensity. Rates for d and R are taxon-specific and are given for 10 assessed taxa in Table 28. Trawl depletion rates are highest for fragile stony corals such as *Goniocorella dumosa, Madrepora oculate, Enallopsammia rostrata* and *Solenosmilla variabilis* (d=0.67, range 0.52-0.82) and lowest for Demospongaie and Hexactinellida (d=0.38, range 0.30-0.46), Gorgonian Alcyonacea (d=0.35, range 0.27-0.43) and Pennatulacea (d=0.34, range 0.26-0.42). Recovery rates vary but are lowest for stony corals such as (R=0.2, range 0.15-0.25).

SPRFMO does not have agreed reference points for VME indicator taxa and/or habitats so interpretation of RBS results can only be done qualitatively until such a time as the current work programme defining reference points for SAIs is completed, or unless reference points are borrowed from elsewhere. The assessment criteria given by the Marine Stewardship Council (MSC 2014) state that, in the case of VMEs [defined as per para. 42 of the FAO Deep-Sea Guidelines], "serious or irreversible harm" is to be interpreted as reductions in habitat structure and function below 80% of the unimpacted level. The threshold defined by MSC applies to the 'Unit of Assessment', which is often a fish stock.

The 2020 BFIA presented RBS results at 3 different spatial scales: the whole SPRFMO Evaluated Area; orange roughy FMAs; and BTMAs (areas open to bottom trawling) within FMAs. Since the 2020 BFIA was submitted, the Commission has directed the Scientific Committee to adopt the Fishery Management Areas (Figure 56) as the appropriate scale of management for assessing the performance of spatial management areas (Para 39; CMM03-2023), and results are only presented at the scale of FMAs.

RBS results are presented for the ten VME indicator taxa analysed for each of nine orange roughy Fishery Management Areas (FMAs) in Tables Table 30 - Table 38. The RBS results are given for three fishing effort scenarios for the BTMAs implemented in CMM03-2023 (future, current and historical, noting however that these are unchanged since the 2020 BFIA, such that 'current' refers to the ten-year period ending in 2019, and 'future' assumes that effort levels will increase; both scenarios will over-estimate impacts and underestimate RBS in FMAs where catch limits were subsequently reduced). For the BTMAs proposed to be implemented in 2024, as described in COMM10-Inf03, RBS results are given for the future effort scenario only. The fishing effort scenarios and abundance sensitivities are described in the previous section.

Overall, the results for the BTMAs implemented under CMM03-2023 generally show that RBS exceeds 95% for most combinations of taxa, FMA and sensitivity. However, there are some exceptions to this, as follows:

- For the **North Lord Howe FMA**, RBS was between 0.8 and 0.95 for the stony coral *Goniocorella dumosa* for most sensitivities using the ROC-linear assessment. For Stylasteridae, RBS was lower than 0.9 for most sensitivities using the ROC-linear assessment (Table 30).
- For the **Central Lord Howe FMA**, RBS was lower than 0.8 for Stylasteridae for most sensitivities (Table 31).
- For the **Northwest Challenger FMA**, RBS was lower than 0.95 for most sensitivities for the stony corals *Enallopsammia rostrata* and *Madrepora oculata*, and the black corals Antipatharia (Table 32).
- For the **Westpac Bank FMA**, RBS was between 0.8 and 0.95 for several sensitivities for Stylasteridae under ROC-linear historic and future fishing sensitivities (Table 33).
- For the **West Norfolk FMA**, RBS was lower than 0.95 for the stony coral *Goniocorella dumosa* under the ROC-linear high sensitivity historic fishing sensitivity (Table 34).
- For the **North Louisville FMA**, RBS was between 0.7 and 0.9 for the Power-mean historic fishing sensitivities for Demospongiae, and less than 0.95 for the historic fishing high sensitivities for the stony coral *Solenosmilia variabilis* (Table 36).
- For the **Central Louisville FMA**, RBS was lower than 0.95 for some sensitivities for Demospongiae, Antipatharia and Stylasteridae, and most sensitivities for the stony corals *Goniocorella dumosa* and *Solenosmillia variabilis* (Table 37).

- For the **South Louisville FMA**, RBS was lower than 0.95 for some historic sensitivities for *Enallopsamia rostrata*, *Goniocorella dumosa* and *Solenosmillia variabilis* (Table 38).
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Similarly, the results for the BTMAs proposed to be implemented in 2024 also generally show that RBS exceeds 95% for most combinations of taxa, FMA and sensitivity for future fishing effort. However, again there are some exceptions to this, as follows:

- For the **North Lord Howe FMA**, RBS was between 0.8 and 0.95 for the stony coral *Goniocorella dumosa* under all the ROC-linear sensitivities, and less than 0.85 for Stylasteridae for all ROC-linear sensitivities (Table 30).
- For the **Central Lord Howe FMA**, RBS was less than 0.8 for Stylasteridae for all sensitivities (Table 31).
- For the **Northwest Challenger FMA**, RBS was less than 0.95 for the stony coral *Enallopsammia rostrata* for all sensitivities, for the medium and high sensitivities for *Madrepora oculata*, and for the medium and high ROC-linear and high Power_mean sensitivities for Antipatharia (Table 32).
- For the **Westpac Bank FMA**< RBS was lower than 0.95 for the ROC-linear median and high sensitivities (Table 33).
- For the **North Louisville FMA**, RBS was lower than 0.95 for Demospongiae for the Power_mean high sensitivity (Table 36).
- For the **Central Louisville FMA**, RBS was lower than 0.95 for the stony coral *Goniocorella dumosa* for most of the sensitivities, and the Power_mean median and high sensitivities for *Solenosmillia variabilis* (Table 37).

Table 30: Low, mean, and high RBS assessment results for the North Lord Howe FMA using BTMAs implemented under CMM03-2023 and BTMAs proposed for implementation in 2024 to meet a minimum level of 70% protection, as described in COMM10-Inf03. Green, yellow and orange cells indicate RBS values < 0.95, 0.9 and 0.8, respectively.

		CMM03-2023 BTMAs						70% protection BTMAs	
		Historic		Current		Future		Future	
VME Indicator Taxa habitat		ROC-linear	Power mean	ROC-linear	Power mean	ROC-linear	Power mean	ROC-linear	Power mean
Sponges (Porifera Demospongiae)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sponges (Porifera Hexactinellida)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Stony corals (*Enallopsammia rostrata*)	Low	0.999	1.000	1.000	1.000	0.999	1.000	0.999	1.000
	Median	0.999	1.000	0.999	1.000	0.999	1.000	0.998	0.999
	High	0.998	0.999	0.999	1.000	0.999	1.000	0.997	0.999
Stony corals (*Goniocorella dumosa*)	Low	0.949	0.998	0.968	0.999	0.964	0.999	0.930	0.998
	Median	0.917	0.997	0.948	0.999	0.941	0.998	0.888	0.997
	High	0.865	0.995	0.916	0.998	0.904	0.998	0.816	0.996
Stony corals (*Madrepora oculata*)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	0.999	1.000	1.000	1.000	1.000	1.000	0.999
Stony corals (*Solenosmilia variabilis*)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Black corals (Antipatharia)	Low	0.998	0.997	0.999	0.999	0.999	0.998	0.998	0.997
	Median	0.996	0.995	0.998	0.998	0.998	0.997	0.997	0.995
	High	0.994	0.993	0.997	0.996	0.997	0.996	0.995	0.994
Gorgonians (Gorgonian Alcyonacea)	Low	0.998	0.994	0.999	0.997	0.999	0.997	0.998	0.994
	Median	0.997	0.991	0.999	0.996	0.998	0.995	0.997	0.991
	High	0.995	0.986	0.998	0.993	0.997	0.992	0.996	0.988
Sea pens (Pennatulacea)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	0.999	1.000	1.000	1.000	1.000	1.000	0.999	1.000
	High	0.999	1.000	0.999	1.000	0.999	1.000	0.999	1.000
Hydrocorals (Stylasteridae)	Low	0.888	0.990	0.930	0.994	0.921	0.993	0.849	0.987
	Median	0.822	0.984	0.889	0.991	0.875	0.990	0.759	0.980

	High	0.713	0.974	0.821	0.985	0.799	0.983	0.612	0.968

Table 31: Low, mean, and high RBS assessment results for the Central Lord Howe FMA using BTMAs implemented under CMM03-2023 and BTMAs proposed for implementation in 2024 to meet a minimum level of 70% protection, as described in COMM10-Inf03. Yellow and orange cells indicate RBS values < 0.9 and 0.8, respectively.

		CMM03-2023 BTMAs						70% protection BTMAs	
		Historic		Current		Future		Future	
VME Indicator Taxa habitat		**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**
Sponges (Porifera Demospongiae)	Low	0.999	0.994	1.000	0.996	0.999	0.996	0.999	0.992
	Median	0.999	0.990	0.999	0.994	0.999	0.993	0.999	0.990
	High	0.999	0.990	0.999	0.990	0.999	0.990	0.998	0.990
Sponges (Porifera Hexactinellida)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Stony corals (*Enallopsammia rostrata*)	Low	0.985	0.986	0.991	0.991	0.990	0.990	0.983	0.984
	Median	0.979	0.979	0.986	0.987	0.985	0.986	0.977	0.978
	High	0.970	0.970	0.980	0.981	0.978	0.979	0.968	0.969
Stony corals (*Goniocorella dumosa*)	Low	0.986	0.991	0.991	0.994	0.990	0.994	0.989	0.990
	Median	0.982	0.986	0.987	0.991	0.986	0.991	0.987	0.986
	High	0.976	0.981	0.983	0.988	0.982	0.986	0.985	0.980
Stony corals (*Madrepora oculata*)	Low	0.983	0.985	0.989	0.990	0.988	0.989	0.980	0.983
	Median	0.976	0.979	0.984	0.986	0.982	0.985	0.972	0.976
	High	0.967	0.971	0.977	0.980	0.975	0.979	0.963	0.967
Stony corals (*Solenosmilia variabilis*)	Low	0.981	0.995	0.987	0.997	0.986	0.996	0.977	0.993
	Median	0.974	0.992	0.981	0.995	0.979	0.994	0.969	0.990
	High	0.966	0.988	0.974	0.992	0.972	0.991	0.961	0.984
Black corals (Antipatharia)	Low	0.992	0.991	0.996	0.994	0.995	0.994	0.991	0.989
	Median	0.988	0.985	0.993	0.991	0.992	0.990	0.986	0.983
	High	0.982	0.978	0.989	0.986	0.988	0.984	0.980	0.976
Gorgonians (Gorgonian Alcyonacea)	Low	0.990	0.984	0.994	0.990	0.993	0.989	0.988	0.981
	Median	0.984	0.974	0.990	0.984	0.989	0.982	0.982	0.972
	High	0.977	0.962	0.985	0.975	0.983	0.972	0.974	0.961
Sea pens (Pennatulacea)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hydrocorals (Stylasteridae)	Low	0.620	0.819	0.762	0.887	0.733	0.873	0.485	0.756
	Median	0.394	0.713	0.622	0.820	0.575	0.798	0.224	0.625
	High	0.153	0.589	0.391	0.711	0.315	0.675	0.057	0.538

Table 32: Low, mean, and high RBS assessment results for the Northwest Challenger FMA using BTMAs implemented under CMM03-2023 and BTMAs proposed for implementation in 2024 to meet a minimum level of 70% protection, as described in COMM10-Inf03. Green, yellow and orange cells indicate RBS values < 0.95, 0.9 and 0.8, respectively.

		CMM03-2023 BTMAs						70% protection BTMAs	
		Historic		Current		Future		Future	
VME Indicator Taxa habitat		**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**
Sponges (Porifera Demospongiae)	Low	0.997	0.996	0.998	0.997	0.998	0.997	0.999	1.000
	Median	0.995	0.994	0.997	0.996	0.997	0.995	0.999	1.000
	High	0.993	0.990	0.996	0.994	0.995	0.992	0.999	0.999
Sponges (Porifera Hexactinellida)	Low	0.975	0.975	0.984	0.985	0.983	0.983	0.988	0.987
	Median	0.961	0.961	0.975	0.976	0.972	0.973	0.982	0.979
	High	0.937	0.937	0.960	0.961	0.956	0.956	0.972	0.966
Stony corals (*Enallopsammia rostrata*)	Low	0.912	0.926	0.944	0.951	0.937	0.946	0.945	0.943
	Median	0.866	0.890	0.913	0.927	0.904	0.919	0.921	0.922
	High	0.796	0.838	0.866	0.891	0.851	0.880	0.891	0.896
Stony corals (*Goniocorella dumosa*)	Low	0.989	0.970	0.994	0.982	0.993	0.979	0.992	0.983
	Median	0.984	0.954	0.991	0.971	0.990	0.968	0.989	0.976
	High	0.976	0.930	0.986	0.955	0.985	0.950	0.986	0.966
Stony corals (*Madrepora oculata*)	Low	0.940	0.946	0.961	0.963	0.957	0.960	0.962	0.961
	Median	0.911	0.922	0.941	0.947	0.935	0.942	0.948	0.948
	High	0.866	0.887	0.912	0.923	0.903	0.916	0.929	0.932
Stony corals (*Solenosmilia variabilis*)	Low	0.998	1.000	0.999	1.000	0.999	1.000	1.000	1.000
	Median	0.997	1.000	0.999	1.000	0.999	1.000	1.000	1.000
	High	0.996	1.000	0.998	1.000	0.998	1.000	1.000	1.000

Black corals (Antipatharia)	Low	0.949	0.955	0.968	0.972	0.964	0.969	0.965	0.967
	Median	0.921	0.931	0.950	0.956	0.944	0.951	0.947	0.950
	High	0.877	0.894	0.921	0.932	0.912	0.924	0.922	0.927
Gorgonians (Gorgonian Alcyonacea)	Low	0.981	0.981	0.988	0.989	0.987	0.987	0.984	0.985
	Median	0.971	0.971	0.982	0.982	0.979	0.980	0.977	0.978
	High	0.955	0.955	0.971	0.972	0.968	0.969	0.967	0.969
Sea pens (Pennatulacea)	Low	0.996	1.000	0.997	1.000	0.997	1.000	0.999	1.000
	Median	0.993	1.000	0.996	1.000	0.995	1.000	0.998	1.000
	High	0.988	1.000	0.993	1.000	0.992	1.000	0.996	1.000
Hydrocorals (Stylasteridae)	Low	0.992	0.990	0.998	0.999	0.997	0.998	0.995	0.997
	Median	0.988	0.985	0.996	0.998	0.996	0.997	0.994	0.996
	High	0.982	0.976	0.995	0.997	0.994	0.996	0.992	0.995

Table 33: Low, mean, and high RBS assessment results for the Westpac Bank FMA using BTMAs implemented under CMM03-2023 and BTMAs proposed for implementation in 2024 to meet a minimum level of 70% protection, as described in COMM10-Inf03. Green and yellow cells indicate RBS values < 0.95 and 0.9, respectively.

		CMM03-2023 BTMAs						70% protection BTMAs	
		Historic		Current		Future		Future	
VME Indicator Taxa habitat		**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**
Sponges (Porifera Demospongiae)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sponges (Porifera Hexactinellida)	Low	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000
	Median	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000
	High	0.998	0.997	1.000	1.000	1.000	1.000	1.000	1.000
Stony corals (*Enallopsammia rostrata*)	Low	0.993	0.994	0.996	0.997	0.993	0.994	0.993	0.994
	Median	0.989	0.991	0.994	0.996	0.989	0.991	0.989	0.991
	High	0.983	0.986	0.991	0.993	0.984	0.987	0.984	0.987
Stony corals (*Goniocorella dumosa*)	Low	0.997	0.994	0.998	0.997	0.997	0.993	0.997	0.993
	Median	0.995	0.991	0.998	0.995	0.995	0.991	0.995	0.991
	High	0.992	0.986	0.996	0.992	0.992	0.987	0.992	0.987
Stony corals (*Madrepora oculata*)	Low	0.995	0.996	0.998	0.998	0.995	0.996	0.995	0.996
	Median	0.992	0.993	0.996	0.997	0.993	0.994	0.993	0.994
	High	0.988	0.989	0.994	0.996	0.989	0.991	0.989	0.991
Stony corals (*Solenosmilia variabilis*)	Low	0.989	0.999	0.993	1.000	0.987	1.000	0.987	1.000
	Median	0.984	0.998	0.989	1.000	0.981	0.999	0.981	0.999
	High	0.977	0.997	0.984	1.000	0.974	0.999	0.974	0.999
Black corals (Antipatharia)	Low	0.993	0.991	0.996	0.995	0.992	0.989	0.992	0.989
	Median	0.990	0.986	0.994	0.992	0.988	0.983	0.988	0.983
	High	0.984	0.978	0.990	0.986	0.983	0.975	0.983	0.975
Gorgonians (Gorgonian Alcyonacea)	Low	0.995	0.986	0.997	0.992	0.994	0.982	0.994	0.982
	Median	0.992	0.978	0.995	0.986	0.991	0.975	0.991	0.975
	High	0.988	0.969	0.993	0.978	0.988	0.966	0.988	0.966
Sea pens (Pennatulacea)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hydrocorals (Stylasteridae)	Low	0.970	0.985	0.981	0.990	0.961	0.980	0.961	0.980
	Median	0.952	0.975	0.970	0.985	0.937	0.968	0.937	0.968
	High	0.923	0.961	0.952	0.975	0.899	0.950	0.899	0.950

Table 34: Low, mean, and high RBS assessment results for the West Norfolk FMA using BTMAs implemented under CMM03-2023 and BTMAs proposed for implementation in 2024 to meet a minimum level of 70% protection, as described in COMM10-Inf03. Green cells indicate RBS values < 0.95.

		CMM03-2023 BTMAs						70% protection BTMAs	
		Historic		Current		Future		Future	
VME Indicator Taxa habitat		**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**
Sponges (Porifera Demospongiae)	Low	1.000	0.999	1.000	1.000	1.000	0.999	1.000	0.999
	Median	1.000	0.998	1.000	1.000	1.000	0.998	1.000	0.998
	High	1.000	0.997	1.000	0.999	1.000	0.997	1.000	0.997
Sponges (Porifera Hexactinellida)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Stony corals (*Enallopsammia rostrata*)	Low	0.989	0.991	0.993	0.995	0.992	0.994	0.994	0.993
	Median	0.982	0.986	0.989	0.992	0.988	0.991	0.990	0.989

	High	0.972	0.978	0.983	0.987	0.981	0.985	0.984	0.982
Stony corals (*Goniocorella dumosa*)	Low	0.972	0.996	0.983	0.998	0.981	0.998	0.981	0.998
	Median	0.956	0.994	0.973	0.997	0.969	0.996	0.969	0.997
	High	0.928	0.991	0.956	0.995	0.950	0.994	0.951	0.995
Stony corals (*Madrepora oculata*)	Low	0.997	0.997	0.998	0.998	0.998	0.998	0.998	0.998
	Median	0.994	0.994	0.997	0.997	0.997	0.997	0.997	0.997
	High	0.991	0.991	0.995	0.995	0.995	0.995	0.995	0.995
Stony corals (*Solenosmilia variabilis*)	Low	0.998	1.000	0.999	1.000	0.999	1.000	0.998	1.000
	Median	0.996	1.000	0.998	1.000	0.998	1.000	0.997	1.000
	High	0.994	1.000	0.997	1.000	0.996	1.000	0.995	1.000
Black corals (Antipatharia)	Low	0.998	0.997	0.999	0.998	0.998	0.998	0.998	0.998
	Median	0.997	0.995	0.998	0.997	0.997	0.997	0.997	0.997
	High	0.994	0.993	0.997	0.996	0.996	0.995	0.996	0.995
Gorgonians (Gorgonian Alcyonacea)	Low	0.998	0.994	0.999	0.997	0.999	0.996	0.998	0.996
	Median	0.997	0.991	0.998	0.994	0.998	0.994	0.997	0.994
	High	0.995	0.985	0.997	0.991	0.997	0.989	0.995	0.990
Sea pens (Pennatulacea)	Low	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	0.998	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	0.997	1.000
Hydrocorals (Stylasteridae)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000
	High	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000

Table 35: Low, mean, and high RBS assessment results for the South Tasman Rise FMA using BTMAs implemented under CMM03-2023 and BTMAs proposed for implementation in 2024 to meet a minimum level of 70% protection, as described in COMM10-Inf03. All cell values are > 0.95.

		CMM03-2023 BTMAs						**70% protection BTMAs**	
		Historic		**Current**		**Future**		**Future**	
VME Indicator Taxa habitat		**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**
Sponges (Porifera Demospongiae)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sponges (Porifera Hexactinellida)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Stony corals (*Enallopsammia rostrata*)	Low	0.989	0.988	1.000	1.000	0.993	0.994	0.993	0.994
	Median	0.984	0.982	1.000	1.000	0.991	0.991	0.991	0.991
	High	0.978	0.973	1.000	1.000	0.987	0.986	0.987	0.986
Stony corals (*Goniocorella dumosa*)	Low	0.997	0.998	1.000	1.000	1.000	0.999	1.000	0.999
	Median	0.996	0.998	1.000	1.000	1.000	0.999	1.000	0.999
	High	0.993	0.996	1.000	1.000	1.000	0.998	1.000	0.998
Stony corals (*Madrepora oculata*)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000
	High	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000
Stony corals (*Solenosmilia variabilis*)	Low	0.996	1.000	1.000	1.000	0.997	1.000	0.997	1.000
	Median	0.994	1.000	1.000	1.000	0.996	1.000	0.996	1.000
	High	0.992	1.000	1.000	1.000	0.995	1.000	0.995	1.000
Black corals (Antipatharia)	Low	0.986	0.995	1.000	1.000	0.992	0.997	0.992	0.997
	Median	0.981	0.993	1.000	1.000	0.988	0.996	0.988	0.996
	High	0.974	0.990	1.000	1.000	0.982	0.994	0.982	0.994
Gorgonians (Gorgonian Alcyonacea)	Low	0.999	0.998	1.000	1.000	0.999	0.999	0.999	0.999
	Median	0.999	0.998	1.000	1.000	0.999	0.998	0.999	0.998
	High	0.998	0.997	1.000	1.000	0.999	0.998	0.999	0.998
Sea pens (Pennatulacea)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hydrocorals (Stylasteridae)	Low	0.998	0.997	1.000	1.000	0.999	0.998	0.999	0.998
	Median	0.997	0.996	1.000	1.000	0.998	0.998	0.998	0.998
	High	0.996	0.995	1.000	1.000	0.998	0.996	0.998	0.996

Table 36: Low, mean, and high RBS assessment results for the North Louisville FMA using BTMAs implemented under CMM03-2023 and BTMAs proposed for implementation in 2024 to meet a minimum level of 70% protection, as described in COMM10-Inf03. Green, yellow and orange cells indicate RBS values < 0.95, 0.9 and 0.8, respectively.

		CMM03-2023 BTMAs						**70% protection BTMAs**	
		Historic		**Current**		**Future**		**Future**	

VME Indicator Taxa habitat		ROC-linear	Power mean	ROC-linear	Power mean	ROC-linear	Power mean	ROC-linear	Power mean
Sponges (Porifera Demospongiae)	Low	0.985	0.872	0.999	0.996	0.997	0.988	0.994	0.972
	Median	0.977	0.797	0.999	0.994	0.996	0.981	0.990	0.956
	High	0.965	0.749	0.998	0.990	0.993	0.969	0.985	0.930
Sponges (Porifera Hexactinellida)	Low	0.997	0.999	1.000	1.000	0.999	1.000	0.998	1.000
	Median	0.995	0.998	1.000	1.000	0.999	1.000	0.997	0.999
	High	0.992	0.997	0.999	1.000	0.998	1.000	0.996	0.999
Stony corals (*Enallopsammia rostrata*)	Low	NaN	0.981	NaN	0.999	NaN	0.997	NaN	0.994
	Median	NaN	0.971	NaN	0.999	NaN	0.996	NaN	0.991
	High	NaN	0.955	NaN	0.998	NaN	0.993	NaN	0.985
Stony corals (*Goniocorella dumosa*)	Low	0.986	0.985	0.998	0.999	0.994	0.996	0.988	0.992
	Median	0.980	0.978	0.997	0.998	0.991	0.994	0.983	0.988
	High	0.969	0.967	0.995	0.997	0.987	0.991	0.975	0.983
Stony corals (*Madrepora oculata*)	Low	0.999	0.998	1.000	1.000	0.999	0.999	0.999	0.998
	Median	0.998	0.996	1.000	0.999	0.999	0.998	0.998	0.996
	High	0.997	0.994	1.000	0.999	0.999	0.997	0.997	0.994
Stony corals (*Solenosmilia variabilis*)	Low	0.973	0.971	0.998	0.998	0.994	0.992	0.986	0.983
	Median	0.959	0.954	0.997	0.996	0.990	0.988	0.979	0.973
	High	0.940	0.932	0.995	0.994	0.984	0.980	0.970	0.963
Black corals (Antipatharia)	Low	0.988	0.989	0.999	0.999	0.997	0.997	0.993	0.993
	Median	0.981	0.982	0.998	0.998	0.995	0.995	0.990	0.989
	High	0.970	0.972	0.998	0.998	0.992	0.992	0.984	0.984
Gorgonians (Gorgonian Alcyonacea)	Low	0.991	0.990	1.000	1.000	0.999	0.999	0.997	0.997
	Median	0.985	0.985	0.999	0.999	0.998	0.998	0.995	0.996
	High	0.976	0.976	0.999	0.999	0.996	0.997	0.992	0.994
Sea pens (Pennatulacea)	Low	0.998	0.999	1.000	1.000	1.000	1.000	0.999	1.000
	Median	0.997	0.999	1.000	1.000	0.999	1.000	0.999	1.000
	High	0.994	0.999	1.000	1.000	0.999	1.000	0.998	1.000
Hydrocorals (Stylasteridae)	Low	0.987	0.983	0.999	0.999	0.997	0.997	0.994	0.993
	Median	0.979	0.974	0.999	0.998	0.995	0.995	0.990	0.988
	High	0.967	0.958	0.998	0.997	0.993	0.992	0.984	0.981

Table 37: Low, mean, and high RBS assessment results for the Central Louisville FMA using BTMAs implemented under CMM03-2023 and BTMAs proposed for implementation in 2024 to meet a minimum level of 70% protection, as described in COMM10-Inf03. Green, yellow and orange cells indicate RBS values < 0.95, 0.9 and 0.8, respectively.

