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Recent and historical benthic VME bycatch data from midwater trawls targeting bentho-pelagic species

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A review of recent and historical benthic VME bycatch data from midwater trawling targeting bentho-pelagic species within the SPRFMO Evaluated Area

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1. Purpose

This paper explores the frequency and the spatial distribution of interactions between midwater trawl targeting bentho-pelagic species and Vulnerable Marine Ecosystem (VME) indicator taxa from New Zealand flagged vessels in the SPRFMO Evaluated Area to inform any potential future improvements to the spatial management measures. This work has been undertaken as part of the SPRFMO Scientific Committee (SC) multiannual workplan task to develop "*a process to review all recent and historical benthic bycatch data to determine the ongoing effectiveness of the spatial management measures*".

2. Background

The Conservation and Management Measure (CMM) for the Management of Bottom Fishing in the SPRFMO Convention Area (CMM03-2023) implements a spatial management regime and complementary encounter protocols designed to, inter alia, prevent Significant Adverse Impacts (SAIs) on Vulnerable Marine Ecosystems (VMEs). These spatial management measures were established under CMM 03- 2019 to protect large proportions of the predicted suitable habitat for VME indicator taxa while permitting access for bottom fisheries. Key components of the spatial management regime are Bottom Trawl Management Areas (BTMAs) and Midwater Trawl Management Areas (MTMAs), which designate areas within Fishery Management Areas (FMAs) within which bottom trawling, and midwater trawling (defined in CMM03-2023 as "*fishing for bentho-pelagic species using a trawl net that is designed to be pulled through the water near the seabed and designed not to come into extended contact with the seabed*") can occur. While bottom trawling is currently restricted to BTMAs, midwater trawling targeting bentho-pelagic species can occur in both BTMAs and MTMAs (para 17; CMM03-2023). Most BTMAs and MTMAs share the same boundaries (Annex 4 of CMM03-2023), with only two FMAs (North Lord Howe, Central Lord Howe) containing MTMAs that extend beyond the boundaries of the BTMAs (Table 1).

Table 1 | For each Fishery Management Area (FMA), the approximate area (in km^2) available to fishing under the current Bottom Trawl Management Areas (BTMAs) and Midwater Trawl Management Areas (MTMAs), as specified in CMM03-2023. Bold indicates different area values between BTMAs and MTMAs.

FMA	Area open to fishing under CMM03-2023 (km^2)	
	BTMAs	**MTMAs**
West Norfolk	3,909	3,909
North Lord Howe	**4,852**	**6,729**
Central Lord Howe	**8,238**	**8,311**
Northwest Challenger	26,210	26,210
Westpac Bank	680	680
North Louisville	4,399	4,399
Central Louisville	4,219	4,219
South Louisville	9,814	9,814
South Tasman Rise	1,423	1,423
Total	**63,744**	**65,694**

CMM 03-2023 includes an encounter protocol that triggers an immediate management response (a 'move-on rule') in areas open to fishing (defined as an 'encounter') 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 (Table 2**Error! Reference source not found.**). In designing the Encounter Protocol, the thresholds for the move-on rule were set at a level that would be triggered when there was evidence that fishing vessels had potentially encountered a VME (SC6-DW09, Geange et al. 2020). The threshold weights and biodiversity weights included in CMM 03-2023 therefore provide a useful reference for evaluating historic bycatch records to determine if VMEs are potentially present in the area where an encounter has taken place. However, the thresholds are only applied to single tows, and the potential presence of a VME can also be inferred from many trawl tows within the same area recording benthic bycatch at weights which may not trigger the Encounter Protocol. Therefore, in addition to using encounter thresholds to evaluate historic benthic bycatch to identify the potential presence of VMEs it could also be useful to evaluate spatial patterns of cumulative bycatch.

Table 2 | Designation of VME indicator taxa included in Annex 5 of CMM03-2023. NA indicates threshold weights are not available within CMM03-2023 for those taxa.

FAO code	VME indicator taxon	Common Name	Qualifying Taxa	CMM03-2023 threshold weight (kg)	CMM03-2023 biodiversity threshold (kg)
PFR	Porifera	Sponges	All taxa of the classes Demospongiae and Hexactinellidae	25	5
CSS	Scleractinia	Stony corals	All taxa within the following genera: *Solenosmilia; Goniocorella; Oculina; Enallopsammia; Madrepora; Lophelia*	60	5
AQZ	Antipatharia	Black corals	All taxa	5	1
AJZ	Alcyonacea	True soft corals	All taxa excluding Gorgonian Alcyonacea	NA	1
GGW	Gorgonian Alcyonacea	Sea fans octocorals	All taxa within the following suborders: Holaxonia; Calaxonia; Scleraxonia	15	1
NTW	Pennatulacea	Sea pens	All taxa	NA	1
ATX	Actiniaria	Anemones	All taxa	35	5
ZOT	Zoantharia	Hexacorals	All taxa	10	1
HQZ	Hydrozoa	Hydrozoans	All taxa within the orders Anthoathecata and Leptothecata, excluding Stylasteridae	NA	1
AXT	Stylasteridae	Hydrocorals	All taxa	NA	1
BZN	Bryozoa	Bryozoans	All taxa within the orders Cheilostomatida and Ctenostomatida	NA	1
BHZ	Brisingida	Armless stars	All taxa	NA	1
CWD	Crinoidea	Sea lillies	All taxa	NA	1

Paragraph 38 of CMM03-2023 requires the SPRFMO Scientific Committee (SC) to "*review all available data and provide advice on the ongoing effectiveness of the management measures in this CMM to ensure the measure meets its objective and the objectives of the Convention and implements the relevant United Nations General Assembly Resolutions*". Historical records of benthic bycatch data, which provide information on where VME indicator taxa potentially occur (or could have occurred in the past), are a potentially useful tool to help evaluate the effectiveness of management measures. Acknowledging this, the SC agreed in 2020 (para 45 SC08-Report) to include a sub-task to the SC multiannual workplan titled "*Development of a process to review all recent and historical benthic bycatch data to determine the ongoing effectiveness of the spatial management measures*" as part of the wider "*VME Encounters and benthic bycatch*".

In response, New Zealand has undertaken: 1) a review of benthic bycatch data in 2022 to determine broad-scale spatial patterns of historic bycatch relative to the location of BTMAs (SC10-DW03); and 2) an approach for fine-scale spatio-temporal analysis of areas within BTMAs where there has historically been a high frequency of interactions with VME indicator taxa (SC11-DW10). The results of those previous mapping exercises identified a series of BTMAs where there has historically been a high frequency of interactions with VME indicator taxa (e.g., the Central Lord Howe – East; Northwest Challenger; and Central Louisville 15 Management Areas) or exceptionally large bycatch events (e.g., of Scleractinia in West Norfolk; North Louisville Ridge 23; and Central Louisville Ridge 13, 14 and 15). Conversely, the mapping also identified BTMAs where bycatch of VME indicator taxa has been relatively infrequent (e.g., North Lord Howe – North; North Lord Howe – South; Westpac Bank; North Louisville Ridge 17 and 18; and South Louisville Ridge 3, 5, 7, 8, 9 and 11).

In 2014, New Zealand undertook an analysis of the potential impact on VMEs of using midwater trawl targeting species near the benthos (SC02-10), which concluded that while this type of gear is known to contact the seabed for a minority of tows, any impact on seafloor taxa is likely to be low due to the nature of the contact (point-based rather than continuous contact as in demersal/bottom trawling). Based on the presentation and discussion of SC02-10, the SC (SC02-Report) agreed that:

- *Midwater trawling for bentho-pelagic species (e.g. alfonsino) falls under the description of "bottom fishing" as defined in paragraph 4 of CMM 2.03;*
- *Midwater trawling for bentho-pelagic species has a low impact on the physical and biological habitat: a value of "2" on the five-point scale developed by Chuenpagdee et al., 2003 (noting that demersal trawling is rated as a "5" on this scale);*
- *Midwater trawling for bentho-pelagic species is unlikely to cause significant adverse effects on VMEs.*

Subsequently, midwater trawling for bentho-pelagic species (e.g. alfonsino; *Beryx* spp.) falls under the description of "bottom fishing" as defined in paragraph 2 of CMM03-2023. While the recent work undertaken by New Zealand analysing patterns of VME indicator taxa bycatch from bottom fishing has focussed on bottom trawling (SC10-DW03, SC11-DW10), no effort has been made to identify likely impacts of midwater trawl gear targeting bentho-pelagic species on VME indicator taxa (thus on potential VMEs). Here we provide a review of midwater trawl (as defined in paragraph 2-b of CMM03-2023) activity from New Zealand flagged vessels in the SPRFMO Convention Area since 2008. The review focusses on exploring the frequency and the spatial distribution of interactions between midwater trawl tows targeting bentho-pelagic species and VME indicator taxa from New Zealand flagged vessels in order to inform any potential future improvements to the spatial management measures within the SPRFMO Evaluated Area.