		CMM03-2023 BTMAs						70% protection BTMAs	
		Historic		Current		Future		Future	
VME Indicator Taxa habitat		ROC-linear	Power mean	ROC-linear	Power mean	ROC-linear	Power mean	ROC-linear	Power mean
Sponges (Porifera Demospongiae)	Low	0.960	0.997	0.993	1.000	0.979	0.998	0.999	0.999
	Median	0.937	0.996	0.989	0.999	0.966	0.998	0.999	0.999
	High	0.907	0.993	0.982	0.999	0.945	0.996	0.999	0.999
Sponges (Porifera Hexactinellida)	Low	0.997	0.997	0.999	1.000	0.998	0.999	1.000	1.000
	Median	0.995	0.996	0.999	0.999	0.997	0.998	0.999	0.999
	High	0.992	0.993	0.999	0.999	0.995	0.997	0.999	0.999
Stony corals (*Enallopsammia rostrata*)	Low	0.993	0.977	0.999	0.996	0.996	0.986	0.992	0.993
	Median	0.989	0.969	0.998	0.993	0.994	0.980	0.987	0.988
	High	0.982	0.958	0.997	0.988	0.990	0.972	0.978	0.982
Stony corals (*Goniocorella dumosa*)	Low	0.903	0.945	0.982	0.990	0.945	0.969	0.942	0.971
	Median	0.862	0.922	0.972	0.984	0.916	0.953	0.918	0.959
	High	0.818	0.895	0.954	0.974	0.878	0.930	0.896	0.947
Stony corals (*Madrepora oculata*)	Low	0.998	0.994	1.000	0.999	0.999	0.997	0.998	0.997
	Median	0.996	0.991	0.999	0.998	0.998	0.995	0.997	0.995
	High	0.994	0.987	0.999	0.997	0.997	0.993	0.995	0.992
Stony corals (*Solenosmilia variabilis*)	Low	0.950	0.892	0.991	0.980	0.972	0.939	0.981	0.953
	Median	0.928	0.845	0.986	0.968	0.957	0.905	0.974	0.938
	High	0.903	0.792	0.977	0.948	0.936	0.859	0.966	0.924
Black corals (Antipatharia)	Low	0.967	0.966	0.994	0.994	0.983	0.982	0.989	0.990
	Median	0.948	0.947	0.991	0.991	0.972	0.971	0.982	0.984
	High	0.923	0.922	0.986	0.985	0.956	0.955	0.973	0.975
Gorgonians (Gorgonian Alcyonacea)	Low	0.987	0.985	0.998	0.997	0.993	0.992	0.996	0.995
	Median	0.979	0.976	0.996	0.996	0.989	0.987	0.994	0.991
	High	0.967	0.962	0.994	0.993	0.982	0.979	0.990	0.987
Sea pens (Pennatulacea)	Low	0.998	1.000	1.000	1.000	0.999	1.000	1.000	1.000
	Median	0.997	1.000	1.000	1.000	0.998	1.000	1.000	1.000
	High	0.995	0.999	0.999	1.000	0.997	1.000	1.000	1.000
Hydrocorals (Stylasteridae)	Low	0.971	0.969	0.995	0.995	0.984	0.983	1.000	1.000
	Median	0.954	0.952	0.992	0.992	0.975	0.974	1.000	1.000
	High	0.930	0.927	0.987	0.986	0.960	0.958	1.000	1.000

Table 38: Low, mean, and high RBS assessment results for the South Louisville FMA using BTMAs implemented under CMM03-2023 and BTMAs proposed for implementation in 2024 to meet a minimum level of 70% protection, as described in COMM10-Inf03. Green cells indicate RBS values < 0.95.

		CMM03-2023 BTMAs						70% protection BTMAs	
		Historic		Current		Future		Future	
VME Indicator Taxa habitat		**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**	**ROC-linear**	**Power mean**
Sponges (Porifera Demospongiae)	Low	0.994	0.999	0.999	1.000	0.997	0.999	1.000	1.000
	Median	0.991	0.998	0.998	1.000	0.995	0.999	1.000	1.000
	High	0.985	0.997	0.997	0.999	0.992	0.998	1.000	1.000
Sponges (Porifera Hexactinellida)	Low	0.999	0.999	1.000	1.000	0.999	0.999	1.000	1.000
	Median	0.998	0.998	1.000	1.000	0.999	0.999	1.000	1.000
	High	0.997	0.997	0.999	0.999	0.998	0.998	1.000	1.000
Stony corals (*Enallopsammia rostrata*)	Low	NaN	0.979	NaN	0.996	NaN	0.989	NaN	0.997
	Median	NaN	0.966	NaN	0.994	NaN	0.981	NaN	0.996
	High	NaN	0.945	NaN	0.990	NaN	0.970	NaN	0.993
Stony corals (*Goniocorella dumosa*)	Low	0.977	0.984	0.996	0.997	0.988	0.992	0.994	0.996
	Median	0.965	0.976	0.994	0.996	0.980	0.987	0.991	0.994
	High	0.948	0.965	0.990	0.993	0.970	0.980	0.985	0.990
Stony corals (*Madrepora oculata*)	Low	1.000	0.999	1.000	1.000	1.000	0.999	1.000	1.000
	Median	0.999	0.998	1.000	1.000	1.000	0.999	1.000	0.999
	High	0.999	0.997	1.000	0.999	0.999	0.998	1.000	0.999
Stony corals (*Solenosmilia variabilis*)	Low	0.984	0.967	0.997	0.995	0.991	0.983	0.995	0.997
	Median	0.974	0.948	0.996	0.991	0.986	0.972	0.993	0.995
	High	0.961	0.919	0.993	0.986	0.978	0.956	0.988	0.992
Black corals (Antipatharia)	Low	0.990	0.987	0.998	0.998	0.995	0.993	0.997	0.996
	Median	0.983	0.979	0.997	0.997	0.991	0.989	0.995	0.994
	High	0.974	0.967	0.996	0.994	0.986	0.982	0.992	0.990
Gorgonians (Gorgonian Alcyonacea)	Low	0.991	0.990	0.999	0.998	0.996	0.995	0.998	0.999
	Median	0.986	0.984	0.998	0.997	0.993	0.992	0.997	0.998
	High	0.978	0.974	0.996	0.996	0.989	0.986	0.996	0.997
Sea pens (Pennatulacea)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Median	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hydrocorals (Stylasteridae)	Low	0.994	0.995	0.999	0.999	0.997	0.997	1.000	1.000
	Median	0.991	0.991	0.998	0.999	0.995	0.995	1.000	1.000
	High	0.985	0.986	0.998	0.998	0.992	0.993	1.000	1.000

4.6 MITIGATION, MANAGEMENT AND MONITORING MEASURES

4.6.1 General approach to avoiding Significant Adverse Impacts on VMEs

The bottom fishing measure was designed to provide an assurance that bottom fishing within the Evaluated Area would not have SAIs on VMEs, taking into account the spatial extent of the impact relative to the availability of suitable habitat for VME indicator taxa. CMM 03-2023 is based on a spatial management approach adopted by the Commission in 2019 (based on the advice of the Scientific Committee – page 16 of the SC2 Report (2014), page 11 of the SC3 Report (2016). CMM03-2023 establishes a network of open Management Areas (differentiated by gear - bottom trawl, midwater trawl and bottom longlining) and closed areas within the Evaluated Area. The primary tools used in CMM03-2023 to protect VMEs are the closed areas and, within the areas open to trawl, a VME encounter protocol that is used as a backstop to complement the spatial closures. Bottom fishing is not allowed outside the open Management Areas, except as provided for by CMM 13-2020 for new and exploratory fisheries.

CMM 03-2023 is intended to work in conjunction with CMM 03a-2023 (Deepwater Species) to ensure the long-term conservation and sustainable use of deep sea fishery resources, including target fish stocks as well as non-target or associated and dependent species, and, in doing so, to safeguard the marine ecosystems in which these resources occur, including inter alia the prevention of SAIs on VMEs.

4.6.2 Design of Spatial Management Areas

The management areas within the Evaluated Area are established to protect large proportions of predicted suitable habitat for VME indicator taxa, while still permitting limited access for deepwater fisheries (bottom trawl, midwater trawl and bottom longlining), following advice from the Scientific Committee that management measures for bottom fisheries in the SPRFMO Convention Area should be based on a spatial management approach (SPRFMO 2017).

The open Management Areas and closed areas (within the Evaluated Area) were designed using an analytical and predictive modelling approach applied within the Zonation decision-support software (Figure). The Scientific Committee agreed that the analytical approach to designing spatial management areas for Bottom Fisheries using the Zonation decision-support software was defensible and appropriate (paragraph 108 of the SC5 Report, 2017). The processes and methods are documented in SC6-DW11 and Figure . Briefly, however:

- The modelling uses all available biological, physical and chemical information from depths between 200 and 3000 meters to predict habitat suitability for (and hence infer the distribution) of a subset of VME indicator taxa.
- A fisheries value layer was developed using historical catch from 54,000 bottom and mid-water trawl tows, primarily by Australian and New Zealand flagged vessels (but 12 flags altogether), operating in the SPRFMO Convention Area between 2007 and 2017. The value to fisheries was assumed to be the sum of total catches for all species recorded, spread evenly across all 1 km^2 cells contacted by the tow. This layer allowed the identification of core areas of fisheries value from historical catches.
- For tows with less reliable data (e.g., start and end positions deemed too close), the value to fisheries (sum of total catches for all species) was assigned in full in the cells with the starting location, and 50% value was allocated to adjacent cells, with an added 10% of the value added to cells contiguous to adjacent cells.

- Fishery value data based on entire catch and other parameters was determined by the fishing industry for the same area.
- The modelled distribution maps of suitable habitat for VME indicator taxa together with the distribution of the value to fishery data layer was used (combined with other information) within the Zonation decision-support tool to prioritise areas to be closed to fishing and areas to be opened to fishing.
- A key output from Zonation is a prioritization of the landscape for conservation (Figure 60). Cells ranked highly from a conservation perspective are those that contribute most to VME representation and where impacts of fishing should be minimized, and low ranked cells are those areas that contribute least to VME representation and are more compatible with bottom fishing.
- The Zonation prioritization formed the basis for informing the design of candidate spatial management areas, which were discussed by relevant stakeholders in an effort to meet their objectives, and to determine the most appropriate boundaries for the areas open to fishing. The process to design the spatial management measures used the Zonation prioritization as an input and automated searches in GIS to identify priority cells to open for fisheries from a 'least cost' to the fishery approach, and from a 'least risk' to VMEs approach. A 'nuanced' approach was then developed by intersecting the 'least cost' and 'least risk' approaches and adjusting boundaries to account for fishability and to aid with compliance.
- This led to the definition of the bottom fishing management areas defined in CMM 03-2019, and which remain in effect in in CMM 03-2023.
- Although both the habitat suitability modelling and the outputs of the Zonation analysis were conducted at the scale of 1 km x 1 km squares, the spatial management areas were designed at a minimum linear scale of ~6 minutes of arc (or ~10 km).
- The performance of the candidate areas was broadly assessed, at the time, as providing greater protection from fishing impacts for stony corals and other VME indicator taxa than the pre-2019 measures applied by Australia and New Zealand.

The Scientific Committee agreed that the scientific approaches applied could be used to underpin the revised bottom fishing CMM (paragraph 113 of the SC6 Report, 2018) and determine the areas to open to bottom fishing.

4.6.3 Previous Evaluation of Spatial Management Areas

Following the establishment of the management areas, Australia and New Zealand worked on a joint Bottom Fisheries Impact Assessment (Delegations of Australia and New Zealand 2020), which updated the spatial modelling of VME indicator taxa and estimated the levels of protection accorded to each taxon, and the levels of impact (and simulated future impact) to each taxon at smaller spatial scales (the Fishery Management Area scale rather than wider scales as in SC6-DW11). The 2020 BFIA also included estimates of recovery of impacted areas that were closed.

The SC8 evaluation of the performance of the spatial management areas in protecting portions of the predicted distribution of VME indicator taxa found that "*"the proportion of suitable VME indicator taxa habitat [for which habitat suitability models exist] protected is uncertain but qualitatively favourable at most scales assessed. However, there are a number of areas at smaller scales (Fishery Management Areas) where the level of suitable habitat protected for some VME taxa is less favourable including Northwest Challenger, Central Louisville and Southern Louisville". SC8 also agreed that "although the appropriate scale to assess and manage impacts on VMEs has not been defined in SPRFMO, the smaller scale of the Fishery Management Areas is likely to be a more biologically* *appropriate scale at which to assess and manage these impacts than larger scales"*. The SC also advised that the Commission *"may wish to consider additional precautionary management measures for areas and taxa at higher risk from bottom trawl fisheries to address uncertainty and provide additional confidence that the CMM will meet its objective*" (page 46 of the SC8 Report, 2020).

4.6.4 Development of updated spatial management measures

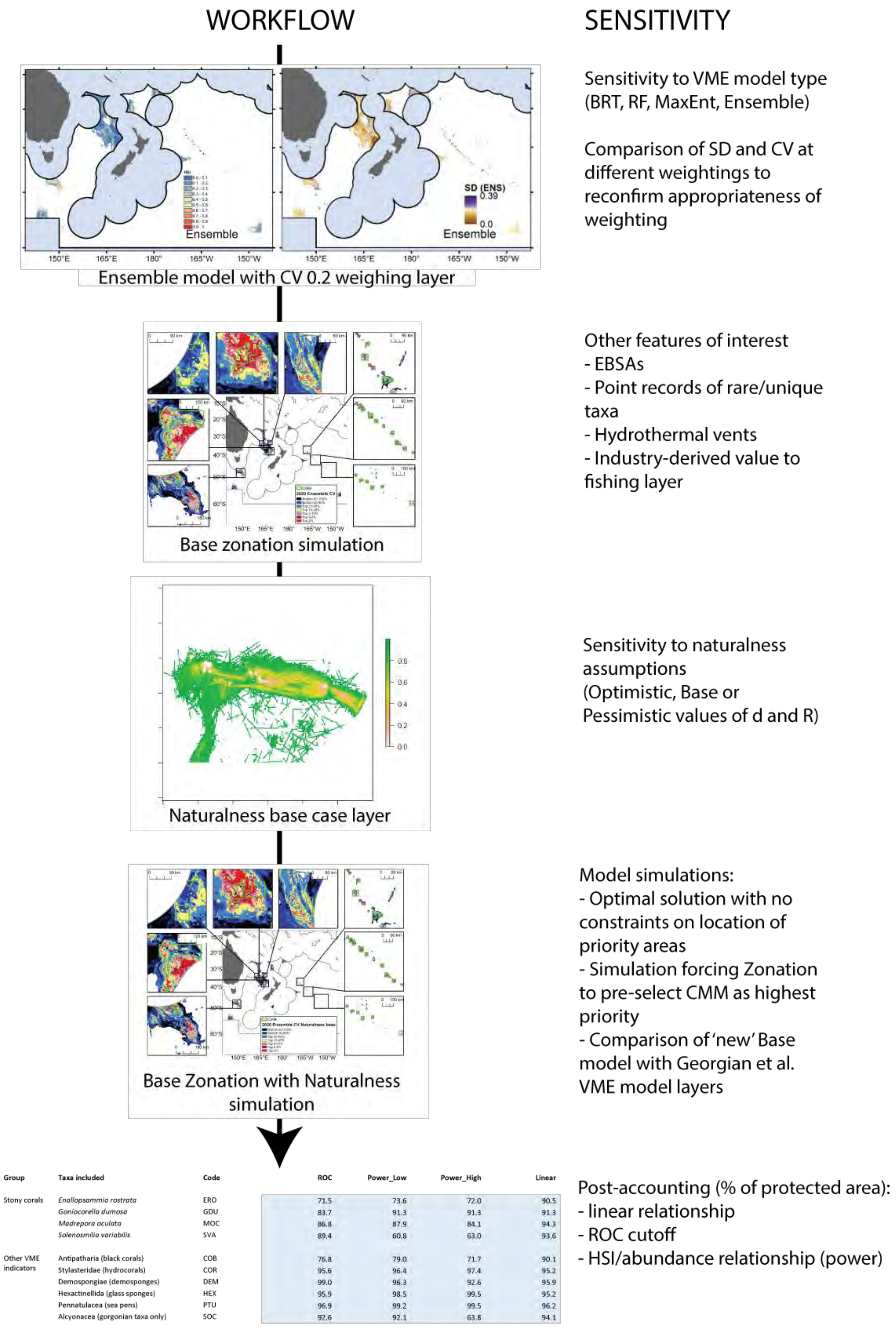
At COMM9, Members noted ongoing discussions relating to the appropriate level of protection to prevent SAIs on VMEs in the SPRFMO Convention Area. Following discussions, Members agreed to specific tasking of the SC to ensure the information required to support the review of CMM03 in 2022 was provided, including:

"*The SC to include in its workplan for 2021+ the development of spatial management scenarios for Bottom Trawling. This work will inform the Commission's determination of the level of protection required to prevent SAI on VMEs in the SPRFMO Convention Area. Scenarios should encompass protection levels of 70%, 80%, 90%, 95% for the modelled VME indicator taxa using temporally static and temporally dynamic assessment methods. The SC should also explicitly account for uncertainties in current model predictions, the relative availability of VME indicator taxa in an area, and recommendations from other RFMOs or guidance documents when formulating its recommendations COMM 10 – Inf 03 3 to the Commission. Evaluations should be undertaken at spatial scales comparable to the Fisheries Management Areas described in SC8-DW07_rev1*."

Australia and New Zealand jointly developed methodology to develop the scenarios and to estimate protection levels which was presented to the 9th meeting of the Scientific Committee (SC9-DW06_rev1). Following discussion at the deepwater workshop preceding the Scientific Committee:

- Noted the metrics used to assess the protection levels for VME indicator taxa, ROC 0-linear and Power Mean, are representative of the metrics spectrum presented in the BFIA.
- Noted that protection level assessment was completed for all protection levels using both temporally static and a temporally dynamic methods, as requested by the Commission.
- Agreed that the approach taken to develop spatial management protection scenarios and report on their performance is appropriate and work will continue intersessionally to refine scenarios to meet all protection targets for presentation to Commission.
- Recommended that the Commission consider the results of the spatial protection scenarios including to inform its determination of the level of protection required to prevent SAI on VMEs in the SPRFMO Convention Area.
- Noted that ecologically relevant spatial scales for assessing protection levels to prevent SAIs on VME indicator taxa still remain to be agreed, but that the existing information at the [Fisheries Management Area] FMA is likely to be a more biologically appropriate compared with larger scales.

Following SC9, Australia and New Zealand continued to refine the spatial management scenarios, which were presented back to COMM10 in COMM10-Inf03, at which time the Commission established an Intersessional Working Group (IWG) charged with responsibility to review SPRFMO's bottom fishing measure, CMM 03-2022. The IWG concluded its work in January 2023, culminating in this submission of its review to the 11th Meeting, at which time the Commission adopted CMM03-2023, paragraph 19 of which requires the Commission from 2024 to "*apply a minimum of 70% protection of suitable habitat for each modelled VME indicator taxa"*, with paragraph 39 directing the Scientific Committee to "*adopt the Fishery Management Area as the appropriate scale of management for assessing the performance of the VME spatial management* *scenarios that underpin this*”. The Bottom Fishing Management Areas (BTMAs) boundaries, as defined in the 70% Protection Scenario (COMM10-Inf03) are mapped in Figure 61: Map of Fishing Management Areas (FMAs) (light purple) across the western side of the SPRFMO Convention Area (light blue) with Bottom Fishing Management Areas (BTMAs) boundaries (light green), as defined in the 70% Protection Scenario [COMM10-Inf03]. FMAs are as follows: 1) South Tasman Rise, 2) Westpac Bank, 3) North-West Challenger, 4) South Lord Howe Rise, 5) North Lord Howe Rise, 6) West Norfolk, 7) North Louisville, 8) Central Louisville and 9) South Louisville.



Group	Taxa included	Code	ROC	Power_Low	Power_High	Linear
Stony corals	*Enallopsammia rostrata*	ERO	71.5	73.6	72.0	90.5
	Goniocorella dumosa	GDU	83.7	91.3	91.3	91.3
	Madrepora oculata	MOC	86.8	87.9	84.1	94.3
	Solenosmilia variabilis	SVA	89.4	60.8	63.0	93.6
Other VME indicators	Antipatharia (black corals)	COB	76.8	79.0	71.7	90.1
	Stylasteridae (hydrocorals)	COR	95.6	96.4	97.4	95.2
	Demospongiae (demosponges)	DEM	99.0	96.3	92.6	95.9
	Hexactinellida (glass sponges)	HEX	95.9	98.5	99.5	95.2
	Pennatulacea (sea pens)	PTU	96.9	99.2	99.5	96.2
	Alcyonacea (gorgonian taxa only)	SOC	92.6	92.1	63.8	94.1

Figure 59: Workflow and inputs of the Zonation simulations, including sensitivity elements tested during the process.

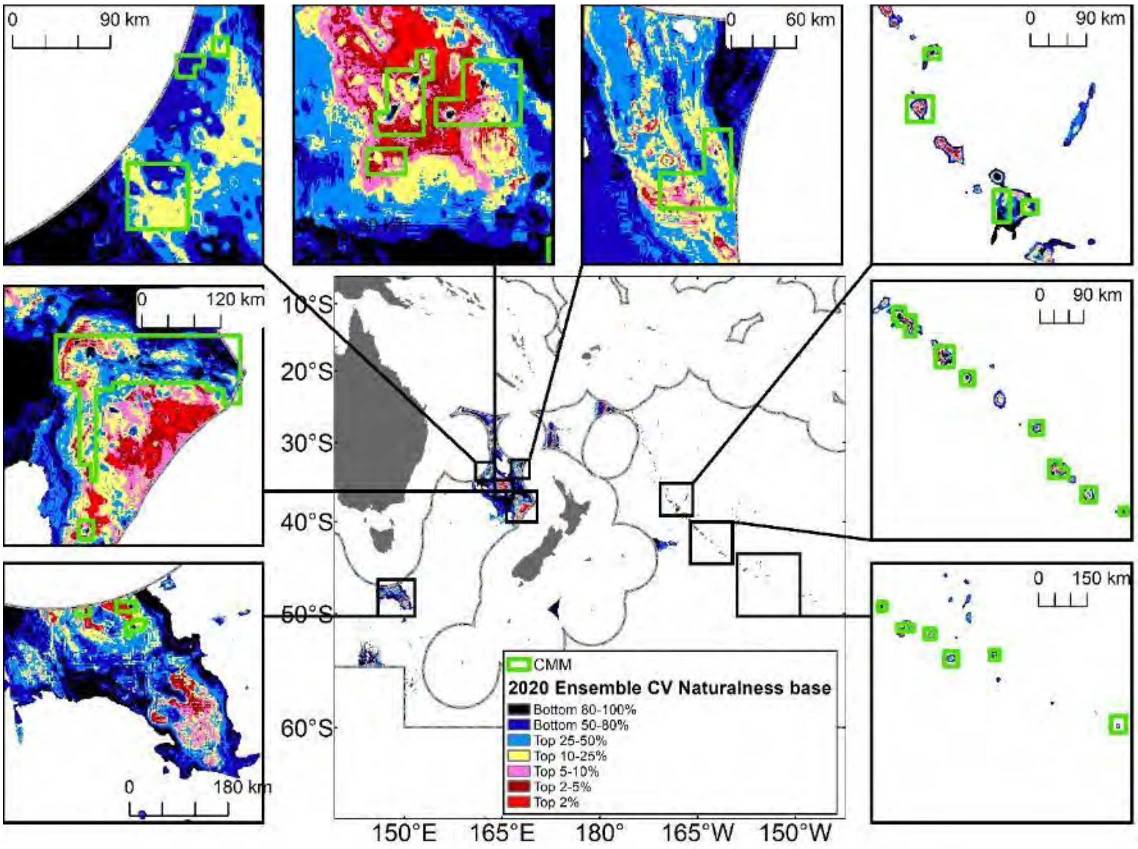


Figure 60: Output from the Zonation prioritization analysis (2020) utilising an ensemble layer for VME indicator taxa distribution, its weighted uncertainty CV, and base case naturalness to identify those areas that make the greatest contribution to the representation of VME indicator taxa. Colours indicate relative priority for conservation. Bottom trawl management areas defined in CMM 03-2020 are shown as green polygons.

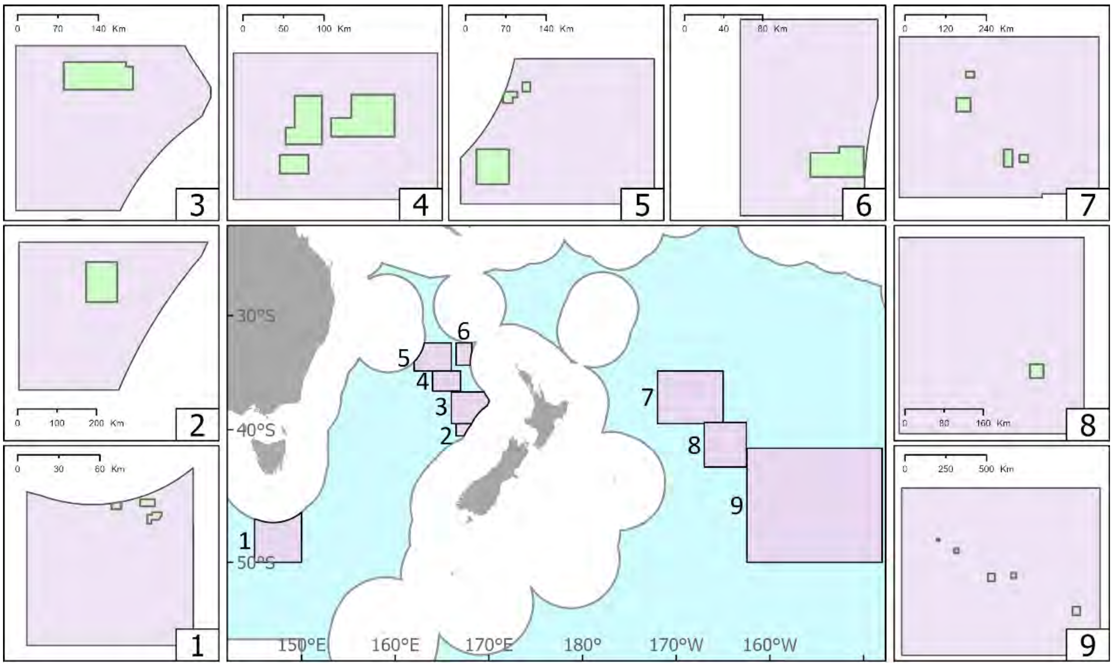


Figure 61: Map of Fishing Management Areas (FMAs) (light purple) across the western side of the SPRFMO Convention Area (light blue) with Bottom Fishing Management Areas (BTMAs) boundaries (light green), as

defined in the 70% Protection Scenario [COMM10-Inf03]. FMAs are as follows: 1) South Tasman Rise, 2) Westpac Bank, 3) North-West Challenger, 4) South Lord Howe Rise, 5) North Lord Howe Rise, 6) West Norfolk, 7) North Louisville, 8) Central Louisville and 9) South Louisville.

4.6.5 Design of VME encounter protocols

Since the BFIA in 2020, new research has been conducted suggesting that catchability is likely to be highly variable between different VME indicator taxa (SC10-DW04), which has implications for the utility of VME bycatch as a means of detecting encounters with potential VMEs. Research is ongoing to evaluate and optimise the design and performance of encounter protocols and/or move-on rules.

The UNGA Resolution 64/72 (UN General Assembly 2010) called upon States and RFMOs to establish and implement science-based "*threshold levels and indicator species*", that would define evidence of an encounter with a VME. Consequently, to complement the spatial management areas, a VME encounter protocol has also been implemented, designed to halt fishing in the event of bycatch of VME indicator taxa above a certain weight. The move-on rule is a key part of the encounter protocol and is a backstop measure to support the spatial management areas, which are presumed to have protected a high proportion of VMEs. For this reason, in contributing to the initial design of the 2019 bottom fishing measure reform, the Scientific Committee recommended that the VME thresholds should be high because they were to be used as a back stop to complement spatial closures (see paragraph 121 of the SC5 Report, 2017).

The method for deriving thresholds for VME indicator taxa is outlined SC6-DW09 and in SC9-DW10. Groomed data on bycatch of VME indicator taxa, benthic bycatch weight distributions, numbers of taxa caught per tow and cumulative weight frequency distributions were used to analyse the metrics that could be used to define VME thresholds. The data used was restricted to New Zealand bottom trawl tows (including mid-water trawls) in the Evaluated Area over the period 2008–18. Preliminary analysis of benthic bycatch records for Australian trawl fisheries in SPRFMO indicated that rates of interaction were lower than for New Zealand fisheries, but Australian data were not included in this analysis because of their lower resolution, which would degrade the usefulness of the other data. There were insufficient data for many taxa at smaller scales to enable the generation of area-specific weight thresholds. Therefore, VME indicator taxon-specific weight thresholds were generated for the entire western SPRFMO Convention Area combined.

The method for deriving thresholds was based on developing VME indicator taxon-specific cumulative distribution curves of historical bycatch weights and then calculating a range of percentiles from the ordered bycatch weights, with the percentiles serving as candidate encounter threshold values (Table 39). Naturally occurring or ecologically relevant reference points were also calculated and used to identify ‘high’ candidate threshold weights for triggering move-on rules and ‘low’ candidate biodiversity weights indicating increasing numbers of taxa in a single tow (Figure 62). Of the ten VME indicator taxa included in Annex 5 of CMM03-2019, six had sufficient historic bycatch records to build cumulative distribution curves.

Table 39: **Percentiles presented in SC9-DW10. The number of bottom trawl tows recorded as bycatch (n), range in bycatch weight (kg), reference points ((0,1) distance and Youden distance) and percentiles in bycatch weight per VME indicator taxon recorded in all New Zealand bottom trawls within the Evaluated Area of the SPRFMO Convention Area between 2008 and 2020. Cell shading indicates percentiles above (blue) and below (green) both reference points. Grey cells indicate reference points could not be calculated due to insufficient**

sample sizes. Note, candidate encounter thresholds are presented for Porifera as a Phylum, and also disaggregated into the Classes Demospongiae and Hexactinellidae.

			Reference Points		Percentiles (candidate encounter thresholds in kg)								
VME indicator taxon	**n**	**range (kg)**	**(0,1)**	**Youden**	**0.7**	**0.8**	**0.85**	**0.9**	**0.95**	**0.96**	**0.97**	**0.98**	**0.99**
Porifera	907	0.02 - 1091.2	26.00	26.00	2.00	3.00	5.00	7.04	12.58	15.00	20.00	22.99	49.70
Scleractinia	1395	0.04 - 5000	60.00	60.00	2.38	5.00	5.20	10.00	20.00	30.00	40.00	67.94	221.99
Antipatharia	739	0.001 - 10.4	1.10	1.10	0.60	1.00	1.00	1.82	2.63	3.00	3.89	4.65	5.50
Alcyonacea	7	0.05 - 0.5	-	-	0.22	0.28	0.32	0.38	0.44	0.45	0.46	0.48	0.49
Gorgonacea	681	0.01 - 200	5.70	5.70	1.00	1.00	1.30	2.00	5.20	7.44	15.07	24.10	34.50
Pennatulacea	99	0.1 - 3.6	1.00	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.05
Actiniaria	977	0.02 - 77	10.00	10.00	5.00	7.00	9.52	11.20	20.00	20.19	23.72	30.00	35.07
Zoantharia	544	0.1 - 114	5.00	5.00	1.00	1.00	1.00	2.00	3.00	4.42	5.00	6.56	11.99
Hydrozoa	12	0.02 - 1.3	-	-	0.47	0.90	1.00	1.00	1.14	1.17	1.20	1.23	1.27
Stylasteridae	33	0.02 - 8	1.00	1.00	0.84	1.00	1.00	1.00	1.82	1.92	2.24	4.16	6.08
Bryozoa	3	0.1 - 4	-	-	1.78	2.52	2.89	3.26	3.63	3.70	3.78	3.85	3.93
Brisingida	29	0.02 - 5	1.00	1.00	0.80	1.00	1.00	1.20	2.60	2.88	3.32	3.88	4.44
Crinoidea	59	0.04 - 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.42

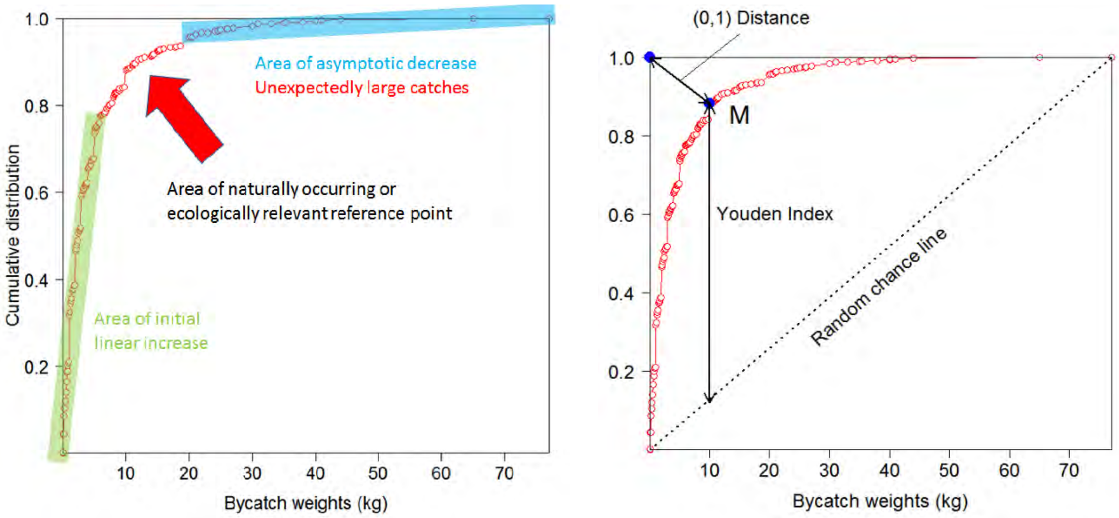


Figure 62: Cumulative distribution curve for the weight of Actiniaria bycatch from the 2008-20 New Zealand bottom trawl fishery in the SPRFMO Convention Area. Left-hand panel distinguishes between the initial part of the curve associated with linear increase and the final part of the curve associated with asymptotic decrease. The area distinguishing between these two parts of the curve potentially indicates a naturally occurring or ecologically relevant reference point. Right-hand panel show two approaches used to distinguish between the two parts of the curve: (1) the point on the curve that is closest to the top-left corner ((0,1)

Distance); and (2) the point on the curve that maximizes the distance between the curve and a random chance line drawn between the extreme points on the curve (Youden Index).

SC6 agreed that two VME indicator taxa thresholds for bottom trawl should be used - a weight threshold (based on the 99th percentile of the distribution of historical positive catch weights) and a biodiversity threshold (based on the 80th percentile of the distribution of historical positive catch weight). The VME indicator taxa encounter thresholds were adopted for the first time at COMM7 in 2019 in CMM 03-2019 (Annex 6). Prior to this, individual Members set their own VME thresholds and move-on encounter distances. The VME encounter protocol includes taxon-specific weight thresholds for VME indicator taxa and a biodiversity threshold where several VME indicator taxa are taken. The encounter protocol is triggered if the bycatch of any one VME indicator taxon in a trawl tow exceeds its taxon-specific weight threshold, or three or more VME indicator taxa exceed their taxon-specific biodiversity weights. Biodiversity thresholds recognise that although the presence of a small amount of a single VME indicator taxon below its weight threshold is unlikely to indicate an encounter with a potential VME (within the meaning of the term 'encounter' in CMM 03-2020), the presence of several VME indicator taxa below their weight thresholds in a single tow may indicate that the fishing event has encountered an area with a diverse seabed fauna, potentially constituting evidence of a VME. Therefore, the aim of the encounter protocol is to avoid repeat disturbances by avoiding trawling the same patch of VME while minimising the likelihood of moving to a different patch of VME, but this is challenging to do given data limitations on the distribution of VMEs.

CMM03-2019 included threshold weights for the six VME indicator taxa for which cumulative distribution curves could be built and biodiversity thresholds for all VME indicator taxa included in Annex 5.

To ensure thresholds were consistent with the objectives of CMM03, the Commission agreed that Scientific Committee regularly review encounter protocols and thresholds to incorporate additional data as they become available. The Commission has steadily refined these thresholds based on updated scientific information or Member proposals to add additional precaution into the management measures given uncertainty in how well the spatial management measures protect VMEs, lowering the threshold in 2020 for stony coral, and again in 2021 for sponges, stony corals and anemones (Table 40). In 2021 the list of VME indicator taxa was also updated to include Zoantharia (with associated threshold weight and biodiversity thresholds) and Hydrozoa and Bryozoa (with associated biodiversity thresholds) following a review of VME indicator taxa presented in SC7-DW13.

Once a threshold is triggered and an area closed to fishing, the information is reviewed by the flag state and then by the Scientific Committee. The Scientific Committee is required by CMM03-2023 (paragraph 33) to *review all encounters reported … and provide advice on management actions proposed by the relevant Member or CNCP under paragraph 32 and any alternate or additional management actions the Scientific Committee considers appropriate. The Scientific Committee shall:*

a) Apply the Convention, including Article 3(2)(a);

b) Consider the detailed analyses provided by a Member or CNCP pursuant to paragraph 32 including:

   i. historical fishing events within 5nm of the encounter tow, in particular, any previous encounters, and all information on benthic bycatch;
   ii. model predictions for all VME indicator taxa;
   iii. details of the relevant fishing activity, including the bioregion; and
   iv. any other information the Scientific Committee considers relevant;

- c) *review the adequacy of the information submitted pursuant to paragraph 31, including the robustness of the analysis;*
- d) *apply the FAO Deep-sea Fisheries Guidelines, including to use the full set of criteria contained therein to identify where VMEs occur or are likely to occur, as well as for assessing significant adverse impacts on such ecosystems, including their associated and dependent species*
- e) *consider whether an area or areas should be closed to prevent significant adverse impacts on VMEs; and*
- f) *ensure its advice and recommendations arising from the review are provided with the objective of avoiding significant adverse impacts on VMEs.*

Decisions on whether the temporary closure should be lifted or confirmed are taken by the Commission, guided by paragraph 35): *the Commission shall determine, for each encounter, management actions to prevent significant adverse impacts on VMEs, which may include: the closing of some areas to some or all bottom fishing gear, temporal restrictions, spatial restriction, reopening areas. Management actions determined by the Commission will apply as appropriate, unless otherwise determined, from the conclusion of the relevant Commission meeting. The Commission shall base its decision on the Scientific Committee's advice; and be satisfied that its decision is consistent with the requirements of the Convention, including Article 3(2)(a).*

Noting the need to provide more biologically meaningful guidance on appropriate VME thresholds SC9 recommended the Commission adds to the VME Encounters and Benthic Bycatch task in the SC Multi-Annual Work Plan a 2023+ subtask to develop a research programme within the SPRFMO Convention Area to allow the determination of taxon-specific estimates of catchability for VME indicator taxa. Progress towards this task is documented by Stephenson et al. (2022a). SC9 also recommended that in the interim, the best available catchability estimates are used to improve the Commission's understanding of the implications of the current encounter thresholds with regard to preventing SAIs on VMEs (SC9 Report paragraph 56).

Table 40: Prescribed weight thresholds for triggering VME encounter protocol in any one tow for a single VME indicator taxon and basis within various iterations of CMM 03. Red cells indicate lowering of thresholds from previous CMM.

			Threshold weights					Biodiversity thresholds				
FAO code	**VME indicator taxon**	**Common Name**	**CMM03-2019**	**CMM03-2020**	**CMM03-2021**	**CMM03-2022**	**CMM03-2023**	**CMM03-2019**	**CMM03-2020**	**CMM03-2021**	**CMM03-2022**	**CMM03-2023**
PFR	Porifera (Phylum)	Sponges	50kg	50kg	25kg	25kg	25kg	5kg	5kg	5kg	5kg	5kg
CSS	Scleractinia (Order)	Stony corals	250kg	80kg	60kg	60kg	60kg	5kg	5kg	5kg	5kg	5kg
AQZ	Antipatharia (Order)	Black corals	5kg	5kg	5kg	5kg	5kg	1kg	1kg	1kg	1kg	1kg
ALZ	Alcyonacea (Order)	True soft corals	60kg	60kg	-	-	-	1kg	1kg	1kg	1kg	1kg
GGW	Gorgonian Alcyonacea (Informal group)	Sea fans octocorals	15kg	15kg	15kg	15kg	15kg	1kg	1kg	1kg	1kg	1kg
NTW	Pennatulacea (Order)	Sea pens	-					1kg	1kg	1kg	1kg	1kg
ATX	Actiniaria (Order)	Anemones	40kg	40kg	35kg	35kg	35kg	5kg	5kg	5kg	5kg	5kg
ZOT	Zoantharia (Order)	Hexacorals	Not included		10kg	10kg	10kg	1kg	1kg	1kg	1kg	1kg
HQZ	Hydrozoa (Class)	Hydrozoans	Not included		-	-	-	1kg	1kg	1kg	1kg	1kg
AXT	Stylasteridae (Family)	Hydrocorals	-	-	-	-	-	1kg	1kg	1kg	1kg	1kg
BHZ	Bryozoa (Phyllum)	Bryozoans	Not included		-	-	-	1kg	1kg	1kg	1kg	1kg
BHZ	Brisingida (Order)	Armless stars	-	-	-	-	-	1kg	1kg	1kg	1kg	1kg
CWD	Crinoidea (Class)	Sea lillies and feather stars	-	-	-	-	-	1kg	1kg	1kg	1kg	1kg

4.6.6 Other complementary measures

As well as reviewing any encounters triggered by catches of VME indicator taxa in excess of the thresholds specified in CMM03-2023, the Scientific Committee also reviews annual analyses and summaries of benthic bycatch data collected during the previous year. These data are provided by flag States (e.g., Geange et al. 2020 SC-08-DW-13).

4.6.7 Estimating the performance of spatial measures

The 2020 BFIA evaluated the performance of spatial management measures at 4 different spatial scales: the whole SPRFMO Evaluated Area; bioregions as proposed by Costello et al. (2017); broad fisheries administrative units; and orange roughy fisheries management areas (FMAs) after Clark et al. (2016). Since the 2020 BFIA was submitted, the Commission has directed the Scientific Committee to adopt the Fishery Management Areas (Figure 56: SPRFMO Convention Area (light green) including the extent of the evaluated area under SC9-) as the appropriate scale of management for assessing the performance of spatial management areas (Para 39; CMM03-2023).

In addition to VME taxon current status and RBS, a key metric of the likely performance of spatial management areas used to advise the Scientific Committee and the Commission has been the estimated proportion of suitable habitat for each VME indicator taxa that inside areas where bottom fishing is prohibited (e.g., Cryer et al. 2018 SC-06-DW-11; Delegation of New Zealand 2019 COMM07-Prop03.1; Delegations of Australia and New Zealand 2022 COMM1--Inf03).

SC06-DW-11 estimated the proportion of the distribution of each taxon exposed (or not) to fishing impacts by summing the habitat suitability indices for all 1 km^2 cells outside (or inside) the spatial management areas specified in CMM03-2019 using no cut-offs for the habitat suitability indices. Using this approach, calculations in 2018 suggested that the proposed spatial management areas would provide substantially greater protection for stony corals and other VME indicator taxa than the management areas implemented by Australia and New Zealand under CMM03-2018. Across the whole Evaluated Area, the estimated proportions of the distribution of suitable habitat for VME indicator taxa protected from any adverse effects of fishing were estimated to increase from 60–70% under CMM03-2018 to over 80% under CMM03-2019.

The approach to estimating the likely performance of spatial management areas used in 2018 assumed that, in effect, the relationship between habitat suitability indices and the abundance of each modelled taxon was linear. Initial analyses (shown in Cryer et al. 2019; Pitcher et al. 2019) and additional detailed work conducted for the 2020 BFIA (SC8-DW07 rev 1) show that the relationship is quite uncertain, probably variable, and is much more complex than the simple linear assumption. In particular, cells with low habitat suitability indices are unlikely to have substantive abundances of VME indicator taxa and only cells with high habitat suitability indices are likely to have very dense populations of VME indicator taxa. Clearly, this complexity has implications for the estimation of the performance of spatial management areas and estimates of the likely performance have, and were therefore, recalculated for the 2020 BFIA (SC8-DW07 rev 1).

Estimates were made by summing habitat suitability indices as in 2018 (for comparability and for some sensitivity trials) but, recognising that this is probably not a good assumption, estimates were also calculated using two alternative approaches. First, estimates were made (using the Receiver Operating Characteristics (ROC) curve) of the proportion of cells inside and outside the areas open to fishing within each FMA that had HSI scores above the cutoff value indicating the presence of suitable habitat in a binary classification setting[15] within each habitat suitability model. This was generally referred to as the ROC approach in the 2020 BFIA assessment. Second, the habitat suitability scores for each taxon were transformed to estimates of abundance using power curves estimated using information on the cover or abundance of VME indicator taxa within grid cells for which habitat suitability predictions were available. These estimates of abundance were summed separately for cells inside and outside the areas open to fishing to estimate the proportion of the overall abundance. This is generally referred to as the power relationship or approach in the 2020 BFIA assessment.

Table 41: Cutoff HSI values for predicted suitable habitat from the receiver operating characteristic (ROC) curves for each VME indicator taxon for which HSI models were developed and used in post-accounting. Results are given for each new model in 2020 and 2022 (RF, random forest; BRT, boosted regression tree; MX, maximum entropy; ENS, ensemble model) and for the ensemble model assembled in 2018 by Georgian et al. (2019).

Group	FAO code	Name	RF	BRT	MX	ENS	ROC cutoff values Georgian et al. (2019)
Stony coral species	FEY	*Enallopsammia rostrata*	0.6519	0.6123	0.3239	0.5024	0.2269
	GDV	*Goniocorella dumosa*	0.5223	0.5155	0.2985	0.3761	0.5728
	MVI	*Madrepora oculata*	0.5657	0.5923	0.2398	0.4455	0.5538
	RTZ	*Solenosmilia variabilis*	0.5981	0.5861	0.3127	0.4603	0.5550
Other VME indicator taxa	AQZ	Antipatharia	0.5673	0.5515	0.3797	0.5210	0.6391
	AXT	Stylasteridae	0.5359	0.4885	0.4317	0.4600	0.5266
	DMO	Demospongiae	0.5031	0.4627	0.3995	0.4570	0.5055
	HXY	Hexactinellida	0.5731	0.4883	0.4597	0.4547	0.6665
	NTW	Pennatulacea	0.5498	0.5142	0.3299	0.4507	0.8605
	ALZ	Alcyonacea	0.5557	0.5203	0.4867	0.5145	0.6455
	ATX	Actiniaria	0.3214	0.3967	0.5791	0.4778	
	ZOT	Zoantharia	0.6220	0.5163	0.4828	0.5870	
	HQZ	Hydrozoa	0.5499	0.4477	0.5363	0.4910	
	BZN	Bryozoa	0.5558	0.4578	0.5355	0.4751	
	BHZ	Brisingida	0.5422	0.5114	0.5431	0.5878	
	CWD	Crinoidea	0.5130	0.4171	0.5165	0.4698	

The ROC approach leads to an estimate of the proportion of suitable habitat for a given VME indicator taxon within or outside the areas open to bottom trawling. It is, arguably, the most natural way of using the predictions from the habitat suitability models which were not designed to predict abundance but have very strong performance (estimated using fully independent data) at classifying presence and (pseudo) absence at the scale of the model grid (1 km). This approach does not distinguish between different levels of habitat suitability within quite a broad range of HSI values. The power approach leads to an estimate of the proportion of total abundance for a given VME indicator taxon within or outside the areas open to trawling. This approach applies fitted relationships between observed abundance and predicted HSI at the sites where such detailed information is available; these typically suggests that VME indicator taxa have substantive observed abundance only when predicted HSI is high. The power approach therefore focuses much more on habitat predicted to be highly suitable, especially when the estimated power curves are very steep.

Both ROC and the power approach were also used to evaluate the performance of spatial management scenarios in SC9-DW06-rev1 and COMM10-Inf03, with some modifications. First, recognizing that using a binary classification of the of HSI scores above and below the ROC cutoff value does not distinguish between different levels of habitat suitability within a broad range of HSI values,

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[15] In the ROC approach, cells were classified as either suitable habitat, or not, for a given taxon. The post accounting counts the number of cells classified as suitable habitat.

a ROC_linear approach was used where cells value above the ROC cutoff are retained and values below are discarded. Second, while the 2020 BFIA incorporated both power_low and power_high transformations to estimate abundance, SC9-DW06-rev1 and COMM03-Inf3 used a power-mean transformation.

SC9 noted that the metrics used to assess the protection levels for VME indicator taxa, ROC 0-linear and Power Mean, are representative of the metrics spectrum presented in the 2020 BFIA and agreed that their use to report on the performance of the spatial management measures is appropriate (Para 78; SC9 Report). Consequently, where available, both ROC_linear and Power-mean approaches are used to report on the performance of spatial management measures within this BFIA.

Interpretation of post accounting results should be done in reference to paragraphs 10 and 39 of CMM03-2023, which state that:

10. *From 2024, the Commission shall apply a minimum of 70% protection of suitable habitat for each modelled VME indicator taxa. The Commission, taking into account the advice and recommendations of the Scientific Committee, shall review the boundaries of the Management Areas established in paragraph 14 and Annex 4 of this CMM and make any modifications necessary to achieve this level of protection at its 12th annual CMM 03-2023 Bottom Fishing 5 meeting in 2024.*

39. *From 2023, the Scientific Committee shall adopt the Fishery Management Area as the appropriate scale of management for assessing the performance of the VME spatial management scenarios that underpin this CMM.*

Therefore, a reference point for evaluating the performance of the spatial management measures is attaining a minimum of 70% protection of suitable habitat for each modelled VME indicator taxa in each FMA. Recognizing that the minimum level of protection does not need to be attained until 2024, we report on the performance of both the spatial management measures implemented in CMM03-2023 (Table 42) and the spatial management measures that are proposed to be adopted by Commission in 2024, as described by the 70% scenario in COMM10-Inf3 (Table 43). Analyses for each modelling approach are presented in Appendix E. In addition, Appendix F provides a comparison of the proportion of suitable habitat for each VME taxon in areas closed to bottom trawling within each FMA for pre-2019 spatial management measures with the current and proposed spatial management measures.