3. Methods

3.1 Data

A comparison of benthic bycatch data collected by Australian and New Zealand observers for use in the 2023 joint Australia – New Zealand "Cumulative Bottom Fishery Impact Assessment for Australian and New Zealand bottom fisheries in the SPRFMO Convention Area" (SC11-DW01_rev1), revealed that Australian benthic bycatch data were not captured in databases with the same precision and resolution as New Zealand benthic bycatch data. There has not been any Australian flagged vessel trawling in the SPRFMO Evaluated Area in recent years (Trent Timmiss, ABARES, pers. comm.), and therefore no new records. For the present analysis we only use New Zealand data as best available scientific information and in line with previous approaches presented to the SC. However, although both the Australian and New Zealand fleets have considerable historical bottom fishing effort on the Challenger Plateau, West Norfolk Ridge and the Louisville Seamount Chain, we acknowledge that the Australian and New Zealand fleets have also fished different areas, particularly before 2008, (e.g., Australia has had considerable historical fishing effort on the South Tasman Rise and New Zealand on the North Lord Howe Rise and South Lord Howe Rise) and that the New Zealand data alone is not fully representative of the combined New Zealand and Australian fishery. Similarly, bycatch data from other fleets that engaged in midwater trawl fishing within the SPRFMO Evaluated Area in the past is not available and therefore not included in the present analysis. These limitations should be considered when interpreting the results of this analysis.

Historical and recent benthic bycatch data from New Zealand midwater trawl tows targeting bentho-pelagic species in the Evaluated Area within the western part of the SPRFMO Convention Area over the period 2008–2024 (**Error! Reference source not found.**) were obtained from the Fisheries New Zealand Centralised Observer Database (*cod*) (accessed 4th July 2024), the specifications of which were documented by Sanders and Fisher (2015). Data were collected by scientific observers (the New Zealand trawl fleet has 100% observer coverage in the SPRFMO Convention Area) and included 578 unique fishing events targeting bluenose (*Hyperoglyphe antarctica*), alfonsinos (*Beryx splendens* and *B. decadactylus*), southern boarfish (*Pseudopentaceros richardsoni*) and orange roughy (*Hoplostethus atlanticus*). These data consisted of tow-by-tow observer data with one record per benthic taxon encountered at each tow, and included trip number, tow number, gear events, start and final tow position (both in latitude-longitude and decimal degree format), fishing method, target species, depth (relative to both gear and vessel, and at the start and final tow positions), benthic species code, common name, bycatch weight, method of weight analysis, life status (e.g., alive/dead), information on whether the benthic material was encrusting anything or encrusted by something else, and observer comments.

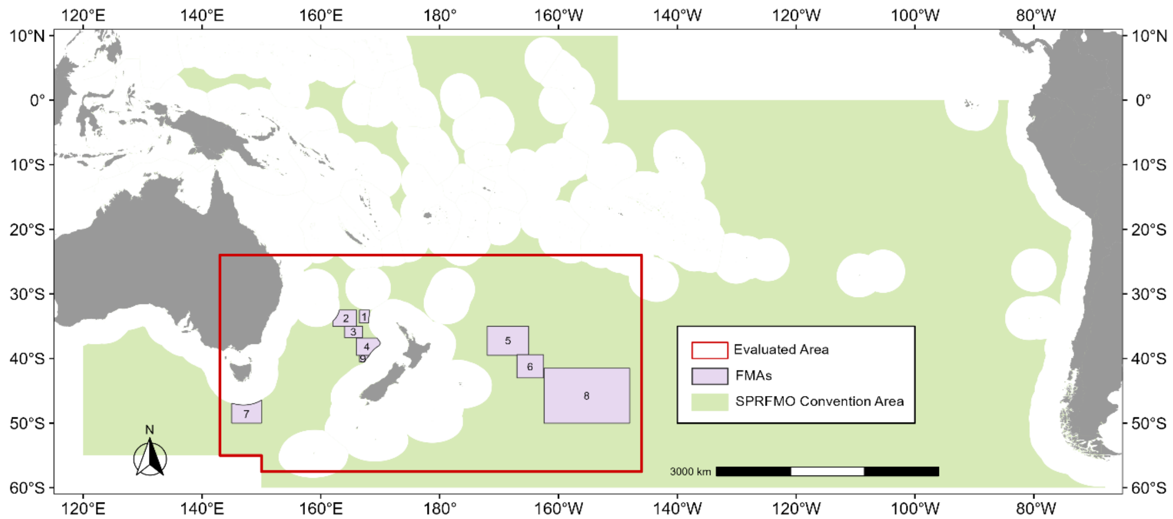


Figure 1 | SPRFMO Convention Area (light green area) including the extent of the Evaluated Area (red boundaries) with numbered Fishery Management Areas (FMAs) defined under SPRFMO CMM03-2023 (purple

polygons). FMAs numbered as 1) West Norfolk, 2) North Lord Howe Rise, 3) Central 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. A detailed figure for each FMA (and their respective Midwater Trawl Management Areas) can be found in Annex 1 – Fishery Management Areas (FMAs).

For tows containing VME indicator taxa bycatch (~2.94% of all midwater trawl tows), individual VME indicator species were aggregated into higher-order VME indicator taxa as defined in Annex 5 of SPRFMO CMM03-2023 using taxonomic designations from the World Register of Marine Species (Bernot et al. 2024), resulting in a final dataset consisting of 578 unique midwater tows, of which 18 tows included 25 VME indicator taxa records (i.e., some tows included bycatch of more than 1 VME indicator taxon). See Appendix 1 of SC9-DW10 for the allocation of New Zealand fisheries codes to VME indicator taxa.

The data was aggregated into 3 nm x 3 nm gridded cells using the statistical software *R* (R Core Team 2019) (see Annex 4 – R packages). To help identify spatial patterns of VME indicator taxa bycatch within and adjacent to MTMAs, a series of cell-based metrics to visualise spatial patterns of benthic bycatch previously developed in SC10-DW03 were used (Table 3**Table 3**).

Table 3 | Key cell-based metrics used to identify spatial patterns of VME indicator taxa bycatch.

Metric	Description
Trawl effort	Per-cell number of tows, based on a straight-line path between the reported start and end point of each tow.
Number of times encounter thresholds triggered	For each VME indicator taxon, the per-cell number of times encounter thresholds in CMM03-2023 would have been exceeded had the Encounter Protocol been in place at the time of the fishing event. The encounter threshold is assumed to have been triggered in each cell intersected by a tow where the VME indicator taxon catch would have exceeded the Encounter Protocol threshold.
Number of times biodiversity thresholds triggered	Per-cell number of times biodiversity thresholds in CMM03-2023 would have been exceeded had the Encounter Protocol been in place at the time of the fishing event. The biodiversity threshold is assumed to have been triggered for each cell intersected by a tow where the VME indicator taxa catch would have triggered the biodiversity threshold.
Average potential bycatch per tow	For each VME indicator taxon, the per-cell average potential bycatch weight (kg) (i.e., taxon-specific cumulative potential bycatch, as defined above, divided by the number of tows intersecting the cell).

A basic analysis was performed to explore the spatio-temporal distribution of the midwater trawl effort targeting bentho-pelagic species by New Zealand over the 2008-2024 period. Tables and bar charts generated with the statistical software *R* (R Core Team 2019) (see Annex 4 – R packages) were used to identify the years and the FMAs that concentrated most of the fishing effort over time.

3.2 Data quality and processing

Not all the analysed tow records had the same level of quality and completeness (e.g., coordinates for both start and end positions, see Table 4). Following similar issues encountered in previous analysis (SC10-DW03), the following decisions were made to groom the data:

1. Bycatch records with zero or undefined bycatch weights (n = 2) for aggregated VME indicator taxa were assigned a taxon-specific minimum weight corresponding to the

minimum non-zero weight that had been recorded for that taxon in the wider dataset (see Annex 2 - Zero Weight Adjustments).

2. For tows with 1) missing seabed depth at the start and/or end positions of the tow (n = 287), or 2) with net (gear) depth greater than seabed depth (indicating an error in the recording of the depths) (n = 7), at the start and/or the end positions of the tow, seabed depth values (in metres) were extracted from publicly available bathymetry gridded data (GEBCO 2021) using the tow start and/or end position.
3. Given the percentage of tows with any coordinate rounded to the nearest minute (62%, Table 4), and the wide range of values obtained in calculating the height of the gear above the seabed at both the initial and the final position of a tow (Figure 8), a decision was made not to apply a layback correction to the positions of each tow. Although the correction aligns with knowledge from fishers familiar with the operation of the SPRFMO bottom trawl fishery (SC05-DW06), considering the granularity of the visualisation approach (see below, 3.3 Spatial visualisation), the application of the correction would have not altered the results presented in this analysis.