Under the spatial management measures implemented in CMM03-2023 (Table 42), most of the VME indicator taxa with > 1% of their Habitat Suitability Index within an FMA have over 70% within areas closed to bottom trawling, but not all taxa in all FMAs. For sponges, protection was high (> 90%) for Demospongiae but only 53% for Hexactinellida within Northwest Challenger (the only FMA with > 1% of the HSI). For stony corals, protection exceeded 70% except within Northwest Challenger (*Enallopsammia rostrata* 27%, *Madrepora oculata* 44%), Central Louisville (*Goniocorella dumosa* 47%, *Solenosmilia variabilis* 18%) and South Lousiville (*Goniocorella dumosa* 45%, *Solenosmilia variabilis* 20%). Black corals do not meet the 70% reference point within Northwest Challenger (26%) or South Lousiville (38%). Among the other VME indicator taxa, only Gorgonian Alcyonacea (65%) in Central Lord Howe and Anemones (28%) and Hexacorals (48%) within Northwest Challenger do not meet the 70% reference point. All VME indicator taxa with > 1% of their Habitat Suitability Index within an FMA meet the 70% reference point within West Norfolk, North Lord Howe, Westpac Bank, South Tasman Rise and North Louisville FMAs. Only about half (7 of 13) of the VME indicator taxa within Northwest

Challenger, and none in the Central Louisville (2 taxa) or South Louisville (3 taxa) meet the 70% reference point.

Table 42: Estimates of the percentage of each VME taxon in areas closed to bottom trawling within each Fishery Management Area (as defined in CMM03-2023) under CMM03-2023. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each Fishery Management Area, derived from the lower of the ROC_linear and Power_mean estimates from the unimpacted baseline for taxa with > 1% of their Habitat Suitability Index within the Fishery Management Area (as presented in Appendix F). ROC_linear and Power_mean estimates are not currently available for all taxa, and * indicates taxa where ROC_linear values are reported. Cell shading refers to taxa with more (green) than 70% of their distribution in closed areas.

VME Indicator Taxon	**West Norfolk**	**North Lord Howe**	**Central Lord Howe**	**Northwest Challenger**	**Westpac Bank**	**South Tasman Rise**	**North Louisville**	**Central Louisville**	**South Louisville**
Sponges (Porifera Demospongiae)	99.35	97.65		94.56					
Sponges (Porifera Hexactinellida)				53.29					
Stony corals (Enallopsammia rostrata)		87.44	72.41	27.10	86.07	70.10			
Stony corals (Goniocorella dumosa)		90.43	82.64	73.86		96.88		46.56	44.93
Stony corals (Madrepora oculata)	77.54		72.61	43.98	87.97	96.26			
Stony corals (Solenosmilia variabilis)						95.46	74.24	18.22	19.62
Black corals (Antipatharia)	79.95	83.59	70.89	25.65	82.30		76.66		38.19
Gorgonians (Gorgonian Alcyonacea)	78.04	82.81	64.59			96.77			
Sea pens (Pennatulacea)		92.80		75.23		100.00			
Anemones (Actiniaria)*				27.56					
Hexacorals (Zoantharia)*		91.56	84.44	48.43		97.85			
Hydroids (Hydrozoa)*				89.20		98.92			
Hydrocorals (Stylasteridae)	97.08					94.69			
Bryozoans (Bryozoa)*				88.34		99.03			
'Armless' Stars (Brisingida)*		94.14		72.99		98.48			
Sea lillies and feather stars (Crinoidea)*		94.32		84.78		98.61			
Max	99.35	97.65	84.44	94.56	87.97	100.00	76.66	46.56	44.93
Min	77.54	82.81	64.59	25.65	82.30	70.10	74.24	18.22	19.62

Protection of VME indicator taxa is improved under the spatial management measures that are proposed to be adopted by Commission in 2024 (Table 43). Under this proposal all the VME indicator taxa with > 1% of their Habitat Suitability Index within an FMA will have over 70% of suitable habitat within areas closed to bottom trawling. Minimum levels of protection increase for West Norfolk (78% to 89%), Central Lord Howe (65% to 71%), Northwest Challenger (26% to 71%), Central Louisville (18% to 90%) and South Louisville (20% to 72%).

Table 43: Estimates of the percentage of each VME taxon in areas closed to bottom trawling within each Fishery Management Area (as described by the 70% scenario in COMM10-Inf3) under proposed 70% spatial management options for adoption by Commission in 2024. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each Fishery Management Area, derived from the lower of the ROC_linear and Power_mean estimates from the unimpacted baseline for taxa with > 1% of their Habitat Suitability Index within the Fishery Management Area (as presented in Appendix F). ROC_linear and Power_mean estimates are not currently available for all taxa, and * indicates taxa where ROC_linear values are reported. Cell shading refers to taxa with more (green) than 70% of their distribution in closed areas.

VME Indicator Taxon	West Norfolk	North Lord Howe	Central Lord Howe	Northwest Challenger	Westpac Bank	South Tasman Rise	North Louisville	Central Louisville	South Louisville
Sponges (Porifera Demospongiae)	99.57	97.65		99.52					
Sponges (Porifera Hexactinellida)				89.26					
Stony corals (Enallopsammia rostrata)		87.44	75.07	74.71	86.07	70.10			
Stony corals (Goniocorella dumosa)		90.43	84.35	92.40		96.88		90.30	82.33
Stony corals (Madrepora oculata)	93.81		74.89	83.23	87.97	96.26			
Stony corals (Solenosmilia variabilis)						95.46	74.24	92.75	90.99
Black corals (Antipatharia)	90.35	83.59	73.66	71.06	82.30		76.66		72.05
Gorgonians (Gorgonian Alcyonacea)	89.45	82.81	71.13			96.77			
Sea pens (Pennatulacea)		92.80		96.85		100.00			
Anemones (Actiniaria)*				80.70					
Hexacorals (Zoantharia)*		91.56	85.79	86.59		97.85			
Hydroids (Hydrozoa)*				99.51		98.92			
Hydrocorals (Stylasteridae)	98.80					94.69			
Bryozoans (Bryozoa)*				99.78		99.03			
‘Armless’ Stars (Brisingida)*		94.14		97.34		98.48			
Sea lillies and feather stars (Crinoidea)*		94.32		99.89		98.61			
Max	99.57	97.65	85.79	99.89	87.97	100.00	76.66	92.75	90.99
Min	89.45	82.81	71.13	71.06	82.30	70.10	74.24	90.30	72.05

The details of a sensitivity analysis examining the spatial management measures proposed for adoption by Commission in 2024, completely excluding all predictions of suitable habitat or abundance of VME indicator taxa throughout the Evaluated Area where the environmental coverage (the level of available data to inform the habitat suitability models) was low (<0.05) are tabulated in Appendix G). In general, and because the fished areas have more records of benthic invertebrates than unfished areas, this clipping reduced the estimated proportion of suitable habitat or abundance outside the areas open to fishing by a few percentage points (on average). The sensitivity varied between taxa and FMA but, in terms of suitable habitat (using the ROC_linear approach), the average reduction for stony corals was 1.4 percentage points (range 0–13 percentage points), the average reduction for sponges was 1.6 percentage points (range 0–9 percentage points), and the average for other VME indicator taxa was 2.8 percentage points (range 0.3 percentage point increase to 36 percentage point decrease). The FMAs most sensitive to environmental coverage were North and South Louisville. Despite the reductions associated with this sensitivity, all the VME indicator taxa with > 1% of their Habitat Suitability Index within an FMA will have over 70% of suitable habitat within areas closed to bottom trawling under the spatial management measures proposed for adoption by Commission in 2024.

Another sensitivity analysis of the spatial management measures proposed for adoption by Commission in 2024, examining the effect of excluding habitat or colonies of VME indicator taxa deeper than the current and historical depth distribution of fishing is tabulated in Appendix H where cells deeper than 1400 m have been excluded from the analysis. The sensitivity varied between taxa and FMA. Some areas (West Norfolk, Central and South Louisville) showed a general increase in the estimated proportion of suitable habitat (using the ROC_linear approach) in areas closed to fishing, while the other FMAs showed a general decrease. Excluding habitat deeper than 1400 m, of the VME indicator taxa with > 1% of their Habitat Suitability Index within an FMA, only the stony coral *Solenosmilia variabilis* (68%) and Antipatharia (67%) within North Louisville will have less than 70% within areas closed to bottom trawling under the spatial management measures proposed for adoption by Commission in 2024.

4.7 HIGH LEVEL ASSESSMENT ACROSS ALL ASSETS/OBJECTIVES

- Key target fish stocks (tiers 1 and 2 in the stock assessment framework):
    - risk is low for orange roughy given the availability of quantitative stock assessment modelling and precautionary area-specific catch limits.
    - risk is low for other target species of trawl fisheries but may be higher for some of the target species of bottom line fisheries (i.e., bluenose/blue-eye trevalla and *Polyprion* spp.). Catch for these species is limited only by aggregate limits for all species combined (excluding orange roughy) and changes in targeting behaviour may lead to higher risks. Collection of more data is recommended to reduce uncertainties.
- Other fish stocks (tier 3 in the stock assessment framework)
    - Risk is generally low to medium for fish stocks other than those in tiers 1 and 2 of the stock assessment framework but continued monitoring and periodic reassessment is recommended for all stocks and more intense data collection is recommended for some species at higher risk.
- Marine mammals, seabirds, reptiles, and other species of concern
    - Captures of marine mammals are very rare and risk is probably very low.
    - Captures of seabirds are rare, and most captured birds are released alive (but with unknown prognosis). However, these fisheries overlap with a large number of seabird species that are known to be vulnerable to fishing impacts and no quantitative estimates of captures or risk to these populations have been made. Risk is probably low but continued monitoring of captures and the implementation and effectiveness of mitigation methods is recommended.
    - Captures of reptiles are very rare and risk is probably very low.
    - Captures of other species of concern are infrequent and those species that have been reported by fishers or observers are assessed to be at low risk by the chondrichthyan risk assessment presented here.
- Benthic habitats and VMEs
    - Habitat suitability index (HSI) models have been made for sixteen taxa included on the VME indicator taxa list at a 1 km scale throughout the Evaluated Area. These models

have very high skill for classifying presence or informed pseudo-absence of relevant VME indicator taxa.

- Using the model predictions of HSI for the sixteen taxa, estimates of the proportion of the estimated distribution of suitable habitat and abundance for each taxon outside the spatial management areas have been calculated for each FMA.
- These calculations have been done for the spatial management measures included in CMM03-2023 and the spatial management measures proposed for adoption in 2024 in each FMA.
- Under the spatial management measures implemented in CMM03-2023 over 70% of Habitat Suitability for most VME indicator taxa within an FMA is within areas closed to fishing, but this reference point is not met for some taxa, particularly within Northwest Challenger, Central Louisville and South Louisville.
- Under the spatial management measures that are proposed to be adopted by Commission in 2024 (CMM03-2023) all VME indicator taxa with > 1% of their HSI within an FMA have at least 70% of suitable habitat within areas closed to fishing.
- A sensitivity analysis excluding areas of low environmental coverage generally reduced the proportion of habitat within FMAs outside areas open to fishing by a few percentage points, but all the VME indicator taxa with > 1% of their HSI within an FMA will have over 70% of suitable habitat within areas closed to bottom trawling under the spatial management measures proposed for adoption by Commission in 2024.
- A sensitivity analysis excluding habitat deeper than the current and historical depth distribution of fishing showed an increase in the proportion of habitat within FMAs outside areas open to fishing in some FMAs, but a decrease in others. Under this sensitivity, two taxa with > 1% of their Habitat Suitability Index within an FMA will have less than 70% within areas closed to bottom trawling under the spatial management measures proposed for adoption by Commission in 2024, suggesting partial depth refugia for these taxa.
- A Relative Benthic Status (RBS) assessment is presented at the scale of the orange roughy FMAs, indicating that for most taxa RBS is >0.8 for most fishing effort and abundance sensitivity scenarios, with some exceptions.
- It should be noted the hypothetical future fishing effort scenario does not account for the reduction in orange roughy catch limits for a number of FMAs under CMM 03a-2023 Deepwater Species (sprfmo.int).

4.8 UNCERTAINTIES, NEXT STEPS AND RESEARCH REQUIREMENTS

The following non-exhaustive list includes information gaps and needs identified during the development of this bottom fishery impact assessment.

4.8.1 Key fish stocks

- Stock structure for key target stocks (ORY, ALF, BWA, HAU, etc.).
- Key biological information (growth, longevity, productivity) and indices of biomass and/or fishing mortality for key target stocks.
- Stock information and first assessment for exploratory fisheries (in progress).
- SPRFMO-specific management targets and limits for key target and other stocks.
- Limitations in the risk assessment for bycaught species.

4.8.2 Marine mammals, seabirds, reptiles, other species of concern

- Frequency of interactions of each species with each fishery, including cryptic mortality. Of particular concern is the absence of information on interactions of seabirds with squid jig fishery due to very low observer coverage in this fishery.
- Identification of seabirds, marine mammals and rare deepwater sharks and rays by fishers and observers.
- At-sea distribution, including seasonality, of species potentially at-risk from SPRFMO bottom fisheries.
- Population size and productivity estimates for species with wide distributional ranges/poorly known biology (might prevent more detailed risk assessments).

4.8.3 Benthic habitats and VMEs

4.8.3.1 Relationships between predicted probability of presence and observed abundances of VME indicator taxa

If assessment of the performance of the spatial management approach in CMM03-2023 is required in terms of abundance of VME indicator taxa, then while VME indicator taxa abundance models (e.g., Stephenson et al. 2022a) are still in development, a key requirement is to understand the relationships between predicted habitat suitability and observed abundances of VME indicator taxa on the seafloor. Results from these analyses can be used to explore and improve the post-accounting summation of the amount of VME indicator taxa abundance assumed to be protected by CMM03-2023 (Section 4.6.7) — as well as the RBS assessment of the status of VME indicator taxa (Section **Error! Reference source not found.**). A series of additional analyses were undertaken for the 2020 BFIA, building on those presented in Pitcher et al. (2019) (SC07-DW21-rev1), using predictions of HSI distribution from both the Georgian et al. (2019) models and the updated (2020) models.

Previous analyses described in SC07-DW21-rev1, based on observed abundance of *Solenosmilia* corals in parts of Australia's southeast marine region that overlapped the Georgian et al. (2019) predictions, showed that the observed *Solenosmilia variabilis* cover of the seabed was non-zero or substantive only at the highest predicted habitat suitability indices. Subsequent explorations of these relationships for additional VME indicator taxa and for additional survey datasets have identified similar results for most survey-taxa combinations but, in some cases, the relationship between predicted habitat suitability and observed abundance was different or lacking. Subsequent analyses have included other Australian research survey data plus NORFANZ survey data for the broader Tasman Sea region, as well as New Zealand research survey data for features of the Louisville Seamount Chain, and from surveys on the Challenger Plateau and Chatham Rise. Surveys have included both towed-video transects and benthic sampling. Wherever possible surveys were aggregated by sampling method (e.g., video, sled) and response metric (e.g., % cover, counts, biomass) to provide the most spatially extensive comparison in each case.

Figure 63 and 64 show example plots for observed abundance against predicted HSI for three VME indicator taxa sampled, using towed-video, by Australian and New Zealand research surveys. These examples illustrate the most frequently observed patterns: 1) a prevalence of zero observations extending well into high and very high predicted HSI, with 2) non-zero observations occurring predominantly at high and very high predicted HSI, with substantive non-zero abundances occurring almost exclusively at the highest predicted HSI in these data sets. Further details of this analysis are provided in the 2020 BFIA. While there may be a relationship between observed abundance and predicted HSI, the relationship is not simple or linear.

Various alternative fits to the observed-versus-predicted data were attempted. A constraint was that fitted parameters had to be readily synthesized across survey-type/response-metric combinations. Given the frequent pattern of typically steeply increasing observed abundance relationships at high predicted HSI, a power relationship was considered appropriate—and when fitted to the observations as a profile (observed abundance/total observed abundance) also met the requirement to be readily synthesized. Initially, a 'super smoother' running means was computed (in log space, weighted by prediction variance $1/SD^2$) to indicate the mean trend in observed abundance against predicted HSI. The 'best' power of the super-smooth profile in natural scale was estimated by searching for the best least squares fit (Rsqd) and for the nearest 1:1 relationship (slope=1) between power transformed HSI and the super-smooth profile. For each power, the goodness of fit (R^2) to the observed abundance profile was tested (raw $\text{profile}^{1/\text{root}} \sim \text{HSI}^{\text{power}}$ where the product of root and power = 'best' power). A direct linear relationship between observed abundance and predicted HSI would be indicated by a 'best' power of 1. In most cases, powers >1 were selected – and where power=1 was retained, it generally had a poor fit to the data. In the majority of cases, the estimated 'best' power closely follows the super-smooth mean profile. Finally, the estimated 'best' powers across each survey-type/response-metric combination, for each taxon, were summarized using weighted means, where the weights were goodness of fit to the observed abundance profile. Overall uncertainty was estimated as the weighted means of the lower and upper Standard Error (SE) of each fit—subject to the overall uncertainty not being less-than or greater than any fitted best estimate. The final range of overall power estimates for comparisons of observed abundance against predicted HSI for each VME taxon is shown in Table 44.

The absence of simple linear relationships between observed abundance and predicted HSI has major implications for performance assessment of the spatial arrangements under CMM 03-2023. In particular, directly summing predicted HSI will lead to over-optimistic estimates of the proportion of VME indicator taxa that are outside of areas where trawling is permitted. This arises because low to medium values of predicted HSI for most taxa will likely correspond to zero or insignificant actual VME indicator taxa abundance. Other post-accounting summations (such as based on the ROC linear and Power-relationship adjusted HSI, as used in this BFIA), substantially change the estimated amount of certain VME indicator taxa outside of trawling areas, and may provide more plausible estimates of the proportions of VME indicator taxa assumed to be protected by CMM 03-2023 than the simple linear assumption used in 2018, but also have substantive uncertainty.

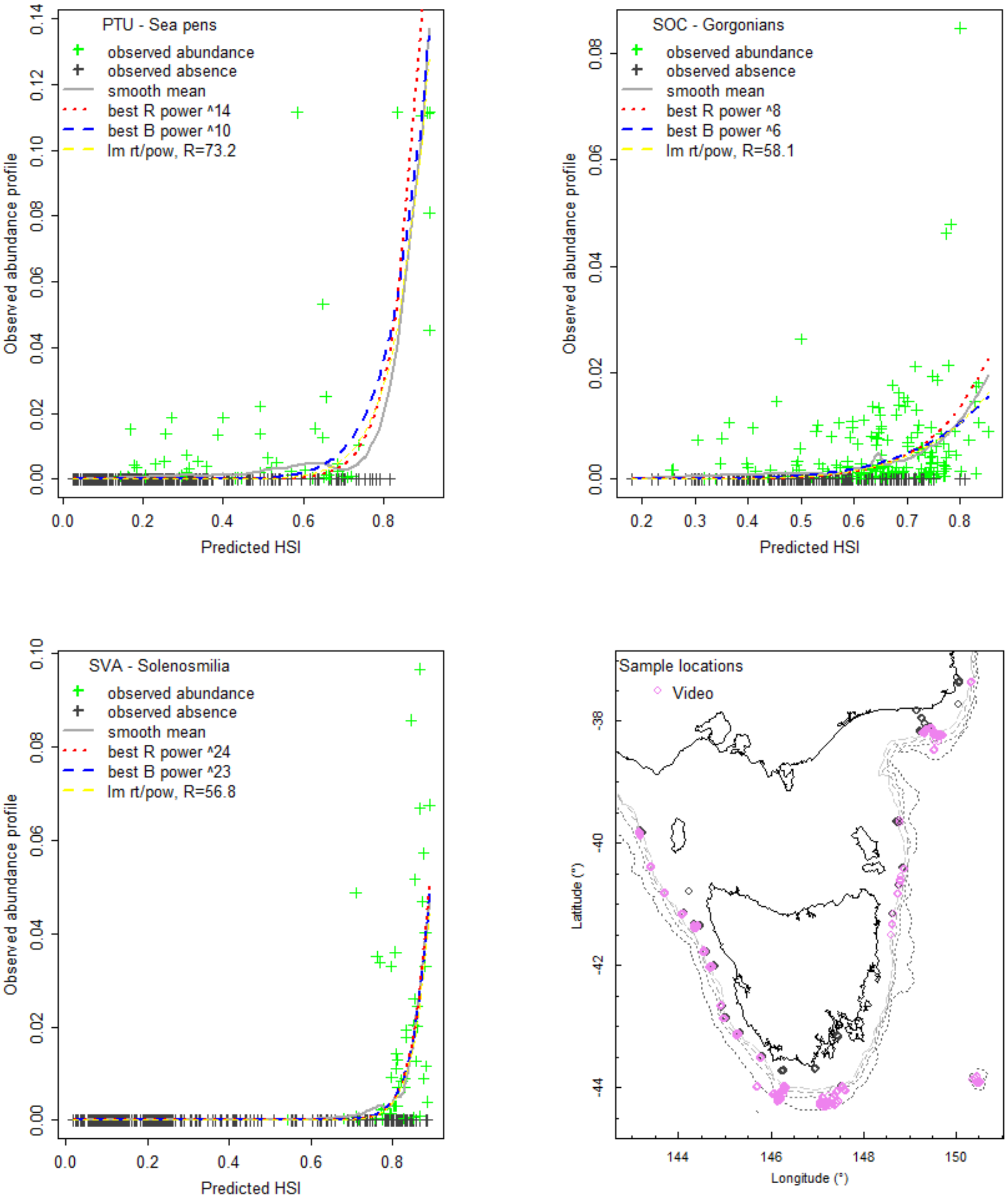

Figure 63: Comparisons of observed abundance against updated 2020 predictions of HSI for three VME indicator taxa in Australia's southeast marine region overlapping the SPRFMO 2020 prediction grid. Curves indicate alternative fits to the data: smooth running mean; best power of HSI based on Rsqd (best R); best power of HSI based on slope (best B); Rsqd of fit (R=%) to root-transformed observations against power-transformed HSI (having same overall paper as best-power). Map shows video transect locations for surveys in the region (Althaus et al. 2009; Pitcher et al. 2015).

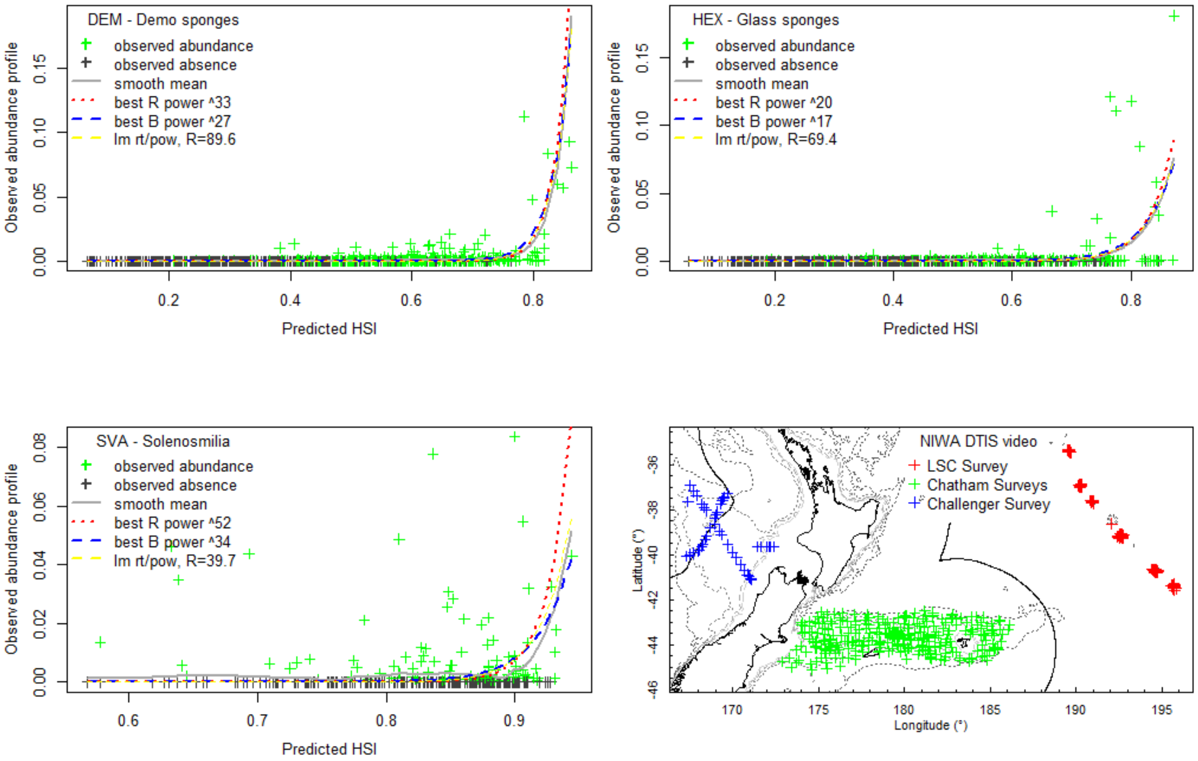

Figure 64: Comparisons of observed abundance against predicted HSI for three VME indicator taxa on New Zealand's Challenger Plateau and Chatham Rise, and on the Louisville Seamount Chain, which overlap the SPRFMO 2020 prediction grid. Curves indicate alternative fits to the data: smooth running mean; best power of HSI based on Rsqd (best R); best power of HSI based on slope (best B); Rsqd of fit (R=%) to root-transformed observations against power-transformed HSI (having same overall paper as best-power). Map shows video transect locations for surveys in the region (Bowden 2011; Clark et al. 2015).

Table 44: Final range of overall power estimates for comparisons of observed abundance against predicted HSI.

	Range of Power		
Taxon	Low	Mean	High
COB	3.3	4.1	5.7
COR	7.0	9.1	12.7
DEM	26.0	33.3	49.3
ERO	5.6	7.8	10.0
GDU	1.0	1.0	1.0
HEX	9.1	13.3	18.0
MOC	5.3	6.4	7.5
PTU	11.7	22.3	52.7
SOC	3.8	7.4	26.7
SVA	29.0	33.2	44.0

4.8.3.2 Potential over-prediction of the SPRFMO HSI modelling

Outputs from the previous section, regarding relationships between predicted habitat suitability and observed abundances of VME indicator taxa, also provide insight into potential over-prediction of habitat suitability for VME indicator taxa by the SPRFMO 1km HSI modelling. Similar to SC07-DW21-rev1 (Pitcher et al. 2019), this involves comparing the SPRFMO predictions with existing observations data, particularly where there is zero observed abundance at increasingly high predicted HSI values.

Figure 63 and 64 in the previous section show example plots for observed abundance against predicted HSI for three VME indicator taxa sampled by towed-video in Australian and New Zealand research surveys. A consistently observed pattern in similar plots for other taxa is the prevalence of observed zero abundances extending well into high and very high predicted HSI.

There are two key potential explanations for these patterns: 1) the grain-size of the sampling that provides the observations is 1000-3000m² whereas the HSI predictions are for larger 1×1km grid cells, which leads to 'false-zero' observations; 2) 'missing predictors' in the underlying HSI modelling and predictions, which leads to high predicted HSI on seabed types where VME indicator taxa do not occur. Both of these issues affect these data; the important question is their relative magnitude. A simulation of the sampling process (using gamma distributions with scale and shape informed by real data for *Solenosmilia* sampling in 2×12.5m segments of 1-3 km long video transects from one NIWA survey on the LSC to characterise a range of transect means and sample variances) suggest that 'false-zeroes' only occur when the expected grid-cell mean abundance is very low (lowest 9% of the expected range). However, observed zeroes frequently occur across the full range of predicted HSI, suggesting that the issue of the prevalence of observed zeroes is much more substantive than can be explained by sampling grain-size alone. Many of the VME indicator taxa do not live on sediments but require hard and/or rocky substratum, yet this predictor is not available to the HSI modelling or predictions in SPRFMO (although percent mud and percent gravel were included in the models, as was variability in bathymetry, as sourced these predictors were very broad scale and provide only indirect proxies for hard substratum at scales larger than required for taxa that require hard/rock substratum). Adding such an unknown factor that causes zero observations when >zero is expected was added to the gamma simulation and generated patterns with a clear split between the zero and >zero observations. This suggests that there may be one or more missing predictors in the underlying HSI models causing the high prevalence of zero observations as predicted HSI increases, such as hard/rocky substrate.

Further work is required to understand why there is a disparity between the observed over-prediction demonstrated in this section, the uncertain and variable relationships between observed abundance and predicted HSI in the previous section, and the very good binary performance results of the presence models described in section 4.4.2.2 (Table 24).

The missing predictors issue cannot be resolved in the short term because it requires substantial amounts of new information.

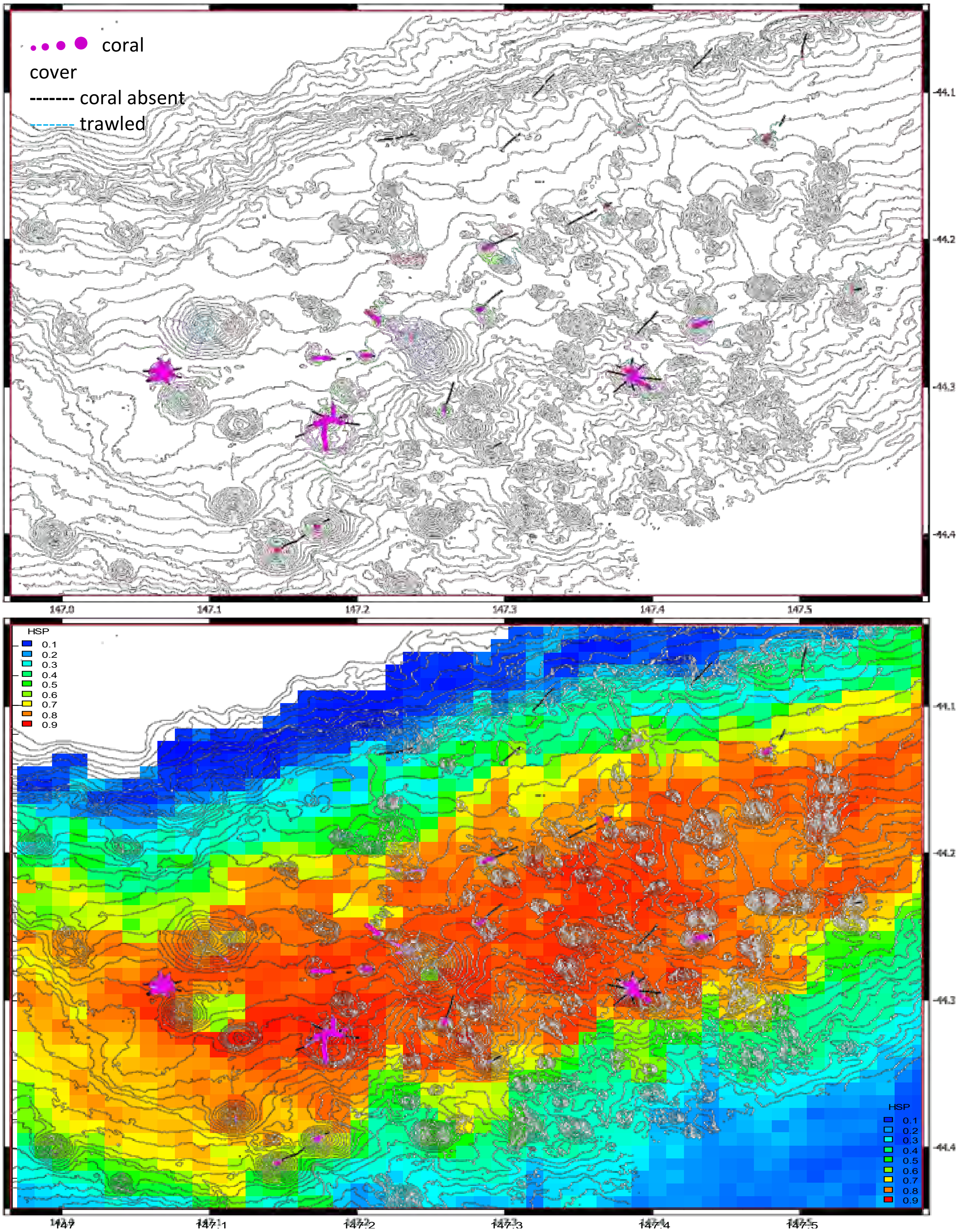

Figure 65: (Top) Map of the southern Tasmanian seamounts showing cover of *Solenosmilia* corals observed in video transects (Williams et al. 2020). *Solenosmilia* is restricted to rocky upper flanks of seamounts and a few rocky pinnacles on the adjacent slope in the appropriate depth range — between seamounts and pinnacles, the seabed is sedimentary substratum where *Solenosmilia* does not occur. (Bottom) Map with underlay of the 2020 SPRFMO predictions, showing high predicted HSI all along the slope in the depth band, and many sedimentary grid cells with medium-to-high HSI and corresponding observations of zero corals.

4.8.3.3 Estimating the catchability of VME indicator taxa

Bottom trawl gear, designed to catch fish, is relatively inefficient at catching benthic invertebrates, including vulnerable marine ecosystem (VME) indicator taxa. Depending on their size and structure, some organisms may be broken into small fragments and lost from the net before it is recovered to the surface for examination of the bycatch, while other organisms might be able to withstand or avoid the passage of the trawl net and therefore not be included in the bycatch. Estimating catchability of benthic bycatch is important for informing future review of the VME encounter protocol included in CMM03-2023 by allowing the potential extent of the impact on the VME corresponding to a given encounter threshold level to be estimated. Knowing the catchability would also inform a review of the appropriateness of the encounter thresholds themselves. However, the relationship between the biomass of benthic bycatch recorded on the surface vs the biomass on the seafloor is poorly understood.

Previous analyses for SPRFMO described in Pitcher et al. (2019, SC7-DW21-rev1), Geange et al. (2019, SC7-DW14) and the 2020 BFIA showed that fish-trawls typically catch (into the net) only very small proportions of VME indicator taxa abundance on the seabed, and that catchability of VME indicator taxa was taxa-dependent (likely reflecting morphological differences determining taxa-specific susceptibility to impacts from bottom trawl gear). Quantitative catchability estimates for VME indicator taxa from these previous studies were only available for a subset of taxa and remained uncertain (i.e., catchability estimates had a wide ranges of possible values), in large part because of the availability and quality of the data. Since these studies, a substantial amount of new data has become available from within the New Zealand EEZ (e.g., towed camera data from Campbell Plateau, Anderson et al. 2021) which could be used to augment previous analyses, and some trawl headline camera imagery is of potential use also (e.g., NORFANZ survey, Clark and Roberts 2008).

Stephenson et al. (2022c, SC10-DW04) describe the most recent analysis exploring catchability of VME indicator taxa by trawl gears within the SPRFMO area. This work concluded that either “paired” (e.g., a comparison of trawl catches with density estimates from samples taken nearby by separate trawl or video camera) or “co-located” (e.g., comparison of trawl catches with density estimates from video taken from trawl headline camera) approaches were the most appropriate to provide robust estimates of catchability, and collated available datasets to undertake such analyses. Results from these analyses are compared with previous estimates from other relevant studies in Table 45.

Stephenson et al. (2022c), consistent with previous studies, found that in general the catchability of VME indicator taxa by bottom trawls is very low to low (<5%), but for some taxa it can be moderately (5-10%) or relatively high (>20%) (Table 45). In addition to variation by taxa, the previous and Stephenson et al. (2022c) paired data analysis for SPRFMO (the most comparable analyses), indicate that catchability can vary by geographic area and depth (Table 45). However, there are a number of issues that relate to these catchability estimates that provide cause for concern about their robustness, despite all the measures that were taken to make them as reliable as possible. These are discussed in more detail by Stephenson et al. (2022c), but include low sample sizes, difficulties in sampling the same area of seabed, scaling the camera footprint to the width of a trawl, difficulty observing smaller organisms with cameras and biomass conversion factors.

Catchability estimates for VME indicator taxa derived from co-located analyses are considered likely to be more reliable. However, the availability of data for such analyses are very limited in the region, with only one dataset from the New Zealand EEZ being included in Stephenson et al. (2022c). Although it is possible that such data could become available from headline camera surveys conducted by the fishing industry in the New Zealand EEZ, even these data will likely be insufficient to determine reliable catchability estimates for some of the reasons indicated above for co-located data. Stephenson et al. (2022c) also provide recommendations for development of a research programme to determine catchability for VME indicator taxa.

Table 45. Estimates of catchability (%) for VME indicator taxa from previous studies compared to the present study. Estimates are recorded in this table only if the published study provides information that allows the estimate to be allocated directly to the VME indicator taxa categories used by SPRFMO, and if estimates are made using direct comparisons with bycatch data from bottom fish trawls (from either co-located or paired analyses). * = estimates >100%, which are excluded as obviously unreliable estimates.

	Sainsbury et al. (1997)	Wassenberg et al. (2002)	Kenchington et al. (2011)	Chimienti et al. (2018)	Geange et al. (2019) (Louisville Seamount Chain)	Stephenson et al. (2022c) (Chatham Rise)	Stephenson et al. (2022c) (Chatham Rise)	Stephenson et al. (2022c) (Challenger Plateau)	Stephenson et al. (2022c) (Campbell Plateau)
VME indicator taxon	**Catchability (%)**								
Gorgonian Alcyonacea	-	0-2	-	-	<0.01	0	0.19	-	0
Stylasteridae	-	-	-	-	0.07	-	*	-	0
Scleractinia	-	-	-	-	21.67	-	2.88	-	0
Antipatharia	-	-	-	-	0.01	-	2.44	-	-
Pennatulacea	-	-	3.7-8.2	0.9	0	1	0.06	-	-
Brisingida	-	-	-	-	<0.01	*	2.29	-	0
Porifera	8	11.1-27.3	0.3-1.6	-	0.21	-	*	10.71	1.45
Actiniaria	-	-	-	-	0.01	*	5.27	-	3.57
Bryozoa	-	-	-	-	-	-	0	-	0
Zoantharia	-	-	-	-	-	*	*	-	-
Hydrozoa	-	-	-	-	-	-	4.28	-	0
Alcyonacea	-	1.6	-	-	-	-	0	-	-
Crinoidea	-	-	-	-	-	-	0	-	0

4.8.3.4 *Other uncertainties*

- Distribution (and abundance) of VME indicator taxa and other VME indicator taxa uncertainties in modelled distributions, as well as in model projections in low environmental predictor resolution areas.
- While abundance models for VME indicator taxa are under development, there remains a need for more abundance/biomass data (particularly in areas with low environmental coverage) to support this further.
- The coarse taxonomic resolution of some of the HSI and abundance models may mask ecological patterns and vulnerabilities at the scale of populations. Aggregating species by taxonomic similarity is a common approach to overcome difficulties in analysis

where the data are limited (e.g., for the development of habitat suitability models) or where species-level identifications are difficult (e.g., for the identification of VME indicator taxa by at-sea observers). While 231 species and 281 genera of VME indicator taxa have been identified, only 18 habitat suitability models have been developed. In addition to known species there are cryptic and un-named species. this This approach assumes that different species within a higher-level taxonomic group have similar characteristics affecting their vulnerability and distribution. This may not always be true. Diverse life-history traits, distribution patterns, and/or meta-population dynamics within coarser taxonomic resolutions can lead to the ecological patterns and vulnerabilities at the population/species level being obscured. This limits SPRFMO's ability to manage SAIs at the community and population level based on data aggregated into coarse taxonomic groupings.

  - The relationship (if any) between habitat suitability and abundance is uncertain and difficult to estimate. There is a need to continue to examine the relationship between HSI indices and abundance of VME indicator taxa to understand difference between presence and abundance models, and the non-linear relationships between HSI and abundance.
  - Quantify the uncertainties around the environmental variables used for modelling the habitat suitability of for VME indicator taxa, and consider how to feed that uncertainty into the predictive models.
  - For the naturalness estimates, include uncertainties in the footprint estimate (might be relevant at small spatial scales) and in the depletion/recovery parameters for VME indicator taxa (i.e., include more site-, method- and taxon-specific estimates of d and R parameters for estimating naturalness and conducting RBS assessments).
  - Investigate automated methods for making polygons to define a range of different features within the seascape to facilitate post-accounting at a range of spatial scales or subsets of features.
  - Continue to investigate the effects of sensitivity in model assumptions/parameters

2. Management measures
   - Propagation and accounting of uncertainties in prioritization tools (post-accounting)
   - SPRFMO-specific management targets and limits, including spatial scale
   - Operational definitions of SAI (refers again to spatial scale), ideally with FAO as part of an across-RFMO initiative.

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Appendix A - List of key species codes, scientific names and common names used

FAO Code	NZ Code	Scientific Name	Common Name
ALF	BYX	*Beryx splendens, B. decadactylus*	Alfonsino & Long-finned beryx
BOE	BOE	*Allocyttus niger*	Black oreo
BWA	BNS	*Hyperoglyphe antarctica*	Bluenose/blue-eye trevalla
CJM	JMM	*Trachurus murphyi*	Chilean jack mackerel
DGS	SPD	*Squalus spp.*	Spiny dogfish, northern spiny dogfish
EDR	SBO	*Pseudopentaceros richardsoni*	Southern boarfish
EGD		*Epigonus denticulatus*	Pencil (or bigeye) cardinalfish
EPI	CDL	*Epigonus telescopus*	Deepsea cardinalfish
GIS	N/A	*Dosidichus gigas*	Jumbo flying squid
GRN	HOK	*Macruronus novaezelandiae*	Hoki, blue grenadier
HAU	HPB	*Polyprion oxygeneios, P. americanus*	Wreckfish (Hapuku & Bass)
MOW	KTA	*Nemadactylus* spp.	King tarakihi
ONV	SOR	*Neocyttus rhomboidalis*	Spiky oreo
ORY	ORH	*Hoplostethus atlanticus*	Orange roughy
RIB	RIB	*Mora moro*	Ribaldo
ROK	SPE	*Helicolenus* spp.	Sea perch
RTX	RAT	*Macrouridae (Family)*	Rattails
RXX	SKI	*Rexea spp.*	Gemfish, southern kingfish
SCK	BSH	*Dalatias licha*	Seal shark
SEM	WAR	*Seriollela brama*	Common warehou
SEP	SWA	*Seriollela punctata*	Silver warehou
SNK	BAR	*Thyrsites atun*	Barracouta
SSO	SSO	*Pseudocyttus maculatus*	Smooth oreo
TAK	TAR	*Nemadactylus macropterus*	Tarakihi/jackass morwong
TOA	TOT	*Dissostichus mawsoni*	Antarctic toothfish
TOP	PTO	*Dissostichus eleginoides*	Patagonian toothfish
YTC	KIN	*Seriola lalandi*	Kingfish

Appendix B - List of Teleost and Chondrichthyan Species Included in the SPRFMO Ecological Risk Assessments

Species name	**Common name**	**Teleost/Chondrichthyan**	**FAO Code (3-alpha)**
Abalistes stellaris	Starry Triggerfish	Teleost	AJS
Alepocephalus australis	Smallscale Slickhead	Teleost	AVS
Allocyttus niger	Black Oreodory	Teleost	BOE
Allocyttus verrucosus	Warty Oreodory	Teleost	ALL
Allomycterus pilatus	Australian Burrfish	Teleost	AYT
Alopias superciliosus	Bigeye Thresher	Chondrichthyan	BTH
Alopias vulpinus	Thresher Shark	Chondrichthyan	ALV
Amblyraja hyperborea	Amblyraja hyperborea	Chondrichthyan	#N/A
Anoplogaster cornuta	Fangtooth	Teleost	AGW
Antimora rostrata	Violet Cod	Teleost	ANT
Aphareus rutilans	Rusty Jobfish	Teleost	ARQ
Aprion virescens	Green Jobfish	Teleost	AVR
Apristurus albisoma	Apristurus albisoma	Chondrichthyan	#N/A
Apristurus ampliceps	Apristurus ampliceps	Chondrichthyan	#N/A
Apristurus australis	Apristurus sp G	Chondrichthyan	#N/A
Apristurus exsanguis	Apristurus exsanguis	Chondrichthyan	#N/A
Apristurus garricki	Apristurus garricki	Chondrichthyan	#N/A
Apristurus longicephalus	Smoothbelly Catshark	Chondrichthyan	CSF
Apristurus melanoasper	Apristurus melanoasper	Chondrichthyan	#N/A
Apristurus pinguis	Apristurus pinguis	Chondrichthyan	#N/A
Apristurus platyrhynchus	Borneo catshark	Chondrichthyan	APZ
Apristurus sinensis	Apristurus sp A	Chondrichthyan	ASI
Argentina elongata	Argentina elongata	Teleost	ARE
Bassanago hirsutus	Deepsea Conger	Teleost	CBH
Bathyraja eatonii	[a skate]	Chondrichthyan	BEA
Bathyraja richardsoni	Richardson's ray	Chondrichthyan	BYQ
Bathyraja shuntovi	Bathyraja shuntovi	Chondrichthyan	BYU
Bathytoshia brevicaudata	Short-tail stingray	Chondrichthyan	#N/A
Bathytoshia lata	Brown stingray / Black Stingray	Chondrichthyan	#N/A
Benthodesmus elongatus	Slender Frostfish	Teleost	BDL
Beryx decadactylus	Imperador	Teleost	BXD
Beryx splendens	Alfonsino	Teleost	BYS
Bodianus perditio	Goldspot Pigfish	Teleost	BDT
Brama brama	Ray's Bream	Teleost	POA
Brochiraja asperula	Brochiraja asperula	Chondrichthyan	#N/A
Brochiraja heuresa	Brochiraja heuresa	Chondrichthyan	#N/A
Brochiraja leviveneta	Brochiraja leviveneta	Chondrichthyan	#N/A
Brochiraja spinifera	Brochiraja spinifera	Chondrichthyan	#N/A
Brochiraja vitticauda	Brochiraja vitticauda	Chondrichthyan	#N/A
Caprodon longimanus	Longfin Perch	Teleost	RNL
Carangoides orthogrammus	Island trevally	Teleost	NGT
Caranx lugubris	Black Trevally	Teleost	NXU
Caranx sexfasciatus	Bigeye Trevally	Teleost	CXS
Carcharhinus altimus	Bignose Shark	Chondrichthyan	CCA
Carcharhinus galapagensis	Galapagos Shark	Chondrichthyan	CCG
Carcharodon carcharias	White Shark	Chondrichthyan	WSH
Centriscops humerosus	Banded Bellowsfish	Teleost	CUQ
Centroberyx affinis	Redfish	Teleost	CXF
Centroberyx gerrardi	Bight Redfish	Teleost	CXZ

Species name	**Common name**	**Teleost/Chondrichthyan**	**FAO Code (3-alpha)**
Centrolophus niger	Rudderfish	Teleost	CEO
Centrophorus granulosus	Gulper Shark	Chondrichthyan	GUP
Centrophorus harrissoni	Harrisson's Dogfish	Chondrichthyan	CEU
Centrophorus moluccensis	Endeavour Dogfish	Chondrichthyan	CEM
Centrophorus squamosus	Leafscale Gulper Shark	Chondrichthyan	GUQ
Centroscyllium kamoharai	Centroscyllium kamoharai	Chondrichthyan	CYK
Centroscymnus coelolepis	Portuguese Dogfish	Chondrichthyan	CYO
Centroscymnus owstonii	Owston's Dogfish	Chondrichthyan	#N/A
Centroselachus crepidater	Golden Dogfish	Chondrichthyan	#N/A
Cephalopholis cyanostigma	Bluespotted Rockcod	Teleost	CFY
Cephalopholis sonnerati	Tomato Rockcod	Teleost	EFT
Cephaloscyllium signourum	Flagtail swellshark	Chondrichthyan	#N/A
Cetorhinus maximus	Basking Shark	Chondrichthyan	BSK
Chauliodus sloani	Sloane's Viperfish	Teleost	CDN
Chelidonichthys kumu	Red Gurnard	Teleost	KUG
Chimaera carophila	Chimaera carophila	Chondrichthyan	#N/A
Chimaera fulva	Southern Chimaera	Chondrichthyan	#N/A
Chimaera lignaria	Giant Chimaera	Chondrichthyan	#N/A
Chimaera macrospina	Longspine Chimaera	Chondrichthyan	#N/A
Chimaera panthera	Chimaera panthera	Chondrichthyan	#N/A
Chlamydoselachus anguineus	Frill Shark	Chondrichthyan	HXC
Cirrhigaleus australis	Cirrhigaleus australis	Chondrichthyan	#N/A
Cnidoglanis macrocephalus	Estuary Cobbler	Teleost	CNM
Coelorinchus fasciatus	Banded Whiptail	Teleost	CQF
Coelorinchus kaiyomaru	Kaiyomaru Whiptail	Teleost	MCK
Coelorinchus oliverianus	Hawknose grenadier	Teleost	CKV
Cyttus australis	Silver Dory	Teleost	ZCU
Cyttus novaezealandiae	New Zealand Dory	Teleost	ZCN
Cyttus traversi	King Dory	Teleost	ZCT
Dalatias licha	Black shark	Chondrichthyan	SCK
Deania calceus	Brier Shark	Chondrichthyan	#N/A
Deania quadrispinosa	Longsnout Dogfish	Chondrichthyan	SDQ
Derichthys serpentinus	Deepwater Neck Eel	Teleost	ADD
Diagramma pictum	Painted Sweetlip	Teleost	DGP
Diastobranchus capensis	Basketwork Eel	Teleost	SDC
Dipturus acrobelus	Deepwater Skate	Chondrichthyan	#N/A
Dipturus innominatus	Dipturus innominatus	Chondrichthyan	DPQ
Diretmichthys parini	Black Spinyfin	Teleost	SFN
Diretmus argenteus	Silver spinyfin	Teleost	DUU
Dissostichus eleginoides	Patagonian toothfish	Teleost	TOP
Dissostichus mawsoni	[an icefish]	Teleost	TOA
Echinorhinus brucus	Bramble Shark	Chondrichthyan	SHB
Echinorhinus cookei	Prickly Shark	Chondrichthyan	ECK
Elagatis bipinnulata	Rainbow Runner	Teleost	RRU
Emmelichthys nitidus	Redbait	Teleost	EMM
Epigonus robustus	Robust Deepsea Cardinalfish	Teleost	EGR
Epigonus telescopus	Black Deepsea Cardinalfish	Teleost	EPI
Epinephelus coioides	Orange-spotted Grouper	Teleost	ENI
Epinephelus cyanopodus	Purple Rockcod	Teleost	EPY
Epinephelus ergastularius	Banded Rockcod	Teleost	#N/A
Epinephelus fasciatus	Blacktip Rockcod	Teleost	EEA
Epinephelus fuscoguttatus	Flowery Rockcod	Teleost	EWF