Table 4 | Type and frequency of incomplete or erroneous trawl data within the dataset, reported as number and percent of all tows and the number and percent of tows with VME indicator taxa bycatch

Type of incomplete or erroneous data	No. tows	% of all tows (n = 578)	No. tows with VME taxa bycatch	% of all tows with VME bycatch (n = 18)
Tows with missing start position	0	0.00	–	–
Tows with missing end position	0	0.00	–	–
Tows with same start and end position	29	5.01	0	0.00
Tows with missing initial absolute depth	133	23.01	3	16.66
Tows with missing final absolute depth	268	46.36	2	11.11
Tows with missing initial gear depth	108	18.68	3	16.66
Tows with missing final gear depth	168	29.06	7	38.88
Tows with missing initial and final gear depths	103	17.82	3	16.66
Tows with missing initial absolute and gear depths	7	1.21	0	0.00
Tows with missing final absolute and gear depths	58	10.03	4	0.69
Tows with net depth greater than seabed depth (at the initial and/or end tow positions)	7	1.21	0	0.00
Tows with 0 or undefined bycatch weight	2	0.34	2	100.00
Tows with any coordinate rounded to nearest minute	357	61.76	7	38.88

3.3 Spatial visualisation

To help visualise patterns of historical VME indicator bycatch, methods previously developed in SC10-DW03 were used. Briefly, tow data were aggregated in a 3 nm x 3 nm grid. Start and end positions (where available) of each tow were used to identify the grid cells that intersected each tow, and figures for each pair of VME indicator taxa group and FMA were developed. Grid cells with less than two unique fishing vessels within their boundaries had to be masked out from the figures due to data confidentiality reasons (Annex 3 – Number of cells omitted from Figures due to release of commercially sensitive data regulations presents the number of cells per FMA omitted from figures due to release of commercially sensitive data regulations), but complementary tables were generated to avoid any information gaps.

Where a tow intersected more than a single grid cell, the metrics derived from that tow (e.g., bycatch weight) were replicated across all the intersecting cells. This approach assumes that the reported bycatch may have come from any of the cells the tow intersected, rather than being evenly distributed across all cells, and is consistent with 1) the expectation that VMEs are likely to be represented by high densities/biomass of VME indicator taxa in discrete patches (e.g., Bullimore et al. 2013, Rowden et al. 2017, Rowden et al. 2020, Williams et al. 2020), and 2) the uncertainty regarding the location where a given midwater trawl tow would have contacted the benthos (SC02-10). While this approach will visually overestimate the spatial distribution of bycatch data, it has the advantage of identifying the cells within which a discrete VME patch may have occurred (which can then be the focus of more detailed analysis to inform the interpretation of the spatial patterns reported here) and potentially avoids missing important spatial patterns that may be smoothed by alternative methods (such as proportionally dividing the bycatch weight across all cells crossed by a tow). It also needs to be acknowledged that midwater trawl tows targeting bentho-pelagic species on features (i.e., seamounts) may start and end at the same (or nearby) location, with the vessel fishing around the perimeter of a feature (Andy Smith, HSFG, pers. comm.), but the intersected cells in such cases cannot be easily inferred. Consequently, spatial patterns presented within the figures of this report should be considered as illustrations of maximum potential bycatch and require careful interpretation.

3.4 Comparing midwater and bottom trawling

Bottom trawling data previously analysed in SC10-DW03 and SC11-DW10 was re-processed using the same methods described in both of those reports but excluding all midwater trawl tows. New VME indicator taxa bycatch metrics derived from bottom trawl records (e.g., maximum average potential bycatch as defined in Table 3) were then used to compare against those obtained from midwater trawl data.

3.5 Assessing potential to contact the seabed

In addition to the recorded benthic material by the observer, gear events recorded by observers for each tow (Table 5) were used to infer likelihood of contact with the seabed. Methods described in SC02-10 were used to classify gear event codes, which were combined with records of benthic bycatch to assess likelihood of contact for each tow. Briefly, tows with benthic bycatch and with recorded event codes 'B' (net caught) and 'H' (gear lost) were treated as categorical indicators of gear contacting the benthos, while following an assessment of all recorded codes, code 'A' (net torn) was considered as strong evidence of contact. Proportion of tows for each gear event code with and without benthic bycatch (including VME indicator taxa) were used to explore likelihood of contact for each FMA, yielding a 'minimum' and a 'potential' seabed contact rate. 'Minimum rate of seabed contact' is evidenced by an observer gear event code 'B' and/or benthic material records for each tow, while 'Potential rate of seabed contact' is evidenced by an observer gear event code 'B' and/or 'A' and/or benthic material record for each tow. Yearly rates for MTMAs with significant levels of effort (subjectively set at >= 15 tows per year) were calculated to explore spatio-temporal variation of likelihood of the gear contacting the seabed.

Initial (at the start of the tow) and/or final (at the end of the tow) seabed and net depths were used to calculate estimates of the position of the net (gear) relative to the seabed for all tows with valid depth values (76.98% of tows had valid initial seabed and gear depths and 34.60% of tows had valid final seabed and gear depths). The estimates for height of the net above the seabed were used to explore the likelihood of the gear contacting the seabed, and histograms were provided to explore the distribution of values across the tows where the estimates were available (Table 4). A subjectively chosen threshold of 10 m above the seabed was used to identify the percentage of tows that were near the seabed, either at the start or at the end of the tow. All calculations were performed using the statistical software *R* (R Core Team 2019) (see Annex 4 – R packages).

Table 5 | Gear event codes used by observers and the interpretation of whether they indicate bottom contact when reported for tows using midwater trawl gear.

Code	Description	Indicative of contact
A	Net torn	Yes, in some instances
B	Net caught/fast	Yes
C	Winch failure during setting	No
D	Winch failure during hauling	No
E	Net deliberately towed for a long period at non fishing depth ("flying the net").	No
F	Haul gear to doors up, turn and then shoot away again	No
G	Twisted warps, crossed doors	Possibly
H	Gear lost	Yes
I	Broken or snapped warp	Possibly
O	Other (detail in comments)	Possibly
U	Unknown, did not see	No
Y	More than three gear events - document in comments section	Yes, if at least one of the codes indicates contact
Z	No gear events	No

4. Results

Approximately 95% of the analysed tows had alfonsino as the target species, with the rest of the effort divided between southern boarfish, bluenose, and orange roughy (Table 6). Most of the tows that included VME indicator taxa bycatch (n = 14) were from the alfonsino fishery (Table 6); however, the percentage of tows with bycatch was the lowest (2.54%) for the alfonsino fishery (n = 551), while the highest (28.57%) was for the orange roughy fishery (n = 7).

Table 6 | Distribution of effort (number of tows) relative to target species from New Zealand trawl vessels by gear (midwater trawl - MW, bottom trawl - BT) between 2008 and 2024 in the SPRFMO Evaluated Area. Also shown is the number and percent of tows with VME indicator bycatch per fishery. Note that species targeted by bottom trawl tows that are not targeted by midwater tows (e.g., yellow boarfish) are excluded.

Target species	No. of tows		No. of tows with VME indicator taxa bycatch		% of tows with VME indicator taxa bycatch	
	MW	BT	MW	BT	MW	BT
Bluenose	8	3	2	0	25.00	0.00
Alfonsinos	551	1,463	14	234	2.54	15.99
Orange roughy	7	8,228	2	3,185	28.57	38.71
Southern boarfish	12	1	0	1	0.00	100.00

Total	578	9,695	18	3,420	3.11	35.28

Midwater trawl effort has been variable through time, initially increasing from 1 tow in 2009 (across all target species) to 121 tows in 2013, then dropping to 23 tows in 2015 before again increasing to over 150 tows in 2018, with little effort in 2019 and 2020 (n = 6, and n = 4 tows, respectively) (Table 7, Figure 2). The percentage of midwater tows with VME indicator taxa was highest in 2010, with 13.33% of the 15 tows being associated to VME indicator taxa bycatch. Since 2010, the percentage of tows relative to the effort was consistently < 5%, except for 2020, where 25% of the tows were associated to VME indicator taxa bycatch (noting that only 4 tows were conducted that year).

Table 7 | Distribution of effort (number of tows) over the 2008-2024 years, and number of times the encounter events that would have exceeded threshold weights had the Encounter Protocol (EP) in CMM03-2023 been in place at the time of the fishing event.