Species name	**Common name**	**Teleost/Chondrichthyan**	**FAO Code (3-alpha)**
Epinephelus maculatus	Highfin Grouper	Teleost	EEC
Epinephelus morrhua	Comet Grouper	Teleost	EEP
Epinephelus quoyanus	Longfin Rockcod	Teleost	EFQ
Epinephelus retouti	Red-tipped grouper	Teleost	EWR
Epinephelus septemfasciatus	Convict Grouper	Teleost	EIF
Etelis carbunculus	Ruby Snapper	Teleost	ETA
Etelis coruscans	Flame Snapper	Teleost	ETC
Etmopterus bigelowi	Smooth Lanternshark	Chondrichthyan	ETB
Etmopterus granulosus	Etmopterus granulosus	Chondrichthyan	ETM
Etmopterus litvinovi	Etmopterus litvinovi	Chondrichthyan	#N/A
Etmopterus lucifer	Blackbelly Lanternshark	Chondrichthyan	ETF
Etmopterus molleri	Moller's Lanternshark	Chondrichthyan	ETL
Etmopterus pusillus	Slender Lanternshark	Chondrichthyan	ETP
Etmopterus pycnolepis	Etmopterus pycnolepis	Chondrichthyan	#N/A
Etmopterus unicolor	Bristled Lanternshark	Chondrichthyan	ETJ
Etmopterus viator	Etmopterus viator	Chondrichthyan	EZT
Euprotomicroides zantedeschia	Euprotomicroides zantedeschia	Chondrichthyan	EUZ
Euprotomicrus bispinatus	Pygmy Shark	Chondrichthyan	EUP
Galeocerdo cuvier	Tiger Shark	Chondrichthyan	TIG
Galeorhinus galeus	School Shark	Chondrichthyan	GAG
Gempylus serpens	Snake Mackerel	Teleost	GES
Genypterus blacodes	Pink Ling	Teleost	CUS
Gnathanodon speciosus	Golden Trevally	Teleost	GLT
Gollum attenuatus	Gollum attenuatus	Chondrichthyan	CPG
Grammicolepis brachiusculus	Thorny Tinselfish	Teleost	GMG
Gymnocranius euanus	Paddletail Seabream	Teleost	GMQ
Gymnocranius grandoculis	Robinson's Seabream	Teleost	GMW
Halargyreus johnsonii	Slender Cod	Teleost	MHJ
Harriotta haeckeli	Harriotta haeckeli	Chondrichthyan	HCH
Harriotta raleighana	Bigspine Spookfish	Chondrichthyan	HCR
Helicolenus percoides	Reef Ocean Perch	Teleost	HFR
Heptranchias perlo	Sharpnose Sevengill Shark	Chondrichthyan	HXT
Hexanchus griseus	Bluntnose Sixgill Shark	Chondrichthyan	SBL
Hexanchus nakamurai	Bigeye Sixgill Shark	Chondrichthyan	HXN
Hoplostethus atlanticus	Orange Roughy	Teleost	ORY
Hoplostethus intermedius	Blacktip Sawbelly	Teleost	#N/A
Hydrolagus bemisi	Hydrolagus bemisi	Chondrichthyan	#N/A
Hydrolagus cf affinis	Smalleyed rabbitfish	Chondrichthyan	#N/A
Hydrolagus homonycteris	Black whitefin	Chondrichthyan	#N/A
Hydrolagus lemures	Blackfin Ghostshark	Chondrichthyan	CYS
Hydrolagus novaezealandiae	Hydrolagus novaezealandiae	Chondrichthyan	CYV
Hydrolagus trolli	Hydrolagus trolli	Chondrichthyan	#N/A
Hyperoglyphe antarctica	Blue-Eye Trevalla	Teleost	BWA
Isistius brasiliensis	Smalltooth Cookiecutter Shark	Chondrichthyan	ISB
Isurus oxyrinchus	Shortfin Mako	Chondrichthyan	SMA
Isurus paucus	Longfin Mako	Chondrichthyan	LMA
Kathetostoma giganteum	Giant stargazer	Teleost	STZ
Lagocephalus lagocephalus	Oceanic puffer;Ocean Puffer	Teleost	LGH
Lamna nasus	Porbeagle	Chondrichthyan	POR
Lampadena speculigera	Mirror lanternfish	Teleost	LDS
Lampris guttatus	Spotted moonfish;Opah	Teleost	LAG
Latridopsis ciliaris	Blue Moki	Teleost	BMO

Species name	**Common name**	**Teleost/Chondrichthyan**	**FAO Code (3-alpha)**
Latridopsis forsteri	Bastard Trumpeter	Teleost	WLF
Latris lineata	Striped Trumpeter	Teleost	LRL
Lepidion microcephalus	Smallhead Cod	Teleost	LMF
Lepidocybium flavobrunneum	Escolar	Teleost	LEC
Lepidoperca pulchella	Eastern Orange Perch	Teleost	LDP
Lepidopus caudatus	Southern Frostfish;Frostfish	Teleost	SFS
Lepidorhynchus denticulatus	Toothed Whiptail	Teleost	LDE
Lethrinus lentjan	Red Spot Emperor	Teleost	LTS
Lethrinus miniatus	Redthroat Emperor	Teleost	LHI
Lethrinus olivaceus	Longnose Emperor	Teleost	LHO
Lethrinus rubrioperculatus	Spotcheek Emperor	Teleost	LHB
Luposicya lupus	Wolfsnout goby	Teleost	UUU
Lutjanus adetii	Hussar	Teleost	LDW
Lutjanus argentimaculatus	Mangrove Jack	Teleost	RES
Lutjanus bohar	Red Bass	Teleost	LJB
Lutjanus fulvus	Blacktail Snapper	Teleost	LJV
Lutjanus lutjanus	Bigeye Snapper	Teleost	LJL
Lutjanus malabaricus	Saddletail Snapper	Teleost	MAL
Macrourus carinatus	Ridgescale Whiptail	Teleost	MCC
Macrourus whitsoni	[a whiptail]	Teleost	WGR
Macruronus novaezelandiae	Blue Grenadier	Teleost	GRN
Melanostomias valdiviae	Valdivia black dragon fish	Teleost	MNV
Merluccius australis	Southern Hake	Teleost	HKN
Mitsukurina owstoni	Goblin Shark	Chondrichthyan	LMO
Mola mola	Ocean Sunfish	Teleost	MOX
Mora moro	Ribaldo	Teleost	RIB
Nemadactylus douglasii	Grey Morwong	Teleost	CDD
Nemadactylus macropterus	Jackass Morwong	Teleost	TAK
Neocyttus rhomboidalis	Spikey Oreodory	Teleost	ONV
Notoraja alisae	Notoraja alisae	Chondrichthyan	#N/A
Notoraja azurea	Blue Skate	Chondrichthyan	#N/A
Notoraja sapphira	Notoraja sapphira	Chondrichthyan	#N/A
Odontaspis ferox	Smalltooth Sandtiger	Chondrichthyan	LOO
Odontaspis noronhai	Odontaspis noronhai	Chondrichthyan	ODH
Ophisurus serpens	Serpent Eel	Teleost	OOS
Optivus elongatus	Slender roughy	Teleost	OVE
Oreosoma atlanticum	Oxeye Oreodory	Teleost	OOT
Ostichthys kaianus	Kai soldierfish	Teleost	HWK
Ostracion cubicus	Yellow Boxfish	Teleost	OTJ
Oxynotus bruniensis	Prickly Dogfish	Chondrichthyan	OXB
Paratrachichthys trailli	Sandpaper fish, Common roughy	Teleost	TPT
Paristiopterus labiosus	Giant Boarfish	Teleost	SWH
Parmaturus macmillani	Parmaturus macmillani	Chondrichthyan	PAE
Pentaceropsis recurvirostris	Longsnout Boarfish	Teleost	ENV
Pentaceros decacanthus	Bigspine Boarfish	Teleost	EMV
Persparsia kopua	Spangled Tubeshoulder	Teleost	PPK
Phosichthys argenteus	Silver Lightfish	Teleost	HOE
Plagiogeneion rubiginosum	Cosmopolitan Rubyfish	Teleost	RYG
Platycephalus richardsoni	Tiger Flathead	Teleost	PHI
Plectropomus leopardus	Common Coral Trout	Teleost	EMO
Plesiobatis daviesi	Giant Stingaree	Chondrichthyan	RPD
Pleuroscopus pseudodorsalis	Scaled Stargazer	Teleost	UPD

Species name	**Common name**	**Teleost/Chondrichthyan**	**FAO Code (3-alpha)**
Polyprion americanus	Bass Groper	Teleost	WRF
Polyprion oxygeneios	Hapuku	Teleost	WHA
Prionace glauca	Blue Shark	Chondrichthyan	BSH
Pristipomoides argyrogrammicus	Ornate jobfish	Teleost	LRY
Pristipomoides auricilla	Goldflag jobfish	Teleost	LWA
Pristipomoides filamentosus	Rosy Snapper	Teleost	PFM
Pristipomoides flavipinnis	Goldeneye Snapper	Teleost	LWF
Pristipomoides multidens	Goldbanded Jobfish	Teleost	LRI
Pristipomoides sieboldii	Lavender Snapper	Teleost	LRB
Pristipomoides zonatus	Oblique-banded Snapper	Teleost	LWZ
Pseudobalistes flavimarginatus	Yellowmargin Triggerfish	Teleost	UBV
Pseudocaranx georgianus	Silver Trevally	Teleost	#N/A
Pseudocarcharias kamoharai	Crocodile Shark	Chondrichthyan	PSK
Pseudocyttus maculatus	Smooth Oreodory	Teleost	SSO
Pseudopentaceros richardsoni	Pelagic Armourhead	Teleost	EDR
Pseudophycis bachus	Red Cod	Teleost	NEC
Pseudophycis breviuscula	Bastard Red Cod	Teleost	PBV
Pseudotriakis microdon	False Catshark	Chondrichthyan	PTM
Pterygotrigla picta	Spotted gurnard	Teleost	JGU
Pterygotrigla polyommata	Latchet	Teleost	BEG
Rajella challengeri	Challenger skate	Chondrichthyan	#N/A
Regalecus glesne	Oarfish ("king of herrings")	Teleost	REL
Rexea solandri	Gemfish	Teleost	GEM
Rhinochimaera pacifica	Pacific Spookfish	Chondrichthyan	RCP
Rhombosolea plebeia	Sand flounder	Teleost	RMP
Ruvettus pretiosus	Oilfish	Teleost	OIL
Schedophilus velaini	Violet warehou	Teleost	SEY
Scomber australasicus	Blue Mackerel	Teleost	MAA
Scymnodalatias albicauda	Scymnodalatias albicauda	Chondrichthyan	YSA
Scymnodalatias oligodon	Sparsetooth dogfish	Chondrichthyan	#N/A
Scymnodalatias sherwoodi	Sherwood dogfish	Chondrichthyan	YSS
Scymnodon ringens	Scymnodon ringens	Chondrichthyan	SYR
Seriola dumerilli	Amberjack	Teleost	#N/A
Seriola hippos	Samsonfish	Teleost	RLH
Seriola lalandi	Yellowtail Kingfish	Teleost	YTC
Seriola rivoliana	Highfin Amberjack	Teleost	YTL
Seriolella brama	Blue Warehou	Teleost	SEM
Seriolella caerulea	White Warehou	Teleost	SEU
Seriolella punctata	Silver Warehou	Teleost	SEP
Somniosus antarcticus	Southern Sleeper Shark	Chondrichthyan	RZZ
Somniosus longus	Somniosus longus	Chondrichthyan	#N/A
Sphoeroides pachygaster	Balloonfish	Teleost	TSP
Sphyraena jello	Pickhandle barracuda	Teleost	BAC
Squaliolus aliae	Smalleye Pygmy Shark	Chondrichthyan	QUA
Squalus acanthias	Whitespotted Spurdog	Chondrichthyan	DGS
Squalus albifrons	Eastern Highfin Spurdog	Chondrichthyan	#N/A
Squalus cholorculus	Greeneye Spurdog	Chondrichthyan	#N/A
Squalus fernandezianus	Squalus fernandezianus	Chondrichthyan	#N/A
Squalus griffini	Northern Spiny Dogfish	Chondrichthyan	#N/A
Squalus megalops	Piked Spurdog;Spikey Dogfish	Chondrichthyan	DOP
Squalus montalbani	Philippine Spurdog	Chondrichthyan	#N/A
Taeniurops meyeni	Blotched Fantail Ray	Chondrichthyan	#N/A

Species name	**Common name**	**Teleost/Chondrichthyan**	**FAO Code (3-alpha)**
Tetragonurus cuvieri	Smalleye Squaretail	Teleost	TGV
Tetronarce nobiliana	Electric ray	Chondrichthyan	#N/A
Tetronarce tremens	Tetronarce tremens	Chondrichthyan	#N/A
Thyrsites atun	Barracouta	Teleost	SNK
Triodon macropterus	Threetooth Puffer	Teleost	TDU
Tubbia tasmanica	Tasmanian Rudderfish	Teleost	TUT
Typhlonarke aysoni	Typhlonarke aysoni	Chondrichthyan	NTY
Variola albimarginata	White-edge Coronation Trout	Teleost	VRA
Variola louti	Yellowedge Coronation Trout	Teleost	VRL
Wattsia mossambica	Mozambique Seabream	Teleost	WTM
Zameus squamulosus	Velvet Dogfish	Chondrichthyan	#N/A
Zanclistius elevatus	Blackspot Boarfish	Teleost	ZAL
Zearaja nasuta	New Zealand rough skate	Chondrichthyan	ZRN
Zenopsis nebulosa	Mirror Dory	Teleost	#N/A
Zeus faber	John Dory	Teleost	JOD

Appendix C - Interactions of bottom fisheries with seabirds, marine mammals, reptiles and other species of concern

Reported interactions (SPRFMO database) of bottom fisheries with marine mammals, seabirds, reptiles and other species of concern and revised classifications following detailed review of records by Australia or New Zealand (O = reported by observer, F = reported by fisher)

Flag	Method	Date	Area	Target	Capture	Scientific name	Common name (no. discarded or kg retained)	Revised classification
AU (F)	Line	Apr-2015	Gascoyne	MZZ	PRX	Procellariidae	Petrels and shearwaters nei (1)	No change
AU (F)	Line	Oct-2016	Gascoyne	MZZ	PFC	*Puffinus carneipes*	Flesh-footed shearwater (1)	No change
AU (F)	Line	Jun-2016	Capel Bank	MZZ	TUG	*Chelonia mydas*	Green turtle (2 kg retained)	No change
AU (F)	Line	Jul-2016	Capel Bank	MZZ	EZZ	Elapidae	Sea snakes nei (1)	No change
NZ (F)	Trawl	May-2010	Challenger	ORY	BSK	*Cetorhinus maximus*	Basking shark (60 kg retained)	Deleted, seal shark
NZ (F)	Trawl	Nov-2010	Challenger	ORY	BSK	*Cetorhinus maximus*	Basking shark (180 kg retained)	Deleted, seal shark
NZ (F)	Line	Oct-2015	Challenger	BWA	POR	*Lamna nasus*	Porbeagle (20 kg retained)	No change
AU (F)	Line	Jun-2016	Capel Bank	MZZ	WSH	*Carcharodon carcharias*	Great white shark (1)	No change
AU (F)	Line	Jun-2016	Capel Bank	MZZ	WSH	*Carcharodon carcharias*	Great white shark (1)	No change
AU (F)	Line	Aug-2016	Capel Bank	MZZ	WSH	*Carcharodon carcharias*	Great white shark (1)	No change
AU (F)	Line	Aug-2017	Capel Bank	MZZ	WSH	*Carcharodon carcharias*	Great white shark (1)	No change
AU (F)	Line	Jul-2018	Capel Bank	MZZ	OCS	*Carcharhinus longimanus*	Oceanic whitetip shark (5 kg retained)	Deleted, white-tip reef shark
AU (F)	Line	Jul-2018	Capel Bank	MZZ	OCS	*Carcharhinus longimanus*	Oceanic whitetip shark (5 kg retained)	Deleted, white-tip reef shark
AU (F)	Line	Aug-2018	Capel Bank	MZZ	OCS	*Carcharhinus longimanus*	Oceanic whitetip shark (7 kg retained)	Deleted, white-tip reef shark
AU (F)	Line	Aug-2018	Capel Bank	MZZ	OCS	*Carcharhinus longimanus*	Oceanic whitetip shark (9 kg retained)	Deleted, white-tip reef shark
AU (F)	Trawl	Sep-2019	Challenger	MZZ	BSK	*Cetorhinus maximus*	Basking shark (1)	No change
AU (O)	Line	Mar-2008	Capel Bank	LHI	PFC	*Puffinus carneipes*	Flesh-footed shearwater (2)	No change
NZ (O)	Line	Oct-2014	Three Kings	BWA	PWA	*Pterodroma leucoptera*	Gould's Petrel (1)	No change
NZ (O)	Trawl	Dec-2015	Lord Howe	EPI	PDM	*Pterodroma macroptera*	Great-winged petrel (2)	No change
NZ (O)	Trawl	Mar-2016	Challenger	ORY	WFS	*Pelagodroma marina*	White-faced storm petrel (1)	No change
NZ (O)	Trawl	Jul-2017	Louisville	ORY	PRX	Procellariidae	Petrels and shearwaters nei (1)	No change
NZ (O)	Trawl	Nov-2017	Lord Howe	ALF	PDM	*Pterodroma macroptera*	Great-winged petrel (1)	No change
NZ (O)	Trawl	Oct-2018	Lord Howe	ALF	PDM	*Pterodroma macroptera*	Great-winged petrel (1)	No change
NZ (O)	Line	Nov-2018	West Norfolk	HAU	PRK	*Procellaria parkinsoni*	Parkinson's petrel (1)	White-chinned petrel
NZ (O)	Line	Nov-2018	West Norfolk	HAU	ALZ	Diomedeidae	Albatrosses nei (1)	Unidentified “black-browed”
NZ (O)	Line	Nov-2018	West Norfolk	HAU	PRK	*Procellaria parkinsoni*	Parkinson's petrel (1)	No change
NZ (O)	Trawl	Dec-2015	Challenger	ORY	MYS	Mysticeti	Baleen whales nei	Deleted, decomposing
NZ (F)	Line	Dec-2020	West Norfolk	HAU	PRX	Procellariidae	Petrels and shearwaters nei (1)	
NZ (O)	Trawl	Aug-2021	Westpac Bank	ORY	PWV	*Pachyptila turtur*	Fairy prion (1)	Originally classified as White chinned petrel
NZ (O)	Line	2022		HAU	PRK	*Procellaria parkinsoni*	Parkinson's petrel (1)	
AU (F)	Line	2021		MZZ	OCS	*Carcharhinus longimanus*	Oceanic whitetip shark (3)	
AU (F)	Line	2021		MZZ	RSK	*Carcharhinidae*	Requiem sharks nei (3, 24 kg retained)	
AU (F)	Line	2021		MZZ	SRX	Rajiformes	Rays, stingrays, mantas nei (3, 96 kg retained)	

Appendix D - Seabird taxa that overlap with SPRFMO bottom fisheries

D.1: TAXA WITH KNOWN HIGH VULNERABILITY TO BYCATCH

English Common Name	**Scientific Name**	**IUCN Status**	**Min. Population**	**Documented Bycatch**
Antipodean Albatross	*Diomedea antipodensis*	Endangered (EN)	44,508	Yes
Southern Royal Albatross	*Diomedea epomophora*	Vulnerable (VU)	27,200	Yes
Wandering Albatross	*Diomedea exulans*	Vulnerable (VU)	unknown	Yes
Northern Royal Albatross	*Diomedea sanfordi*	Endangered (EN)	25,000	Yes
Buller's Albatross	*Thalassarche bulleri*	Near Threatened (NT)	61,000	Yes
Indian Yellow-nosed Albatross	*Thalassarche carteri*	Endangered (EN)	160,000	Yes
Shy Albatross	*Thalassarche cauta*	Near Threatened (NT)	60,000	Yes
White-capped Albatross	*Thalassarche steadi*	Near Threatened (NT)	*559,000	Yes
Grey-headed Albatross	*Thalassarche chrysostoma*	Endangered (EN)	250,000	Yes
Campbell Albatross	*Thalassarche impavida*	Vulnerable (VU)	49,200	Yes
Black-browed Albatross	*Thalassarche melanophris*	Near Threatened (NT)	2,100,000	Yes
Salvin's Albatross	*Thalassarche salvini*	Vulnerable (VU)	90,000	Yes
Sooty Albatross	*Phoebetria fusca*	Endangered (EN)	26,400	Yes
Light-mantled Albatross	*Phoebetria palpebrata*	Near Threatened (NT)	87,000	Yes
White-chinned Petrel	*Procellaria aequinoctialis*	Vulnerable (VU)	3,000,000	Yes
Grey Petrel	*Procellaria cinerea*	Near Threatened (NT)	160,000	Yes
Black Petrel	*Procellaria parkinsoni*	Vulnerable (VU)	*10,000	Yes
Westland Petrel	*Procellaria westlandica*	Vulnerable (VU)	16,000	Yes
Southern Giant Petrel	*Macronectes giganteus*	Least Concern(LC)	150,000	Yes
Northern Giant Petrel	*Macronectes halli*	Least Concern(LC)	17,000	Yes
Buller's Shearwater	*Ardenna bulleri*	Vulnerable (VU)	1,500,000	Yes
Flesh-footed Shearwater	*Ardenna carneipes*	Least Concern(LC)	650,000	Yes
Sooty Shearwater	*Ardenna grisea*	Near Threatened (NT)	20,000,000	Yes
Wedge-tailed Shearwater	*Ardenna pacifica*	Least Concern(LC)	5,200,000	Yes
Short-tailed Shearwater	*Ardenna tenuirostris*	Least Concern(LC)	23,000,000	Yes
Cape Petrel	*Daption capense*	Least Concern(LC)	2,000,000	Yes

* lower limit of 95% credible interval from Richard et al. (2020) NZAEBR #237.

D.2: TAXA WITH MEDIUM VULNERABILITY TO BYCATCH OR VULNERABLE TO LIGHT ATTRACTION / DECK STRIKES

English Common Name	***Scientific Name***	**IUCN Status**	**Min. Population**	**Documented Bycatch**
Fiordland Penguin	*Eudyptes pachyrhynchus*	Vulnerable (VU)	5,000	Yes
White-bellied Storm Petrel	*Fregetta grallaria*	Least Concern(LC)	300,000	Undocumented
New Zealand Storm Petrel	*Fregetta maoriana*	Critically Endangered (CR)	1	Undocumented
Black-bellied Storm Petrel	*Fregetta tropica*	Least Concern(LC)	unknown	Yes
Grey-backed Storm Petrel	*Garrodia nereis*	Least Concern(LC)	200,000	Yes
Australasian Gannet	*Morus serrator*	Least Concern(LC)	105,328	Yes
Wilson's Storm Petrel	*Oceanites oceanicus*	Least Concern(LC)	12,000,000	Yes
Slender-billed Prion	*Pachyptila belcheri*	Least Concern(LC)	7,000,000	Undocumented
Fulmar Prion	*Pachyptila crassirostris*	Least Concern(LC)	150,000	Yes
Antarctic Prion	*Pachyptila desolata*	Least Concern(LC)	50,000,000	Yes
Salvin's Prion	*Pachyptila salvini*	Least Concern(LC)	unknown	Yes
Fairy Prion	*Pachyptila turtur*	Least Concern(LC)	5,000,000	Yes
Broad-billed Prion	*Pachyptila vittata*	Least Concern(LC)	15,000,000	Yes
White-faced Storm Petrel	*Pelagodroma marina*	Least Concern(LC)	4,000,000	Yes
Common Diving Petrel	*Pelecanoides urinatrix*	Least Concern(LC)	16,000,000	Yes
Cook's Petrel	*Pterodroma cookii*	Vulnerable (VU)	670,000	Undocumented
Mottled Petrel	*Pterodroma inexpectata*	Near Threatened (NT)	60,000	Yes
White-headed Petrel	*Pterodroma lessonii*	Least Concern(LC)	600,000	Yes
Gould's Petrel	*Pterodroma leucoptera*	Vulnerable (VU)	3,000	Undocumented
Great-winged Petrel	*Pterodroma macroptera*	Least Concern(LC)	1,500,000	Yes
Grey-faced Petrel	*Pterodroma gouldi*	Least Concern(LC)	*839,000	Yes
Soft-plumaged Petrel	*Pterodroma mollis*	Least Concern(LC)	5,000,000	Undocumented
Providence Petrel	*Pterodroma solandri*	Vulnerable (VU)	100,000	Yes
Little Shearwater	*Puffinus assimilis*	Least Concern(LC)	300,000	Undocumented
Fluttering Shearwater	*Puffinus gavia*	Least Concern(LC)	100,000	Yes
Hutton's Shearwater	*Puffinus huttoni*	Endangered (EN)	300,000	Yes

* lower limit of 95% credible interval from Richard et al. (2020) NZAEBR #237.

D.3: TAXA WITH LOWER VULNERABILITY TO BYCATCH

English Common Name	*Scientific Name*	IUCN Status	Min. Population	Documented Bycatch
Kerguelen Petrel	*Aphrodroma brevirostris*	Least Concern(LC)	1,000,000	Yes
Silver Gull	*Chroicocephalus novaehollandiae*	Least Concern(LC)	1,000,000	Yes
Little Penguin	*Eudyptula minor*	Least Concern(LC)	1,000,000	Yes
Southern Fulmar	*Fulmarus glacialoides*	Least Concern(LC)	2,000,000	Yes
Gull-billed Tern	*Gelochelidon nilotica*	Least Concern(LC)	150,000	Undocumented
Blue Petrel	*Halobaena caerulea*	Least Concern(LC)	3,000,000	Undocumented
Caspian Tern	*Hydroprogne caspia*	Least Concern(LC)	240,000	Yes
Kelp Gull	*Larus dominicanus*	Least Concern(LC)	3,300,000	Yes
Pacific Gull	*Larus pacificus*	Least Concern(LC)	unknown	Undocumented
Little Pied Cormorant	*Microcarbo melanoleucos*	Least Concern(LC)	10,000	Yes
Australian Pelican	*Pelecanus conspicillatus*	Least Concern(LC)	unknown	Yes
Great Cormorant	*Phalacrocorax carbo*	Least Concern(LC)	1,400,000	Yes
Black-faced Cormorant	*Phalacrocorax fuscescens*	Least Concern(LC)	20,000	Yes
Australian Pied Cormorant	*Phalacrocorax varius*	Least Concern(LC)	unknown	Yes
Grey Noddy	*Procelsterna albivitta*	Least Concern(LC)	unknown	Undocumented
Brown Skua	*Stercorarius antarcticus*	Least Concern(LC)	10,000	Yes
Parasitic Jaeger	*Stercorarius parasiticus*	Least Concern(LC)	500,000	Yes
Pomarine Skua	*Stercorarius pomarinus*	Least Concern(LC)	250,000	Yes
White-fronted Tern	*Sterna striata*	Least Concern(LC)	24,000	Yes
Little Tern	*Sternula albifrons*	Least Concern(LC)	190,000	Undocumented
Fairy Tern	*Sternula nereis*	Vulnerable (VU)	2,500	Yes
Greater Crested Tern	*Thalasseus bergii*	Least Concern(LC)	150,000	Yes

Appendix E Details of post-accounting results to estimate the proportion of each VME indicator taxon outside the bottom trawl management areas

This appendix includes the detailed post-accounting results at and the scale of the nine orange roughy fishery management areas (FMAs).

Post accounting results are calculated using ROC_linear and Power_mean estimates of the proportion of each VME taxon in areas closed to bottom trawling using impacted and unimpacted baselines. Results are presented separately for closed areas within each Fishery Management Area as defined in CMM03-2023, and for areas proposed for adoption by Commission in 2024 to meet the required minimum level of 70% protection.

Areas closed to bottom trawling within each Fishery Management Area as defined in CMM03-2023

Table E.1. ROC-linear estimates of the proportion of each VME taxon in areas closed to bottom trawling within each FMA as defined in CMM03-2023. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each FMA using ROC_linear from the unimpacted baseline for taxa with > 1% of their Habitat Suitability Index within the FMA. Cell shading refers to taxa with more (green) than 70% of their distribution in closed areas or less (yellow) that 1% of their Habitat Suitability Index within the FMA. Taxa with > 1% of their HSI within the FMA excluded from Max and Min calculation.

	West Norfolk		North Lord Howe		Central Lord Howe		Northwest Challenger		Westpac Bank		South Tasman Rise		North Louisville		Central Louisville		South Louisville	
VME Indicator Taxon	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**
Sponges (Porifera Demospongiae)	1.13	99.35	1.14	97.65	0.13	99.85	1.23	94.56	0.10	100.00	0.04	100.00	0.11	77.51	0.01	29.15	<0.01	79.97
Sponges (Porifera Hexactinellida)	0.54	90.63	0.87	97.86	0.73	97.32	1.35	53.29	0.12	99.81	0.02	99.83	0.34	80.23	0.11	60.76	0.04	61.51
Stony corals (*Enallopsammia rostrata*)	0.96	49.66	3.76	87.44	10.78	74.19	5.43	27.10	1.36	86.58	3.99	77.99	<0.01	0.00	<0.01	0.00	0.00	NA
Stony corals (*Goniocorella dumosa*)	0.23	39.14	0.02	56.47	0.29	72.83	10.04	90.39	0.06	83.61	0.01	100.00	0.29	70.41	1.06	46.56	2.23	44.93
Stony corals (*Madrepora oculata*)	1.50	77.54	0.20	98.87	2.18	76.72	4.27	43.98	0.89	85.92	3.48	97.79	0.18	60.28	0.08	77.33	0.10	93.31
Stony corals (*Solenosmilia variabilis*)	0.40	70.79	0.14	100.00	0.20	67.71	0.17	95.34	0.41	75.50	3.68	95.46	1.52	74.24	1.33	48.78	0.97	36.06
Black corals (Antipatharia)	2.99	81.99	7.23	84.20	8.53	74.59	5.74	25.65	1.14	82.30	0.45	86.74	1.73	81.75	0.75	53.95	1.26	38.19
Gorgonians (Gorgonian Alcyonacea)	0.92	85.88	2.03	88.31	1.32	71.61	0.95	65.30	0.37	87.10	3.33	97.46	0.49	79.65	0.21	64.57	0.19	39.72
Sea pens (Pennatulacea)	0.38	90.51	1.42	92.80	0.79	94.35	1.90	75.23	0.22	99.13	1.58	100.00	0.10	80.31	0.01	67.33	<0.01	66.57
Anemones (Actiniaria)	0.13	93.26	0.42	84.10	0.51	77.13	1.68	27.56	0.12	99.30	0.17	100.00	0.00	NA	0.00	NA	0.00	NA
Hexacorals (Zoantharia)	0.92	86.92	2.03	91.56	1.81	84.44	2.07	48.43	0.40	92.70	1.99	97.85	0.08	96.15	0.01	84.77	0.03	65.44
Hydroids (Hydrozoa)	0.73	89.56	0.76	97.43	0.74	89.94	1.46	89.20	0.22	94.70	1.83	98.92	0.32	78.58	0.18	58.17	0.20	48.90
Hydrocorals (Stylasteridae)	1.85	97.08	<0.01	32.34	<0.01	0.00	0.08	98.04	<0.01	85.94	2.24	94.69	0.75	75.88	0.26	23.61	0.05	19.79
Bryozoans (Bryozoa)	0.71	89.32	0.95	95.99	0.58	91.16	1.05	88.34	0.18	95.18	1.78	99.03	0.38	79.22	0.22	57.86	0.26	47.61
‘Armless’ Stars (Brisingida)	0.53	81.29	1.34	94.14	0.85	87.35	1.38	72.99	0.32	93.78	2.41	98.48	0.15	83.93	0.14	60.16	0.21	49.39
Sea lillies and feather stars (Crinoidea)	0.84	87.88	1.18	94.32	0.77	90.53	1.19	84.78	0.23	92.66	1.88	98.61	0.38	79.28	0.23	57.98	0.25	48.14
Max		99.35		97.65		84.44		94.56		86.58		100.00		81.75		48.78		44.93
Min		77.54		84.20		71.61		25.65		82.30		77.99		74.24		46.56		38.19

Table E.2. ROC-linear estimates of the proportion of each VME taxon in areas closed to bottom trawling within each FMA as defined in CMM03-2023. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each FMA using ROC_linear from the impacted baseline for taxa with > 1% of their Habitat Suitability Index within the FMA. Cell shading refers to taxa with more (green) than 70% of their distribution in closed areas or less (yellow) that 1% of their Habitat Suitability Index within the FMA. Taxa with > 1% of their HSI within the FMA excluded from Max and Min calculation. NOTE: ROC-linear estimates are not available (NA) for six taxa.

	West Norfolk		North Lord Howe		Central Lord Howe		Northwest Challenger		Westpac Bank		South Tasman Rise		North Louisville		Central Louisville		South Louisville	
VME Indicator Taxon	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**
Sponges (Porifera Demospongiae)	1.13	99.36	1.14	97.66	0.13	99.95	1.23	94.89	0.10	100.00	0.04	100.00	0.11	77.60	0.01	31.21	<0.01	85.19
Sponges (Porifera Hexactinellida)	0.54	90.66	0.87	97.89	0.73	97.36	1.29	55.54	0.12	99.81	0.02	99.83	0.34	80.36	0.11	61.17	0.04	61.60
Stony corals (*Enallopsammia rostrata*)	0.95	50.53	3.80	87.53	10.66	75.63	4.78	30.86	1.36	87.58	3.97	78.90	<0.01	0.00	<0.01	0.00	0.00	NA
Stony corals (*Goniocorella dumosa*)	0.22	40.71	0.02	58.91	0.28	74.88	9.89	91.87	0.06	84.60	0.01	100.00	0.29	71.28	0.94	52.36	2.18	46.09
Stony corals (*Madrepora oculata*)	1.50	77.83	0.20	98.90	2.14	78.20	3.90	48.21	0.89	86.21	3.49	97.80	0.18	60.45	0.08	77.51	0.10	93.37
Stony corals (*Solenosmilia variabilis*)	0.40	71.01	0.14	100.00	0.20	69.40	0.17	95.59	0.40	76.61	3.66	95.90	1.46	75.04	1.23	52.71	0.94	37.01
Black corals (Antipatharia)	3.01	82.23	7.26	84.40	8.49	75.39	5.32	27.77	1.14	83.08	0.45	88.25	1.71	82.24	0.72	56.47	1.24	38.73
Gorgonians (Gorgonian Alcyonacea)	0.92	86.06	2.03	88.45	1.30	72.42	0.93	66.65	0.36	87.57	3.33	97.56	0.48	79.75	0.21	65.68	0.19	40.04
Sea pens (Pennatulacea)	0.38	90.52	1.42	92.84	0.79	94.36	1.89	75.82	0.22	99.13	1.59	100.00	0.10	80.37	0.01	67.55	<0.01	66.58
Anemones (Actiniaria)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexacorals (Zoantharia)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydroids (Hydrozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydrocorals (Stylasteridae)	1.85	97.11	<0.01	37.93	<0.01	0.00	0.08	98.23	<0.01	89.13	2.24	94.92	0.73	76.19	0.25	24.74	0.05	19.96
Bryozoans (Bryozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
‘Armless’ Stars (Brisingida)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sea lillies and feather stars (Crinoidea)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Max		99.36		97.66		78.20		94.89		87.58		100.00		82.24		52.71		46.09
Min		77.83		84.40		72.42		27.77		83.08		78.90		75.04		52.71		38.73

Table E.3. Power_mean estimates of the proportion of each VME taxon in areas closed to bottom trawling within each FMA as defined in CMM03-2023. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each FMA using Power_mean from the unimpacted baseline for taxa with > 1% of their Habitat Suitability Index within the FMA. Cell shading refers to taxa with more (green) than 70% of their distribution in closed areas or less (yellow) that 1% of their Habitat Suitability Index within the FMA. Taxa with > 1% of their HSI within the FMA excluded from Max and Min calculation. NOTE: Power_mean estimates are not available (NA) for six taxa.

	West Norfolk		North Lord Howe		Central Lord Howe		Northwest Challenger		Westpac Bank		South Tasman Rise		North Louisville		Central Louisville		South Louisville	
VME Indicator Taxon	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**
Sponges (Porifera Demospongiae)	<0.01	99.99	<0.01	99.05	<0.01	75.98	<0.01	52.32	<0.01	100.00	<0.01	100.00	<0.01	51.13	<0.01	1.16	<0.01	99.66
Sponges (Porifera Hexactinellida)	0.26	99.25	0.11	99.84	0.57	99.96	0.14	58.06	<0.01	99.97	<0.01	99.72	0.26	83.57	0.04	60.88	<0.01	80.57
Stony corals (*Enallopsammia rostrata*)	0.87	44.87	3.77	96.71	22.87	72.41	5.80	41.57	1.76	86.07	7.64	70.10	<0.01	78.97	<0.01	34.83	<0.01	48.31
Stony corals (*Goniocorella dumosa*)	0.62	81.51	1.15	90.43	1.20	82.64	2.89	73.86	0.25	90.77	1.38	96.88	0.36	77.86	0.33	53.92	0.50	45.17
Stony corals (*Madrepora oculata*)	1.40	79.50	0.22	96.77	1.61	72.61	4.76	46.18	1.01	87.97	2.41	96.26	0.11	69.00	0.06	69.39	0.10	72.26
Stony corals (*Solenosmilia variabilis*)	<0.01	91.24	<0.01	100.00	<0.01	83.27	<0.01	99.99	0.01	73.71	0.45	99.95	32.74	77.85	17.29	18.22	5.92	19.62
Black corals (Antipatharia)	2.53	79.95	4.66	83.59	9.25	70.89	5.40	35.01	0.98	78.05	0.80	91.38	1.03	76.66	0.59	54.69	0.87	34.86
Gorgonians (Gorgonian Alcyonacea)	1.05	78.04	2.25	82.81	1.77	64.59	0.83	69.33	0.37	72.89	3.84	96.77	0.47	83.66	0.13	64.17	0.11	39.07
Sea pens (Pennatulacea)	<0.01	94.72	0.26	99.86	0.25	99.08	1.77	97.52	0.14	100.00	0.58	100.00	<0.01	87.88	<0.01	55.29	<0.01	72.60
Anemones (Actiniaria)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexacorals (Zoantharia)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydroids (Hydrozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydrocorals (Stylasteridae)	3.73	99.57	<0.01	98.27	<0.01	44.47	0.02	97.36	<0.01	84.75	0.59	93.94	0.32	78.84	0.14	19.68	0.02	12.57
Bryozoans (Bryozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
'Armless' Stars (Brisingida)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sea lillies and feather stars (Crinoidea)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Max		99.57		96.71		82.64		97.52		87.97		96.88		77.85		18.22		19.62
Min		78.04		82.81		64.59		35.01		86.07		70.10		76.66		18.22		19.62

Table E.4. Power_mean estimates of the proportion of each VME taxon in areas closed to bottom trawling within each FMA as defined in CMM03-2023. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each FMA using Power_mean from the impacted baseline for taxa with > 1% of their Habitat Suitability Index within the FMA. Cell shading refers to taxa with more (green) than 70% of their distribution in closed areas or less (yellow) that 1% of their Habitat Suitability Index within the FMA. Taxa with > 1% of their HSI within the FMA excluded from Max and Min calculation. NOTE: Power_mean estimates are not available (NA) for six taxa.

	West Norfolk		North Lord Howe		Central Lord Howe		Northwest Challenger		Westpac Bank		South Tasman Rise		North Louisville		Central Louisville		South Louisville	
VME Indicator Taxon	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**
Sponges (Porifera Demospongiae)	<0.01	99.99	<0.01	99.08	<0.01	95.96	<0.01	52.53	<0.01	100.00	<0.01	100.00	<0.01	48.39	<0.01	1.06	<0.01	99.69
Sponges (Porifera Hexactinellida)	0.26	99.25	0.11	99.85	0.57	99.96	0.13	61.25	<0.01	99.97	<0.01	99.73	0.26	83.58	0.04	61.11	<0.01	80.67
Stony corals (*Enallopsammia rostrata*)	0.87	45.41	3.82	96.74	22.68	73.76	5.24	46.30	1.76	86.83	7.60	70.98	<0.01	79.03	<0.01	35.72	<0.01	49.17
Stony corals (*Goniocorella dumosa*)	0.62	81.89	1.15	90.59	1.19	83.55	2.77	77.11	0.25	91.40	1.38	97.08	0.35	78.43	0.30	58.02	0.49	46.08
Stony corals (*Madrepora oculata*)	1.40	79.80	0.22	96.80	1.58	74.13	4.41	49.96	1.01	88.24	2.42	96.30	0.11	69.24	0.06	70.02	0.10	72.43
Stony corals (*Solenosmilia variabilis*)	<0.01	91.26	<0.01	100.00	<0.01	83.64	<0.01	99.99	0.01	73.73	0.47	99.96	32.68	79.03	15.52	21.08	5.86	20.46
Black corals (Antipatharia)	2.54	80.28	4.67	83.90	9.18	71.87	5.06	37.45	0.97	79.20	0.80	91.86	1.01	77.18	0.57	57.43	0.86	35.55
Gorgonians (Gorgonian Alcyonacea)	1.04	78.60	2.23	83.12	1.73	65.83	0.81	70.78	0.36	74.09	3.83	96.95	0.46	83.71	0.13	65.76	0.11	39.54
Sea pens (Pennatulacea)	<0.01	94.72	0.26	99.86	0.25	99.08	1.77	97.54	0.14	100.00	0.58	100.00	<0.01	87.87	<0.01	55.31	<0.01	72.60
Anemones (Actiniaria)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexacorals (Zoantharia)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydroids (Hydrozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydrocorals (Stylasteridae)	3.73	99.57	<0.01	98.54	<0.01	59.06	0.02	97.54	<0.01	85.78	0.59	94.36	0.31	79.16	0.13	20.66	0.02	12.64
Bryozoans (Bryozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
‘Armless’ Stars (Brisingida)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sea lillies and feather stars (Crinoidea)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Max		99.57		96.74		83.55		97.54		88.24		97.08		79.03		21.08		20.46
Min		78.60		83.12		65.83		37.45		86.83		70.98		77.18		21.08		20.46

Areas closed to bottom trawling within each Fishery Management Area as proposed for adoption at Commission in 2024 to achieve a minimum level of 70% protection

Table E.5. ROC-linear estimates of the proportion of each VME taxon in areas closed to bottom trawling within each FMA as proposed for adoption at Commission in 2024 to achieve a minimum level of 70% protection. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each FMA using ROC_linear from the unimpacted baseline for taxa with > 1% of their Habitat Suitability Index within the FMA. Cell shading refers to taxa with more (green) than 70% of their distribution in closed areas or less (yellow) that 1% of their Habitat Suitability Index within the FMA. Taxa with > 1% of their HSI within the FMA excluded from Max and Min calculation.

	West Norfolk		North Lord Howe		Central Lord Howe		Northwest Challenger		Westpac Bank		South Tasman Rise		North Louisville		Central Louisville		South Louisville	
VME Indicator Taxon	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**
Sponges (Porifera Demospongiae)	1.13	99.57	1.14	97.65	0.13	99.85	1.23	99.52	0.10	100.00	0.04	100.00	0.11	77.51	0.01	100.00	<0.01	100.00
Sponges (Porifera Hexactinellida)	0.54	94.80	0.87	97.86	0.73	97.37	1.35	89.26	0.12	99.81	0.02	99.83	0.34	80.23	0.11	99.57	0.04	89.23
Stony corals (*Enallopsammia rostrata*)	0.96	80.14	3.76	87.44	10.78	76.21	5.43	74.71	1.36	86.58	3.99	77.99	<0.01	0.00	<0.01	100.00	0.00	NA
Stony corals (*Goniocorella dumosa*)	0.23	79.91	0.02	56.47	0.29	75.24	10.04	95.88	0.06	83.61	0.01	100.00	0.29	70.41	1.06	90.30	2.23	82.33
Stony corals (*Madrepora oculata*)	1.50	93.81	0.20	98.87	2.18	78.30	4.27	83.23	0.89	85.92	3.48	97.79	0.18	60.28	0.08	100.00	0.10	98.89
Stony corals (*Solenosmilia variabilis*)	0.40	87.52	0.14	100.00	0.20	71.87	0.17	99.89	0.41	75.50	3.68	95.46	1.52	74.24	1.33	92.75	0.97	80.57
Black corals (Antipatharia)	2.99	92.10	7.23	84.20	8.53	76.58	5.74	71.06	1.14	82.30	0.45	86.74	1.73	81.75	0.75	83.15	1.26	72.05
Gorgonians (Gorgonian Alcyonacea)	0.92	94.10	2.03	88.31	1.32	75.17	0.95	91.74	0.37	87.10	3.33	97.46	0.49	79.65	0.21	91.77	0.19	85.19
Sea pens (Pennatulacea)	0.38	94.05	1.42	92.80	0.79	95.87	1.90	96.85	0.22	99.13	1.58	100.00	0.10	80.31	0.01	100.00	<0.01	76.75
Anemones (Actiniaria)	0.13	99.41	0.42	84.10	0.51	77.23	1.68	80.70	0.12	99.30	0.17	100.00	0.00	NA	0.00	NA	0.00	NA
Hexacorals (Zoantharia)	0.92	94.10	2.03	91.56	1.81	85.79	2.07	86.59	0.40	92.70	1.99	97.85	0.08	96.15	0.01	95.58	0.03	76.98
Hydroids (Hydrozoa)	0.73	94.91	0.76	97.43	0.74	91.51	1.46	99.51	0.22	94.70	1.83	98.92	0.32	78.58	0.18	94.70	0.20	76.03
Hydrocorals (Stylasteridae)	1.85	98.80	<0.01	32.34	<0.01	0.00	0.08	99.57	<0.01	85.94	2.24	94.69	0.75	75.88	0.26	100.00	0.05	99.71
Bryozoans (Bryozoa)	0.71	94.72	0.95	95.99	0.58	92.76	1.05	99.78	0.18	95.18	1.78	99.03	0.38	79.22	0.22	93.48	0.26	76.96
‘Armless’ Stars (Brisingida)	0.53	91.23	1.34	94.14	0.85	89.08	1.38	97.34	0.32	93.78	2.41	98.48	0.15	83.93	0.14	91.52	0.21	73.58
Sea lillies and feather stars (Crinoidea)	0.84	94.30	1.18	94.32	0.77	92.19	1.19	99.89	0.23	92.66	1.88	98.61	0.38	79.28	0.23	93.77	0.25	76.70
Max		99.57		97.65		85.79		99.89		86.58		100.00		81.75		92.75		82.33
Min		92.10		84.20		75.17		71.06		82.30		77.99		74.24		90.30		72.05

Table E.6. ROC-linear estimates of the proportion of each VME taxon in areas closed to bottom trawling within each FMA as proposed for adoption at Commission in 2024 to achieve a minimum level of 70% protection. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each FMA using ROC_linear from the impacted baseline for taxa with > 1% of their Habitat Suitability Index within the FMA. Cell shading refers to taxa with more (green) than 70% of their distribution in closed areas or less (yellow) that 1% of their Habitat Suitability Index within the FMA. Taxa with > 1% of their HSI within the FMA excluded from Max and Min calculation. NOTE: ROC-linear estimates are not available (NA) for six taxa.

	West Norfolk		North Lord Howe		Central Lord Howe		Northwest Challenger		Westpac Bank		South Tasman Rise		North Louisville		Central Louisville		South Louisville	
VME Indicator Taxon	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**
Sponges (Porifera Demospongiae)	1.13	99.57	1.14	97.66	0.13	99.95	1.23	99.58	0.10	100.00	0.04	100.00	0.11	77.60	0.01	100.00	<0.01	100.00
Sponges (Porifera Hexactinellida)	0.54	94.81	0.87	97.89	0.73	97.41	1.29	90.25	0.12	99.81	0.02	99.83	0.34	80.36	0.11	99.57	0.04	89.22
Stony corals (*Enallopsammia rostrata*)	0.95	80.59	3.80	87.53	10.66	77.61	4.78	78.16	1.36	87.58	3.97	78.90	<0.01	0.00	<0.01	100.00	0.00	NA
Stony corals (*Goniocorella dumosa*)	0.22	80.91	0.02	58.91	0.28	77.03	9.89	96.74	0.06	84.60	0.01	100.00	0.29	71.28	0.94	90.22	2.18	82.48
Stony corals (*Madrepora oculata*)	1.50	93.95	0.20	98.90	2.14	79.81	3.90	86.09	0.89	86.21	3.49	97.80	0.18	60.45	0.08	100.00	0.10	98.89
Stony corals (*Solenosmilia variabilis*)	0.40	87.73	0.14	100.00	0.20	73.67	0.17	99.92	0.40	76.61	3.66	95.90	1.46	75.04	1.23	92.63	0.94	80.68
Black corals (Antipatharia)	3.01	92.22	7.26	84.40	8.49	77.36	5.32	72.89	1.14	83.08	0.45	88.25	1.71	82.24	0.72	82.91	1.24	72.01
Gorgonians (Gorgonian Alcyonacea)	0.92	94.20	2.03	88.45	1.30	75.97	0.93	92.89	0.36	87.57	3.33	97.56	0.48	79.75	0.21	91.94	0.19	85.18
Sea pens (Pennatulacea)	0.38	94.05	1.42	92.84	0.79	95.87	1.89	97.02	0.22	99.13	1.59	100.00	0.10	80.37	0.01	100.00	<0.01	76.75
Anemones (Actiniaria)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexacorals (Zoantharia)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydroids (Hydrozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydrocorals (Stylasteridae)	1.85	98.81	<0.01	37.93	<0.01	0.00	0.08	99.77	<0.01	89.13	2.24	94.92	0.73	76.19	0.25	100.00	0.05	99.71
Bryozoans (Bryozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
'Armless' Stars (Brisingida)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sea lillies and feather stars (Crinoidea)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Max		99.57		97.66		79.81		99.58		87.58		100.00		82.24		92.63		82.48
Min		92.22		84.40		75.97		72.89		83.08		78.90		75.04		92.63		72.01

Table E.7. Power_mean estimates of the proportion of each VME taxon in areas closed to bottom trawling within each FMA as proposed for adoption at Commission in 2024 to achieve a minimum level of 70% protection. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each FMA using Power_mean from the unimpacted baseline for taxa with > 1% of their Habitat Suitability Index within the FMA. Cell shading refers to taxa with more (green) than 70% of their distribution in closed areas or less (yellow) that 1% of their Habitat Suitability Index within the FMA. Taxa with > 1% of their HSI within the FMA excluded from Max and Min calculation. NOTE: Power_mean estimates are not available (NA) for six taxa.