Year	Tows	No. of tows with VME ind. taxa bycatch	% of tows with VME ind. taxa bycatch	No. times EP triggered for Single VME ind. taxa	No. times EP triggered for 3 or more VME ind. taxa
2008	0	0	0.00	0	0
2009	1	0	0.00	0	0
2010	15	2	13.33	0	0
2011	62	3	4.84	0	0
2012	52	2	3.85	0	0
2013	121	0	0.00	0	0
2014	0	0	0.00	0	0
2015	23	1	4.35	0	0
2016	42	0	0.00	0	0
2017	91	2	2.20	0	0
2018	161	6	3.73	0	0
2019	6	0	0.00	0	0
2020	4	1	25.00	0	0
2021	0	0	0.00	0	0
2022	0	0	0.00	0	0
2023	0	0	0.00	0	0
2024	0	0	0.00	0	0

None of the tows would have exceeded the thresholds weights defined in CMM03-2023 and therefore the Encounter Protocol would not have been triggered, if the Encounter Protocol had been in place at the time the fishing took place (Table 7).

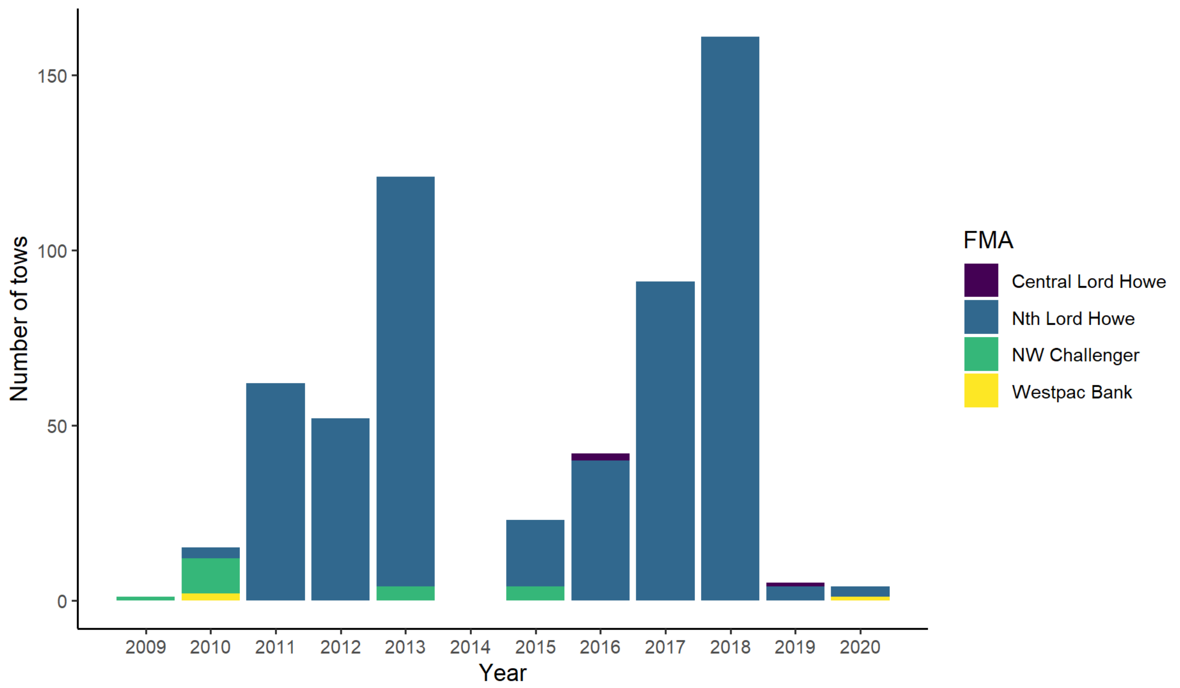


Figure 2 | Distribution of effort (number of tows) across each Fishery Management Area (FMA) and over the 2008–2024 period (noting there was no midwater trawling effort for the years 2008, 2014, and 2021, 2022, 2023 and 2024).

Most of the midwater trawl effort took place in the North Lord Howe FMA (n = 554 of a total of 578 tows) which included 14 tows with VME indicator taxa bycatch (Table 8). Bycatch records from across all FMAs included the VME indicator taxa Porifera, Scleractinia, Antipatharia, Gorgonian Alcyonacea, Actinaria and Crinoidea.

4.1 VME indicator taxa bycatch metrics

The highest cumulative weight for any bycatch record of VME indicator taxa was 8.9 kg of Gorgonian Alcyonacea (from 7 unique tows) from the North Lord Howe – Central MTMA (Table 8). However, effort within the North Lord Howe FMA was higher in the North Lord Howe – East MTMA (n = 237), with all the tows except one being assigned to a single cell (n = 236) (Figure 3).

Despite some fishing effort (and associated VME indicator taxa bycatch) located in other FMAs (Central Lord Howe, Northwest Challenger, Westpac Bank) (Figure 2), no figures were produced for these areas given that the fishing events were associated with cells that had less than three unique fishing vessels operating in them, in accordance with Fisheries New Zealand regulations for the release of commercially sensitive data (Annex 3 – Number of cells omitted from Figures due to release of commercially sensitive data regulations).

Average potential bycatch values (as defined in Table 3) for Scleractinia, Actinaria, and Antipatharia in the North Lord Howe FMA were between < 0.001 (Scleractinia in the North Lord Howe – East MTMA) and 0.47 (Gorgonian Alcyonacea in the North Lord Howe – Central MTMA) (Table **9**9, Figure 4, Figure 5 and Figure 6). Average potential bycatch in the other FMAs were 0.006 (Antipatharia in the Westpac Bank), 0.025 (Gorgonian Alcyonacea in the Northwest Challenger – Closed Area), 0.5 (Scleractinia in the Northwest Challenger – Closed Area) and 0.025 (Gorgonian Alcyonacea in the Northwest Challenger – Closed Area) (Table 9).

Table 8 | Cumulative VME indicator taxa bycatch (kg) from New Zealand midwater trawl vessels between 2008 and 2024 for each Midwater Trawl Management Area (MTMA). Closed is the area outside MTMAs within a Fishery Management Area (FMA) that is closed to trawling.

				VME Indicator taxa												
Fishery Management Area (FMA)	Midwater Trawl Management Area (MTMA)	No. tows	No. tows with VME indicator taxa bycatch	**Porifera**	**Scleractinia**	**Antipatharia**	**Alcyonacea**	**Gorgonian Alcyonacea**	**Pennatulacea**	**Actiniaria**	**Zoantharia**	**Hydrozoa**	**Stylasteridae**	**Bryozoa**	**Brisingida**	**Crinoidea**
Central Lord Howe	S. Lord Howe – East	2	0	–	–	–	–	–	–	–	–	–	–	–	–	–
Central Lord Howe	S. Lord Howe - West	2	1	–	0.10	–	–	–	–	–	–	–	–	–	–	–
Central Lord Howe	S. Lord Howe - South	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–
Central Lord Howe	Closed	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–
Nth Lord Howe	N. Lord Howe - Central	89	7	–	6.50	–	–	8.90	–	0.10	–	–	–	–	–	0.44
Nth Lord Howe	N. Lord Howe - East	237	1	–	–	0.10	–	–	–	–	–	–	–	–	–	–
Nth Lord Howe	N. Lord Howe - South	169	4	0.30	–	0.40	–	0.20		3.00	–	–	–	–	–	0.10
Nth Lord Howe	N. Lord Howe - West	54	2	–	0.10	0.50	–	–	–	–	–	–	–	–	–	–
Nth Lord Howe	Closed	3	0	–	–	–	–	–	–	–	–	–	–	–	–	–
NW Challenger	Northwest Challenger	5	0	–	–	–	–	–	–	–	–	–	–	–	–	–
NW Challenger	Closed	14	2	–	0.50	–	–	0.10	–	–	–	–	–	–	–	–
Westpac Bank	Westpac Bank	3	1	–	–	0.02	–	–	–	–	–	–	–	–	–	–
Westpac Bank	Closed	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		578	18	0.30	7.20	1.02	–	9.20	–	0.40	–	–	–	–	–	0.54

Table 9 | Maximum Average Potential Bycatch (as defined in Table 3) of VME indicator taxa from New Zealand midwater trawl vessels between 2008 and 2024 for each Midwater Trawl Management Area (MTMA). Closed is the area outside MTMAs within a Fishery Management Area (FMA) that is closed to trawling.

Fishery Management Area (FMA)	Midwater Trawl Management Area (MTMA)	VME Indicator taxa														
		No. tows	No. tows with VME indicator taxa bycatch	**Porifera**	**Scleractinia**	**Antipatharia**	**Alcyonacea**	**Gorgonian Alcyonacea**	**Pennatulacea**	**Actiniaria**	**Zoantharia**	**Hydrozoa**	**Stylasteridae**	**Bryozoa**	**Brisingida**	**Crinoidea**
Nth Lord Howe	N. Lord Howe - Central	89	7	–	0.361	–	–	0.477	–	0.005	–	–	–	–	–	0.024
Nth Lord Howe	N. Lord Howe - East	237	1	–	–	< 0.001	–	–	–	–	–	–	–	–	–	–
Nth Lord Howe	N. Lord Howe - South	169	4	0.050	–	0.030	–	0.033		0.085	–	–	–	–	–	0.007
Nth Lord Howe	N. Lord Howe - West	54	2		0.002	0.021	–	–	–	–	–	–	–	–	–	–
Nth Lord Howe	Closed	3	0	–	–	–	–	–	–	–	–	–	–	–	–	–
Central Lord Howe	S. Lord Howe - East	2	0	–	–	–	–	–	–	–	–	–	–	–	–	–
Central Lord Howe	S. Lord Howe - West	2	1	–	0.100	–	–	–	–	–	–	–	–	–	–	–
Central Lord Howe	S. Lord Howe - South	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–
Central Lord Howe	Closed	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–
NW Challenger	Northwest Challenger	5	0	–	–	–	–	–	–	–	–	–	–	–	–	–
NW Challenger	Closed	14	2	–	0.500	–	–	0.025	–	–	–	–	–	–	–	–
Westpac Bank	Westpac Bank	3	1	–	–	0.006	–	–	–	–	–	–	–	–	–	–
Westpac Bank	Closed	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–

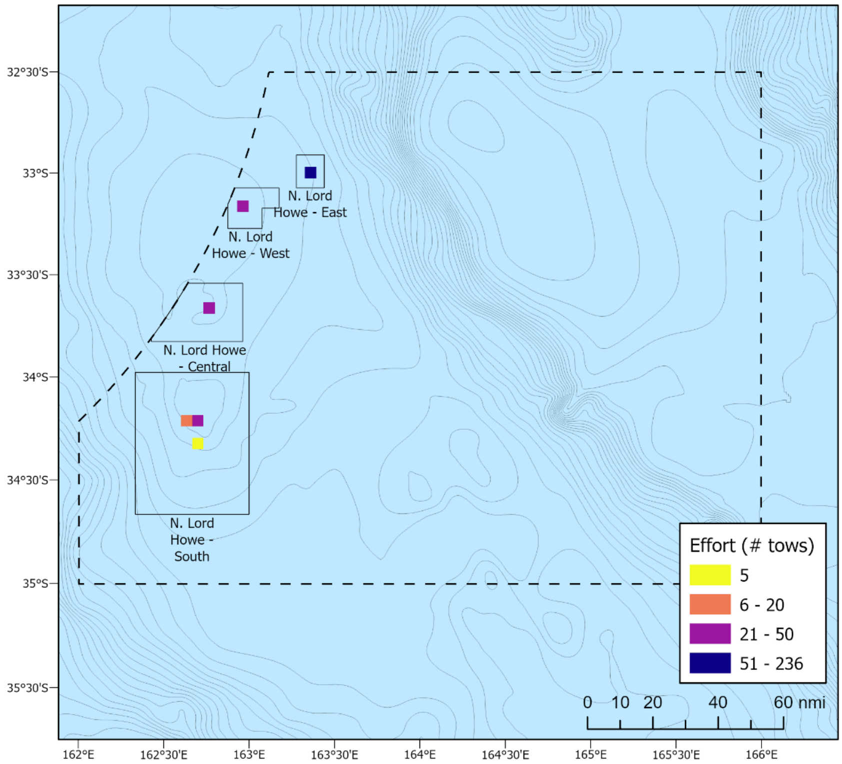


Figure 3 | Per cell number of tows by New Zealand trawl vessels from 2008 to 2024 in the North Lord Howe Fishery Management Area. Note 46 cells have been omitted from the figure to comply with Fisheries New Zealand regulations for the release of commercially sensitive data (see Annex 3 – Number of cells omitted from Figures due to release of commercially sensitive data regulations).

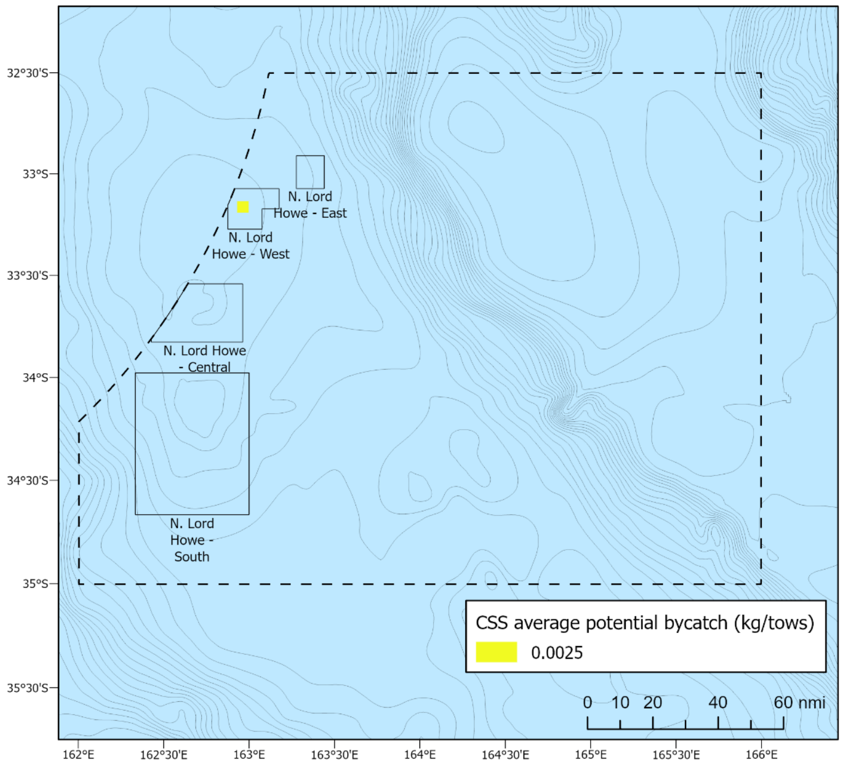


Figure 4 | Average potential bycatch weigh of Scleractinia (CSS) in the North Lord Howe Fishery Management Area by New Zealand trawl vessels from 2008 to 2024. Note 2 cells have been omitted from the figure to comply

with Fisheries New Zealand regulations for the release of commercially sensitive data (see Annex 3 – Number of cells omitted from Figures due to release of commercially sensitive data regulations).

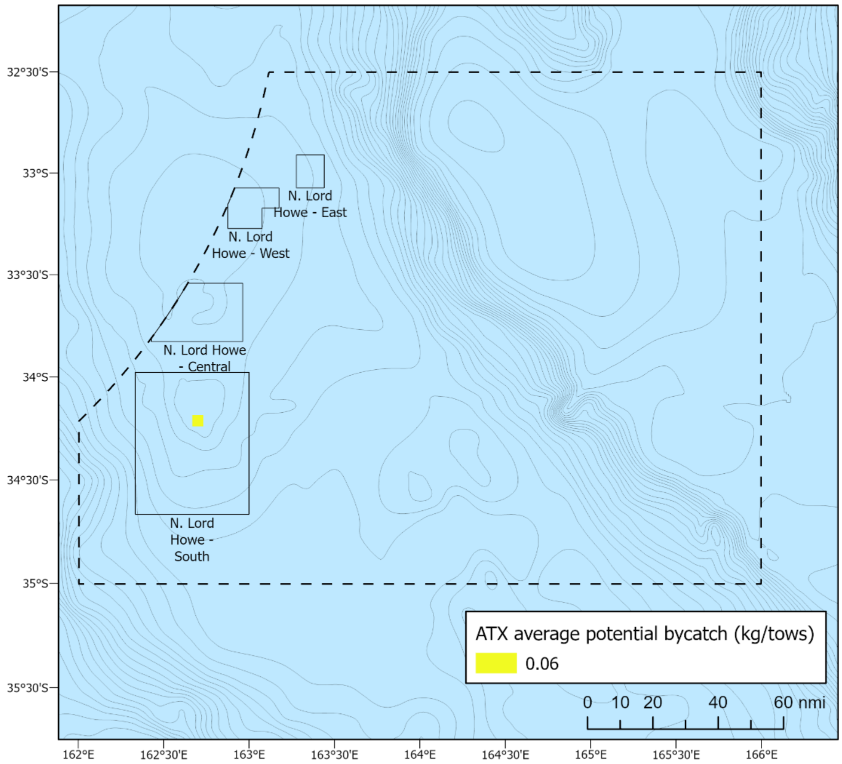


Figure 5 | Average potential bycatch weigh of Actinaria (ATX) in the North Lord Howe Fishery Management Area by New Zealand trawl vessels from 2008 to 2024. Note 3 cells have been omitted from the figure to comply with Fisheries New Zealand regulations for the release of commercially sensitive data (see Annex 3 – Number of cells omitted from Figures due to release of commercially sensitive data regulations).