	West Norfolk		North Lord Howe		Central Lord Howe		Northwest Challenger		Westpac Bank		South Tasman Rise		North Louisville		Central Louisville		South Louisville	
VME Indicator Taxon	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**
Sponges (Porifera Demospongiae)	<0.01	100.00	<0.01	99.05	<0.01	75.98	<0.01	99.93	<0.01	100.00	<0.01	100.00	<0.01	51.13	<0.01	100.00	<0.01	99.78
Sponges (Porifera Hexactinellida)	0.26	99.45	0.11	99.84	0.57	99.96	0.14	87.55	<0.01	99.97	<0.01	99.72	0.26	83.57	0.04	99.95	<0.01	96.78
Stony corals (*Enallopsammia rostrata*)	0.87	72.81	3.77	96.71	22.87	75.07	5.80	76.53	1.76	86.07	7.64	70.10	<0.01	78.97	<0.01	99.88	<0.01	72.35
Stony corals (*Goniocorella dumosa*)	0.62	91.66	1.15	90.43	1.20	84.35	2.89	92.40	0.25	90.77	1.38	96.88	0.36	77.86	0.33	91.19	0.50	79.11
Stony corals (*Madrepora oculata*)	1.40	93.86	0.22	96.77	1.61	74.89	4.76	83.57	1.01	87.97	2.41	96.26	0.11	69.00	0.06	97.57	0.10	88.47
Stony corals (*Solenosmilia variabilis*)	<0.01	98.87	<0.01	100.00	<0.01	84.72	<0.01	100.00	0.01	73.71	0.45	99.95	32.74	77.85	17.29	96.15	5.92	90.99
Black corals (Antipatharia)	2.53	90.35	4.66	83.59	9.25	73.66	5.40	75.64	0.98	78.05	0.80	91.38	1.03	76.66	0.59	84.74	0.87	73.21
Gorgonians (Gorgonian Alcyonacea)	1.05	89.45	2.25	82.81	1.77	71.13	0.83	93.06	0.37	72.89	3.84	96.77	0.47	83.66	0.13	92.33	0.11	89.00
Sea pens (Pennatulacea)	<0.01	96.01	0.26	99.86	0.25	99.58	1.77	99.89	0.14	100.00	0.58	100.00	<0.01	87.88	<0.01	100.00	<0.01	90.94
Anemones (Actiniaria)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexacorals (Zoantharia)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydroids (Hydrozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydrocorals (Stylasteridae)	3.73	99.77	<0.01	98.27	<0.01	44.49	0.02	99.51	<0.01	84.75	0.59	93.94	0.32	78.84	0.14	100.00	0.02	98.72
Bryozoans (Bryozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
‘Armless’ Stars (Brisingida)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sea lillies and feather stars (Crinoidea)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Max		99.77		96.71		84.35		99.89		87.97		96.88		77.85		96.15		90.99
Min		89.45		82.81		71.13		75.64		86.07		70.10		76.66		96.15		90.99

Table E.8. Power_mean estimates of the proportion of each VME taxon in areas closed to bottom trawling within each FMA as proposed for adoption at Commission in 2024 to achieve a minimum level of 70% protection. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each FMA using Power_mean from the impacted baseline for taxa with > 1% of their Habitat Suitability Index within the FMA. Cell shading refers to taxa with more (green) than 70% of their distribution in closed areas or less (yellow) that 1% of their Habitat Suitability Index within the FMA. Taxa with > 1% of their HSI within the FMA excluded from Max and Min calculation. NOTE: Power_mean estimates are not available (NA) for six taxa.

	West Norfolk		North Lord Howe		Central Lord Howe		Northwest Challenger		Westpac Bank		South Tasman Rise		North Louisville		Central Louisville		South Louisville	
VME Indicator Taxon	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**	**% within FMA**	**% closed**
Sponges (Porifera Demospongiae)	<0.01	100.00	<0.01	99.08	<0.01	95.96	<0.01	99.93	<0.01	100.00	<0.01	100.00	<0.01	48.39	<0.01	100.00	<0.01	99.78
Sponges (Porifera Hexactinellida)	0.26	99.45	0.11	99.85	0.57	99.96	0.13	89.17	<0.01	99.97	<0.01	99.73	0.26	83.58	0.04	99.95	<0.01	96.78
Stony corals (*Enallopsammia rostrata*)	0.87	73.32	3.82	96.74	22.68	76.40	5.24	80.99	1.76	86.83	7.60	70.98	<0.01	79.03	<0.01	99.90	<0.01	72.02
Stony corals (*Goniocorella dumosa*)	0.62	91.85	1.15	90.59	1.19	85.22	2.77	93.96	0.25	91.40	1.38	97.08	0.35	78.43	0.30	91.16	0.49	79.14
Stony corals (*Madrepora oculata*)	1.40	94.04	0.22	96.80	1.58	76.46	4.41	86.84	1.01	88.24	2.42	96.30	0.11	69.24	0.06	97.56	0.10	88.50
Stony corals (*Solenosmilia variabilis*)	<0.01	98.87	<0.01	100.00	<0.01	85.10	<0.01	100.00	0.01	73.73	0.47	99.96	32.68	79.03	15.52	95.79	5.86	91.05
Black corals (Antipatharia)	2.54	90.52	4.67	83.90	9.18	74.62	5.06	77.75	0.97	79.20	0.80	91.86	1.01	77.18	0.57	84.59	0.86	73.14
Gorgonians (Gorgonian Alcyonacea)	1.04	89.74	2.23	83.12	1.73	72.34	0.81	94.19	0.36	74.09	3.83	96.95	0.46	83.71	0.13	92.68	0.11	88.96
Sea pens (Pennatulacea)	<0.01	96.01	0.26	99.86	0.25	99.58	1.77	99.90	0.14	100.00	0.58	100.00	<0.01	87.87	<0.01	100.00	<0.01	90.94
Anemones (Actiniaria)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexacorals (Zoantharia)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydroids (Hydrozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydrocorals (Stylasteridae)	3.73	99.77	<0.01	98.54	<0.01	59.09	0.02	99.69	<0.01	85.78	0.59	94.36	0.31	79.16	0.13	100.00	0.02	98.71
Bryozoans (Bryozoa)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
'Armless' Stars (Brisingida)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sea lillies and feather stars (Crinoidea)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Max		99.77		96.74		85.22		99.90		88.24		97.08		79.03		95.79		91.05
Min		89.74		83.12		72.34		77.75		86.83		70.98		77.18		95.79		91.05

Appendix F – Estimates of the proportion of VME indicator taxa protected by historical spatial management measures

The spatial management approach has iteratively refined the areas closed to bottom trawling. Results are given presenting changes in the performance of the spatial management measures in protecting suitable habitat for each VME indicator taxon for the pre-2019 spatial management measures, the measures implement in 2019 under CMM03-2019 through to CMM03-2023, and spatial management measures proposed for adoption at Commission in 2024 to achieve a minimum level of 70% protection.

Table F.1. Estimates of the percentage of suitable habitat for each VME taxon in areas closed to bottom trawling within each Fishery Management Area as per closed areas implemented pre-2019, in CMM03-2019, and as proposed for adoption at Commission in 2024 to achieve a minimum level of 70% protection. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each Fishery Management Area using ROC_linear from the unimpacted baseline. Cell colours indicate an increase (green) or decrease (red) in spatial protection from previous spatial management measures. Bold type represents VMA taxa with > 1% of their Habitat Suitability Index within the Fishery Management Area.

VME Indicator Taxon	West Norfolk			North Lord Howe			Central Lord Howe			Northwest Challenger			Westpac Bank			South Tasman Rise			North Louisville			Central Louisville			South Louisville		
	Pre-2019	CMM03-2019	70% protection	Pre-2019	CMM03-2019	70% protection	Pre-2019	CMM03-2019	70% protection	Pre-2019	CMM03-2019	70% protection	Pre-2019	CMM03-2019	70% protection	Pre-2019	CMM03-2019	70% protection	Pre-2019	CMM03-2019	70% protection	Pre-2019	CMM03-2019	70% protection	Pre-2019	CMM03-2019	70% protection
Sponges (Porifera Demospongiae)	**91**	**99**	**100**	**95**	**98**	**98**	97	100	100	**50**	**95**	**100**	99	100	100		100	100	35	78	78	32	29	100	40	80	100
Sponges (Porifera Hexactinellida)	78	91	95	86	98	98	97	97	97	**47**	**53**	**89**	83	100	100		100	100	51	80	80	46	61	100	70	62	89
Stony corals (*Enallopsammia rostrata*)	26	50	80	**85**	**87**	**87**	**71**	**74**	**76**	**38**	**27**	**75**	**69**	**87**	**87**		**78**	**78**	0	0	0	0	0	100	NA	NA	NA
Stony corals (*Goniocorella dumosa*)	18	39	80	56	56	56	50	73	75	**22**	**90**	**96**	79	84	84		100	100	40	70	70	**25**	**47**	**90**	**49**	**45**	**82**
Stony corals (*Madrepora oculata*)	**43**	**78**	**94**	99	99	99	**59**	**77**	**78**	**17**	**44**	**83**	60	86	86		**98**	**98**	33	60	60	18	77	100	98	93	99
Stony corals (*Solenosmilia variabilis*)	28	71	88	100	100	100	56	68	72	86	95	100	59	76	76		**95**	**95**	**36**	**74**	**74**	**42**	**49**	**93**	48	36	81
Black corals (Antipatharia)	**60**	**82**	**92**	**64**	**84**	**84**	**71**	**75**	**77**	**35**	**26**	**71**	**66**	**82**	**82**		87	87	**50**	**82**	**82**	52	54	83	**43**	**38**	**72**
Gorgonians (Gorgonian Alcyonacea)	61	86	94	73	88	88	**62**	**72**	**75**	71	65	92	74	87	87		**97**	**97**	41	80	80	52	65	92	44	40	85
Sea pens (Pennatulacea)	81	91	94	**85**	**93**	**93**	92	94	96	**57**	**75**	**97**	91	99	99		**100**	**100**	45	80	80	61	67	100	62	67	77
Anemones (Actiniaria)	78	93	99	68	84	84	81	77	77	**26**	**28**	**81**	89	99	99		100	100	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexacorals (Zoantharia)	69	87	94	**80**	**92**	**92**	**82**	**84**	**86**	**49**	**48**	**87**	79	93	93		**98**	**98**	88	96	96	72	85	96	72	65	77
Hydroids (Hydrozoa)	70	90	95	95	97	97	86	90	92	**59**	**89**	**100**	85	95	95		**99**	**99**	48	79	79	46	58	95	55	49	76
Hydrocorals (Stylasteridae)	**69**	**97**	**99**	32	32	32	0	0	0	6	98	100	49	86	86		**95**	**95**	18	76	76	23	24	100	84	20	100
Bryozoans (Bryozoa)	70	89	95	90	96	96	87	91	93	**72**	**88**	**100**	88	95	95		**99**	**99**	49	79	79	46	58	93	53	48	77
‘Armless’ Stars (Brisingida)	57	81	91	**85**	**94**	**94**	83	87	89	**72**	**73**	**97**	82	94	94		**98**	**98**	60	84	84	49	60	92	52	49	74
Sea lillies and feather stars (Crinoidea)	68	88	94	**87**	**94**	**94**	86	91	92	**71**	**85**	**100**	83	93	93		**99**	**99**	51	79	79	46	58	94	54	48	77

Appendix G – Sensitivity analysis for excluding areas of low environmental coverage in HSI model inputs

This sensitivity analysis applies an environmental coverage threshold to estimate the proportion of suitable habitat for each VME indicator taxon in areas proposed to be closed to fishing to achieve a minimum level of 70% protection. Results are given for each Fisheries Management Area. For the sensitivity run in each location, the domain was clipped to cells with good environmental coverage for the respective ensemble habitat suitability model (>0.05 following Stephenson et al. 2020). No discounting for naturalness is included.

Table G.1. Estimates of the proportion of each VME indicator taxon in areas proposed for adoption at Commission in 2024 to achieve a minimum level of 70% protection with and without clipping to good environmental coverage. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each Fishery Management Area using ROC_linear from the unimpacted baseline. Cell colours indicate an increase (green) or decrease (red) in spatial protection compared to not clipping by environmental coverage. Bold type represents for taxa with > 1% of their Habitat Suitability Index within the FMA.

VME Indicator Taxon	**West Norfolk**			**North Lord Howe**			**Central Lord Howe**			**Northwest Challenger**			**Westpac Bank**			**South Tasman Rise**			**North Louisville**			**Central Louisville**			**South Louisville**		
	Unclipped	Clipped to env. coverage	% difference	Unclipped	Clipped to env. coverage	% difference	Unclipped	Clipped to env. coverage	% difference	Unclipped	Clipped to env. coverage	% difference	Unclipped	Clipped to env. coverage	% difference	Unclipped	Clipped to env. coverage	% difference	Unclipped	Clipped to env. coverage	% difference	Unclipped	Clipped to env. coverage	% difference	Unclipped	Clipped to env. coverage	% difference
Sponges (Porifera Demospongiae)	**99.57**	**99.29**	-0.27	**97.65**	**95.96**	-1.69	99.85	98.94	-0.91	**99.52**	**99.17**	-0.35	100.00	100.00	0.00	100.00	100.00	0.00	77.51	74.76	-2.75	100.00	100.00	0.00	100.00	100.00	0.00
Sponges (Porifera Hexactinellida)	94.80	88.90	-5.90	97.86	**96.31**	-1.55	97.37	97.30	-0.08	**89.26**	**80.52**	-8.74	99.81	99.72	-0.08	99.83	99.42	-0.42	80.23	76.49	-3.74	99.57	99.57	-0.01	89.23	87.68	-1.56
Stony corals (*Enallopsammia rostrata*)	80.14	80.06	-0.08	**87.44**	**87.44**	0.00	**76.21**	**76.20**	0.00	**74.71**	**74.71**	0.00	**86.58**	**86.58**	0.00	**77.99**	**77.65**	-0.34	0.00	0.00	0.00	100.00	100.00	0.00	NA	NA	
Stony corals (*Goniocorella dumosa*)	79.91	79.80	-0.11	56.47	56.47	0.00	75.24	75.24	0.00	**95.88**	**95.87**	-0.01	83.61	83.61	0.00	100.00	100.00	0.00	70.41	57.93	-12.49	**90.30**	88.28	-2.01	**82.33**	**81.84**	-0.50
Stony corals (*Madrepora oculata*)	**93.81**	**93.70**	-0.10	98.87	98.87	-0.01	**78.30**	**77.49**	-0.81	**83.23**	**83.03**	-0.19	85.92	**85.77**	-0.15	**97.79**	**91.53**	-6.26	60.28	47.42	-12.86	100.00	100.00	0.00	98.89	98.35	-0.54
Stony corals (*Solenosmilia variabilis*)	87.52	86.93	-0.59	100.00	100.00	0.00	71.87	65.49	-6.39	99.89	99.89	0.00	75.50	75.06	-0.44	**95.46**	**93.02**	-2.43	**74.24**	**72.69**	-1.55	**92.75**	**92.60**	-0.15	80.57	**79.99**	-0.58
Black corals (Antipatharia)	**92.10**	**91.58**	-0.52	**84.20**	**84.11**	-0.09	**76.58**	**76.47**	-0.10	**71.06**	**70.93**	-0.12	**82.30**	**82.29**	-0.01	86.74	86.59	-0.15	**81.75**	**75.44**	-6.31	83.15	83.12	-0.04	**72.05**	**71.66**	-0.39
Gorgonians (Gorgonian Alcyonacea)	94.10	**93.00**	-1.10	**88.31**	**86.62**	-1.69	**75.17**	**73.57**	-1.60	91.74	**88.91**	-2.83	87.10	85.78	-1.33	**97.46**	**93.68**	-3.78	79.65	76.48	-3.17	91.77	91.34	-0.43	85.19	85.47	0.28
Sea pens (Pennatulacea)	94.05	84.32	-9.73	**92.80**	**88.69**	-4.10	95.87	**95.96**	0.09	**96.85**	**93.74**	-3.11	99.13	98.44	-0.69	**100.00**	100.00	0.00	80.31	76.55	-3.76	100.00	100.00	0.00	76.75	41.04	-35.71
Anemones (Actiniaria)	99.41	98.77	-0.64	84.10	81.59	-2.50	77.23	75.21	-2.03	**80.70**	**79.11**	-1.59	99.30	99.16	-0.14	100.00	100.00	0.00	NA	NA		NA	NA		NA	NA	
Hexacorals (Zoantharia)	94.10	**91.94**	-2.16	**91.56**	**88.46**	-3.10	**85.79**	**82.14**	-3.65	**86.59**	**81.44**	-5.15	92.70	89.78	-2.91	**97.85**	**96.44**	-1.41	96.15	92.26	-3.89	95.58	81.45	-14.13	76.98	65.61	-11.37
Hydroids (Hydrozoa)	94.91	**93.24**	-1.68	97.43	94.05	-3.38	91.51	86.05	-5.46	**99.51**	**99.19**	-0.32	94.70	90.22	-4.48	**98.92**	**98.18**	-0.74	78.58	73.47	-5.11	94.70	94.48	-0.21	76.03	74.73	-1.31
Hydrocorals (Stylasteridae)	**98.80**	**98.76**	-0.03	32.34	32.34	0.00	0.00	0.00	0.00	99.57	99.56	0.00	85.94	85.94	0.00	**94.69**	**90.02**	-4.67	75.88	**74.84**	-1.04	100.00	100.00	0.00	99.71	99.68	-0.04
Bryozoans (Bryozoa)	94.72	**92.89**	-1.83	95.99	**92.52**	-3.47	92.76	85.96	-6.80	**99.78**	**99.51**	-0.27	95.18	89.86	-5.32	**99.03**	**98.32**	-0.71	79.22	74.04	-5.17	93.48	92.59	-0.89	76.96	75.77	-1.19
'Armless' Stars (Brisingida)	91.23	87.45	-3.79	**94.14**	**90.70**	-3.44	89.08	**84.72**	-4.36	**97.34**	**94.86**	-2.47	93.78	90.05	-3.73	**98.48**	**97.53**	-0.95	83.93	77.73	-6.20	91.52	90.44	-1.08	73.58	71.70	-1.89
Sea lillies and feather stars (Crinoidea)	94.30	**92.63**	-1.67	**94.32**	**90.67**	-3.65	92.19	**87.64**	-4.56	**99.89**	**99.78**	-0.11	92.66	87.18	-5.48	**98.61**	**97.72**	-0.88	79.28	73.68	-5.60	93.77	93.00	-0.77	76.70	75.66	-1.04

Appendix H - Sensitivity analysis of a fishable depth cutoff in post-accounting

In this sensitivity analysis, the proportion of suitable habitat for each VME indicator taxon are re-calculated after assuming that there will be no fishing-related disturbance deeper than 1400 m. Over the 30-year history of the bottom trawl fishery for orange roughy, virtually all bottom trawl tows have been shallower than 1250 m (see Figure 8) and the depth distribution of tows has shown no directional change. It is acknowledged that there is limited information as to the abundance of a number of taxa below these depths. Taxa within each group as in Table K1.

Table H.1. Estimates of the proportion of each VME indicator taxon in areas proposed for adoption at Commission in 2024 to achieve a minimum level of 70% protection with and without a 1400 m depth cutoff. Values are percent (%) Habitat Suitability Index that is closed to bottom trawl fishing within each Fishery Management Area using ROC_linear from the unimpacted baseline. Cell colours indicate an increase (green) or decrease (red) in spatial protection compared to not clipping by fishable depth. Bold type represents for taxa with > 1% of their Habitat Suitability Index within the FMA.

VME Indicator Taxon	**West Norfolk**			**North Lord Howe**			**Central Lord Howe**			**Northwest Challenger**			**Westpac Bank**			**South Tasman Rise**			**North Louisville**			**Central Louisville**			**South Louisville**		
	Unclipped	Clipped to fishable depth	% difference	Unclipped	Clipped to fishable depth	% difference	Unclipped	Clipped to fishable depth	% difference	Unclipped	Clipped to fishable depth	% difference	Unclipped	Clipped to fishable depth	% difference	Unclipped	Clipped to fishable depth	% difference	Unclipped	Clipped to fishable depth	% difference	Unclipped	Clipped to fishable depth	% difference	Unclipped	Clipped to fishable depth	% difference
Sponges (Porifera Demospongiae)	**99.57**	99.78	0.21	**97.65**	95.66	-1.99	99.85	98.73	-1.11	**99.52**	**99.17**	-0.35	100.00	100.00	0.00	100.00	100.00	0.00	77.51	77.88	0.38	100.00	100.00	0.00	100.00	100.00	0.00
Sponges (Porifera Hexactinellida)	94.80	96.59	1.79	97.86	**96.22**	-1.65	97.37	97.43	0.06	**89.26**	**80.69**	-8.57	99.81	99.68	-0.13	99.83	99.25	-0.59	80.23	75.55	-4.68	99.57	100.00	0.43	89.23	95.70	6.47
Stony corals (*Enallopsammia rostrata*)	80.14	79.59	-0.55	**87.44**	**87.32**	-0.12	**76.21**	**76.08**	-0.13	**74.71**	**74.65**	-0.06	**86.58**	**86.58**	0.00	**77.99**	**77.64**	-0.35	0.00	NA		100.00	NA		NA	NA	
Stony corals (*Goniocorella dumosa*)	79.91	79.30	-0.61	56.47	56.47	0.00	75.24	75.33	0.09	**95.88**	**95.88**	0.00	83.61	83.61	0.00	100.00	100.00	0.00	70.41	52.49	-17.92	**90.30**	91.09	0.79	**82.33**	83.89	1.55
Stony corals (*Madrepora oculata*)	**93.81**	**94.25**	0.44	98.87	98.84	-0.03	**78.30**	**77.78**	-0.52	**83.23**	**83.13**	-0.10	85.92	**86.03**	0.11	**97.79**	85.40	-12.39	60.28	100.00	39.72	100.00	NA		98.89	100.00	1.11
Stony corals (*Solenosmilia variabilis*)	87.52	90.52	3.00	100.00	100.00	0.00	71.87	33.03	-38.85	99.89	99.85	-0.03	75.50	54.66	-20.84	**95.46**	**87.64**	-7.82	**74.24**	**68.05**	-6.19	**92.75**	96.02	3.27	80.57	81.85	1.28
Black corals (Antipatharia)	**92.10**	**91.86**	-0.24	**84.20**	**83.95**	-0.26	**76.58**	**76.47**	-0.11	**71.06**	**70.91**	-0.14	**82.30**	**82.17**	-0.14	86.74	85.88	-0.86	**81.75**	**66.82**	-14.93	83.15	90.34	7.19	**72.05**	72.31	0.26
Gorgonians (Gorgonian Alcyonacea)	94.10	**92.94**	-1.16	**88.31**	**86.20**	-2.11	**75.17**	**72.89**	-2.27	91.74	**88.05**	-3.70	87.10	81.62	-5.49	**97.46**	**89.78**	-7.68	79.65	74.59	-5.06	91.77	86.62	-5.15	85.19	89.96	4.77
Sea pens (Pennatulacea)	94.05	96.10	2.04	**92.80**	**87.83**	-4.97	95.87	92.91	-2.95	**96.85**	**93.49**	-3.36	99.13	97.10	-2.03	**100.00**	100.00	0.00	80.31	76.24	-4.07	100.00	100.00	0.00	76.75	NA	
Anemones (Actiniaria)	99.41	99.48	0.07	84.10	81.71	-2.38	77.23	74.87	-2.36	**80.70**	**78.90**	-1.80	99.30	99.26	-0.04	100.00	100.00	0.00	NA	NA		NA	NA		NA	NA	
Hexacorals (Zoantharia)	94.10	**94.48**	0.39	**91.56**	**88.07**	-3.49	**85.79**	**81.37**	-4.42	**86.59**	**79.98**	-6.61	92.70	88.50	-4.19	**97.85**	**82.40**	-15.45	96.15	80.18	-15.97	95.58	92.44	-3.14	76.98	75.36	-1.62
Hydroids (Hydrozoa)	94.91	**96.39**	1.48	97.43	**93.50**	-3.93	91.51	**84.88**	-6.63	**99.51**	**99.10**	-0.41	94.70	83.77	-10.94	**98.92**	90.66	-8.26	78.58	68.56	-10.02	94.70	98.86	4.16	76.03	76.43	0.40
Hydrocorals (Stylasteridae)	**98.80**	**98.83**	0.03	32.34	19.25	-13.09	0.00	0.00	0.00	99.57	99.57	0.00	85.94	0.00	-85.94	**94.69**	**83.63**	-11.06	75.88	71.03	-4.84	100.00	100.00	0.00	99.71	100.00	0.29
Bryozoans (Bryozoa)	94.72	**95.88**	1.16	95.99	**92.15**	-3.84	92.76	84.01	-8.75	**99.78**	**99.40**	-0.39	95.18	76.54	-18.64	**99.03**	90.37	-8.66	79.22	69.82	-9.40	93.48	94.75	1.27	76.96	80.61	3.65
‘Armless’ Stars (Brisingida)	91.23	91.48	0.25	**94.14**	**90.24**	-3.90	89.08	**83.31**	-5.78	**97.34**	**93.73**	-3.60	93.78	85.98	-7.80	**98.48**	**89.38**	-9.10	83.93	73.02	-10.92	91.52	98.91	7.39	73.58	70.35	-3.23
Sea lillies and feather stars (Crinoidea)	94.30	**95.32**	1.02	**94.32**	**90.24**	-4.08	92.19	**87.08**	-5.12	**99.89**	**99.74**	-0.15	92.66	78.06	-14.60	**98.61**	**89.45**	-9.15	79.28	68.10	-11.17	93.77	96.45	2.67	76.70	79.18	2.47