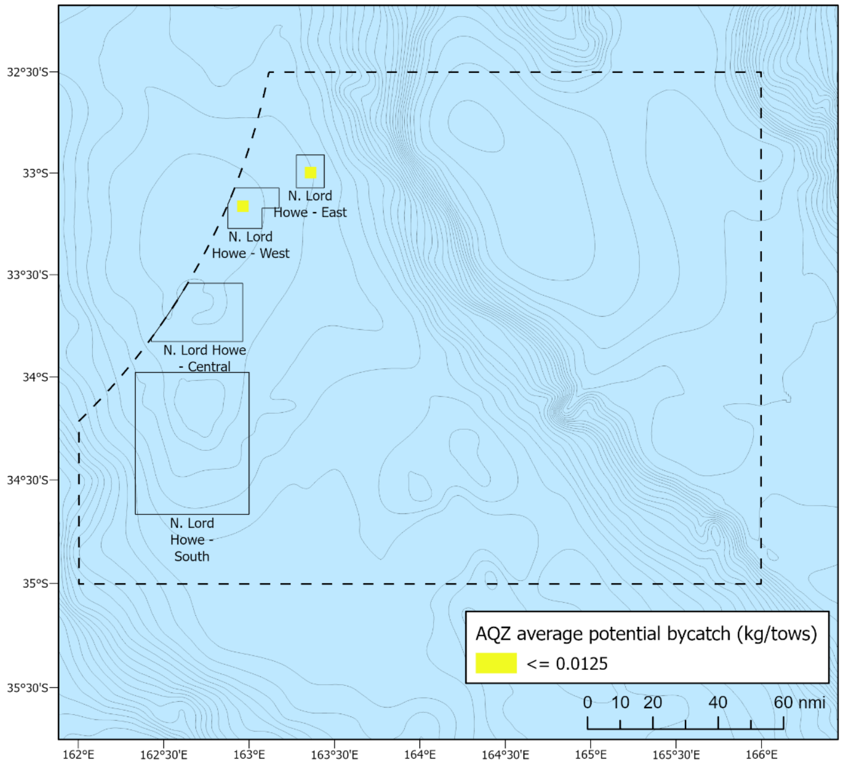


Figure 6 | Average potential bycatch weigh of Antipatharia (AQZ) in the North Lord Howe Fishery Management Area by New Zealand trawl vessels from 2008 to 2024. Note 3 cells have been omitted from the figure to comply with Fisheries New Zealand regulations for the release of commercially sensitive data (see Annex 3 – Number of cells omitted from Figures due to release of commercially sensitive data regulations).

4.2 Comparing midwater and bottom trawling

Midwater trawl effort was approximately seventeen times lower than bottom trawl effort during the same period, with 578 midwater trawl tows and 9,695 bottom trawl tows targeting the same species within the boundaries of the SPRFMO Evaluated Area (Table 7). Similarly, the percentage of tows with VME indicator taxa bycatch was approximately 12 times lower for midwater trawl (2.94%) than for bottom trawl (35.28%). The percentage of bottom trawl tows targeting alfonsino and orange roughy that had VME indicator taxa bycatch was 15.99% and 38.71%, respectively, significantly higher than for midwater trawl tows, which for those same target species was 2.54% (alfonsino) and 16.67% (orange roughy) (Table 7), noting the large difference between effort (551 midwater trawl tows targeting alfonsino and only 7 targeting orange roughy).

Maximum average potential bycatch values of VME indicator taxa for Bottom Trawl Management Areas (SC11-DW10) were re-calculated and filtered by taxa (Porifera, Scleractinia, Antipatharia, Gorgonian Alcyonacea, Actinaria and Crinoidea) and FMAs (North Lord Howe, Northwest Challenger and Westpac Bank) relevant to the midwater trawl activity described in the present analysis (Table 10). Maximum average potential bycatch values were consistently greater for bottom trawling than midwater trawling, except for Antipatharia in the North Lord Howe - East Management Area (< 0.001 for midwater trawling and low levels of bottom trawl effort) and Gorgonian Alcyonacea in the closed area of the Northwest Challenger (0.025 and 0.006 for midwater and bottom trawling respectively). Bottom trawl effort was several magnitudes larger in all management areas except for the North Lord

Howe - East Management Area, where the number of midwater trawl tows (n = 237) was more than 30 times greater than the number of midwater trawl tows (n = 7).

Table 10 | Comparison of Maximum Average Potential Bycatch (as defined in Table 3) of VME indicator taxa from New Zealand midwater trawl vessels (MW) and bottom trawl vessels (BT) between 2008 and 2024 for each Management Area. Closed is the area outside management areas within a Fishery Management Area (FMA) that is closed to trawling. Note that the North Lord Howe – Central management area is not currently open to bottom trawling. Red values indicates greater (or equal) positive effort and bycatch values for midwater trawling, compared to those from bottom trawling. The table only presents values for VME indicator taxa (6 of the 13 listed in CMM03-2023) caught by midwater trawl vessels (other VME indicator taxa that were caught by bottom trawl but not by midwater trawl are excluded).

Fishery Management Area (FMA)	Management Area (MA)	No. tows		No. tows with VME indicator taxa bycatch		Maximum Average Potential Bycatch of VME Indicator Taxa (kg/#tows)											
						Porifera		Scleractinia		Antipatharia		Gorgonian Alcyonacea		Actiniaria		Crinoidea	
		MW	BT	MW	BT	MW	BT	MW	BT	MW	BT	MW	BT	MW	BT	MW	BT
Central Lord Howe	S. Lord Howe - East	2	205	0	130	0.000	5.200	0.000	8.250	0.000	9.699	0.000	61.974	0.000	3.000	0.000	0.007
Central Lord Howe	S. Lord Howe - West	2	1,346	1	401	0.000	1.250	0.100	0.500	0.000	0.400	0.000	3.099	0.000	2.228	0.000	0.000
Central Lord Howe	S. Lord Howe - South	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Central Lord Howe	Closed	0	6	0	4	NA	0.000	NA	7.000	NA	2.099	NA	1.000	NA	0.000	NA	0.000
Nth Lord Howe	N. Lord Howe - Central	89	0	7	NA	0.000	NA	0.36	NA	0.000	NA	0.470	NA	0.005	NA	0.020	NA
Nth Lord Howe	N. Lord Howe - East	237	7	1	2	0.000	3.071	0.000	0.000	< 0.001	0.000	0.000	0.014	0.000	0.000	0.000	0.000
Nth Lord Howe	N. Lord Howe - South	169	922	4	114	0.050	0.428	0.000	0.038	0.030	0.550	0.030	0.906	0.085	0.699	0.007	0.020
Nth Lord Howe	N. Lord Howe - West	54	280	2	31	0.000	0.042	0.002	0.004	0.020	0.333	0.000	0.466	0.000	1.066	0.000	0.001
Nth Lord Howe	Closed	3	249	0	98	0.000	0.428	0.000	0.032	0.000	0.699	0.000	7.500	0.000	0.699	0.000	0.100
NW Challenger	Northwest Challenger	5	3,328	0	1440	0.000	11.000	0.000	1.596	0.000	0.636	0.000	0.190	0.000	65.000	0.000	1.000
NW Challenger	Closed	14	25	2	6	0.000	10.000	0.500	1.000	0.000	0.000	0.025	0.000	0.000	10.000	0.000	0.222
Westpac Bank	Westpac Bank	3	467	1	79	0.000	< 0.001	0.000	0.023	0.003	0.171	0.000	0.030	0.000	0.050	0.000	0.000
Westpac Bank	Closed	0	8	0	3	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.100	0.000	5.000	0.000	0.000

4.3 Assessing potential to contact the seabed

Deriving seabed contact rates from gear codes

Gear codes ‘H’ (indicative of contact), ‘U’ and ‘Y’ were not recorded for any of the analysed tows (Table 11). Codes unrelated to evidence of seabed contact such as ‘C’ (n = 1), ‘D’ (n = 1) and ‘E’ (n = 4) were rarely recorded. Tows with gear codes indicating potential contact with the seabed (e.g., ‘A’) were further scrutinised by analysing the rest of associated event codes (when more than one code was registered for a single tow). For example, from the 38 tows with the ‘A’ code, 11 also had the ‘B’ code and 4 had benthic bycatch, resulting in 14 tows with unequivocal evidence of seabed contact. The percentage of tows with the code ‘B’ within tows coded ‘A’ was the highest across the other gear codes (e.g. for code ‘O’, 1 out of 32 tows was coded ‘B’) (Figure 7). The highest percentage of tows with confirmed (and likely) evidence of contacting was related to code ’A’, with about half of the tows indicating unequivocal or potential likelihood of seabed contact.

Table 11 | Number of occurrences of specific gear event codes and confirmed or likely seabed contact from New Zealand midwater trawl vessels between 2008 and 2022. Note the total number of tows exceeds 578 due to multiple codes being used for some tows.

Code	Number of tows	Number of tows with benthic bycatch	Other considerations indicating possibility of contact	Seabed contact			
				Confirmed		Likely	
				No.	%	No.	%
A	38	4	11 with code ‘B’ 1 with code ‘I’ 1 with codes ‘F’ and ‘O’	14	36.84	3	7.89
B	30	2	NA	30	100.00	0	0.00
C	1	0	NA	0	0.00	0	0.00
D	1	0	NA	0	0.00	0	0.00
E	4	0	1 with code ‘O’ and ‘F’ 1 with code ‘F’	0	0.00	2	50.00
F	94	3	8 with code ‘B’ 6 with code ‘A’	10	10.63	6	6.38
G	4	0	1 with code ‘B’ and ‘F’	1	25.00	0	0.00
H	0	0	NA	–	–	–	–
I	2	0	1 with code ‘A’	0	0.00	2	100.00
O	32	1	1 with code ‘B’ 1 with codes ‘A’ and ‘F’	2	6.25	1	3.20
U	0	0	NA	–	–	–	–
Y	0	0	NA	–	–	–	–
Z	402	14	1 with longline	14	3.48	1	0.24

Tows with a snapped or broken warp (code ‘I’) (n = 2) may have contacted the seabed, with one of the tows also coded ‘A’, although were not found to be associated to other codes or to have reported benthic bycatch (Figure 7). While code ‘F’ would not be indicative of the gear contacting the bottom, 3 out of the 94 tows coded ‘F’ had benthic bycatch and 8 were also coded ‘B’, giving a total percentage of ~10% of tows coded ‘F’ showing unequivocal evidence of contact. Code ‘Z’ (no gear events were observed) was the most used code among all tows (n = 402), with 14 with benthic bycatch and 1 having caught discarded or lost longline gear (Table 11).

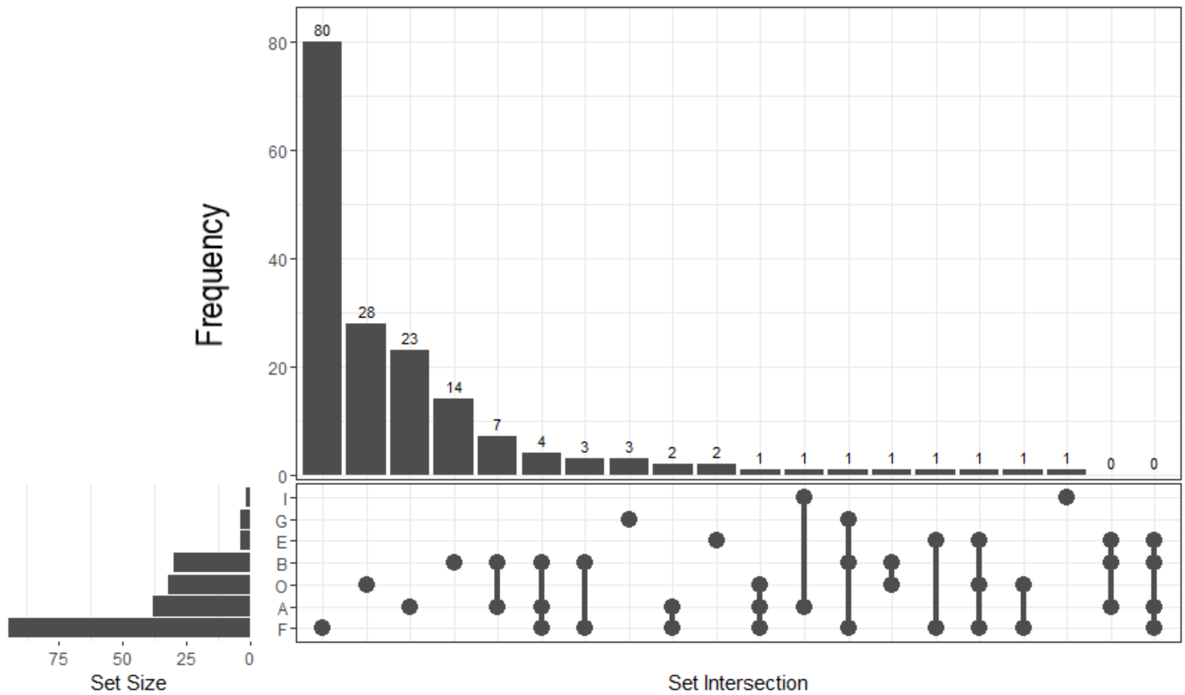


Figure 7 | Occurrence of gear event codes 'A', 'B', 'E', 'F', 'G', 'I', 'O' and number of times codes were found in combination with another code(s). Set size (left panel) represents number of tows with given code. Set intersection (right panel) represents number of times (tows) a code was found in combination with one or more codes. For example, from all tows with code 'I' (n = 2), one didn't have any other code associated to it, while one was found in combination with code 'A'. Note codes absent in the dataset (e.g., 'H') or unrelated to other codes (e.g., 'Z') are excluded from the figure to facilitate its readability.

Yearly minimum rates of seabed contact ranged from 0% (2019, only one tow) to 75% (2020, only 4 tows), with a rate of 5.59% for the year yielding the highest effort (2018, with 161 tows) (

Table **12**). Other years with significant levels of effort (2011 to 2013 and 2015 to 2017) had a minimum rate of seabed contact ranging from 5.77% (2012, n = 52) to 13.22% (2013, n = 121). Yearly potential rates of seabed contact were logically equal or greater than the yearly minimum rates, with the largest increase detected in 2016, a jump from 11.90% to 28.57% (n = 42) (

Table **12**).

Table 12 | The overall percentage of midwater tows from New Zealand midwater trawl vessels between 2008 and 2024 that 1) showed unequivocal evidence of having touched the seabed (labelled as 'Minimum rate of seabed contact'), and 2) showed strong evidence of having touched the seabed (labelled as 'Potential rate of seabed contact'). 'Minimum rate of seabed contact' is evidenced by an observer gear event code 'B' and/or benthic material record for each tow, while 'Potential rate of seabed contact' is evidenced by an observer gear event code 'B' and/or 'A' and/or benthic material record for each tow.

Year	Tows	Min. rate of seabed contact		Potential rate of seabed contact	
		No. of tows contacting	% of tows contacting	No. of tows contacting	% of tows contacting
2008	0	0	0.00	0	0.00
2009	1	0	0.00	0	0.00
2010	15	2	13.33	3	20.00
2011	62	5	8.06	8	12.90
2012	52	3	5.77	7	13.46
2013	121	16	13.22	24	19.83
2014	0	0	0.00	0	0.00
2015	23	2	8.70	2	8.70
2016	42	5	11.90	12	28.57
2017	91	3	3.30	4	4.39
2018	161	9	5.59	9	5.59
2019	6	2	33.33	2	33.33
2020	4	3	75.00	3	75.00
2021	0	0	0.00	0	0.00
2022	0	0	0.00	0	0.00
2023	0	0	0.00	0	0.00
2024	0	0	0.00	0	0.00
Total	578	50	8.65	74	12.80

Restricting the calculation of rates of seabed contact to management areas with at least 15 tows per year resulted in a reduced set of results representing the alfonsino fishery in the North Lord Howe FMA (

Table **13**). Minimum and potential rate of seabed contact ranged from 0% (e.g., minimum rate for 2011 in the North Lord Howe - Central) to 25% (potential rate for 2016 in the North Lord Howe – East). The North Lord Howe - East was the Management Area where significant effort (n > 15) was constant over the 2011-2013 and 2016-2018 periods (Figure 2), and minimum and potential rates of seabed contact were greater than 0 except for the year 2018.

Table 13 | The percentage of midwater tows from New Zealand midwater trawl vessels targeting alfonsino between 2008 and 2024 that 1) showed unequivocal evidence of having touched the seabed (labelled as 'Min.' - minimum), and 2) showed strong evidence of having touched the seabed (labelled as 'Pot.' – potential). 'Minimum rate of seabed contact' is evidenced by an observer gear event code 'B' and/or benthic material record for each tow, while 'Potential rate of seabed contact' is evidenced by an observer gear event code 'B' and/or 'A' and/or benthic material record for each tow. Note only pairs of MTMA-Year with effort greater or equal than 15 tows are provided, with the rest excluded from the table.

Midwater Trawl Management Area (MTMA)	**Yearly rates of seabed contact**											
	2011		2012		2013		2016		2017		2018	
	Min.	Pot.	Min.	Pot.	Min.	Pot.	Min.	Pot.	Min.	Pot.	Min.	Pot.
N. Lord Howe - Central	0.00	13.33	–	–	–	–	–	–	–	–	13.00	13.00
N. Lord Howe - East	11.76	11.76	2.70	10.81	12.24	14.28	12.50	25.00	–	–	0.00	0.00
N. Lord Howe - West	–	–	–	–	–	–	–	–	0.00	5.88	–	–
N. Lord Howe - South	–	–	–	–	9.52	20.63	–	–	4.62	4.62	0.00	0.00

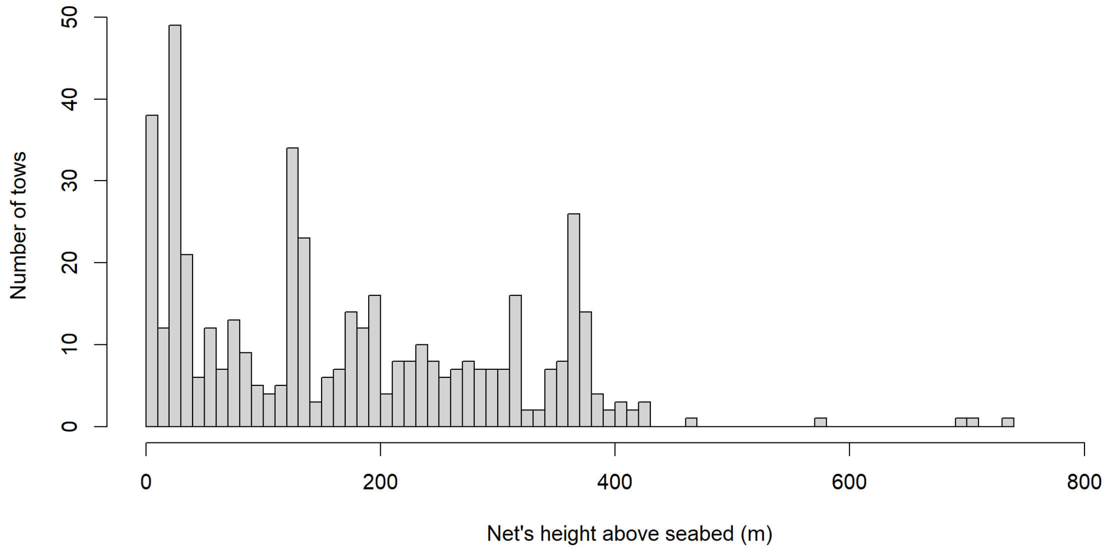
For each pair of year and Management Area with at least 15 tows targeting alfonsino, the percentage of tows with VME indicator taxa was consistently lower than the potential rate of seabed contact (and by definition lower than the minimum rate of seabed contact as well) (Table 14). 2011 in the North Lord Howe – East saw the largest percentage of tows having benthic bycatch (11.76%) which matched the minimum rate of seabed contact, although the percentage of tows having VME indicator taxa bycatch was 5.88%.

Table 14 | The percentage of midwater tows from New Zealand midwater trawl vessels targeting alfonsino between 2008 and 2024 1) that had benthic bycatch (labelled as 'B'), and 2) had VME indicator taxa bycatch (labelled as 'VME'). Note only pairs of MTMA-Year with effort greater or equal than 15 tows are provided, with the rest excluded from the table.

Midwater Trawl Management Area (MTMA)	**Percentage of tows with benthic bycatch and VME indicator taxa**											
	2011		2012		2013		2016		2017		2018	
	B	VME	B	VME	B	VME	B	VME	B	VME	B	VME
N. Lord Howe - Central	0.00	0.00	–	–	–	–	–	–	–	–	11.10	11.10
N. Lord Howe - East	11.76	5.88	0.00	0.00	0.00	0.00	3.12	0.00	–	–	0.00	0.00
N. Lord Howe - West	–	–	–	–	–	–	–	–	0.00	0.00	–	–
N. Lord Howe - South	–	–	–	–	1.59	0.00	–	–	3.08	3.08	0.00	0.00

Estimates of net position relative to the seabed

For tows with either an initial (n = 470) or final (n = 410) net (gear) and seabed depths, the estimated height of the net above the seabed ranged from 0 m to 739 m and 813 m, respectively, with the majority of values between 100 m and 400 m (Figure 8). 38 tows (8.08%) had an initial estimated net height above the seabed ≤ 10 m, with 20 (5.81%) of those tows having a height above the seabed of 0 m (since net depth was equal to seabed depth). Similarly, 27 tows (6.58%) had a final (relative to the tow's end position) estimated net height above the seabed ≤ 10 m, with 18 (4.39%) of those tows having a height above the seabed of 0m (Table 15).



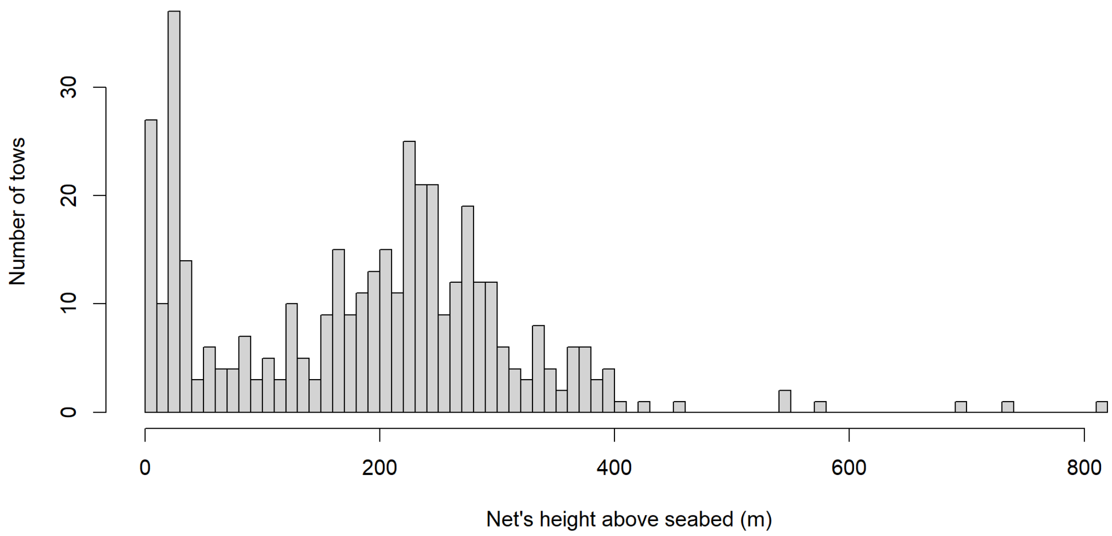


Figure 8 | Distribution of the estimated height of the tow's net relative to the seabed in meters (X axis) at the start (above figure) and end (below figure) positions, using 100 breaks (intervals). Y axis represents the number of tows (frequency). Note that the range (max limit) for both axes is slightly different between the above and below figure.

Table 15 | Number and percentage of tows with start and/or end estimated heights of the net (gear) near (≤ 10 m) and on (at 0 m) the seabed (in meters).

		≤ 10 m estimated above seabed				**0 m (estimated on seabed)**			
	Tows	**No. of tows**	**% of tows**	**No. of tows with benthic bycatch**	**% tows with benthic bycatch**	**No. of tows**	**% of tows**	**No. of tows with benthic bycatch**	**% of tows with benthic bycatch**
Initial (tow start)	470	38	8.08	3	0.63	20	4.25	1	0.21
Final (tow end)	410	27	6.58	4	0.97	18	4.39	3	0.73

5. Discussion

Here we update VME indicator taxa bycatch metrics presented in SC10-DW03 and SC11-DW10, but restricted to records from the New Zealand midwater trawl fishery targeting bentho-pelagic species (n = 578), mainly alfonsino (*Beryx splendens* and *B. decadactylus*). While occasionally targeted by a limited number of the analysed tows (as shown here), fishing for orange roughy (*Hoplostethus atlanticus*) using midwater trawl gear has been proven largely ineffective, mainly due to the well-documented diving behaviour of the fish when being approached by the gear (Koslow et al. 1995, O'Driscoll et al. 2012) and the roughness of the fishing grounds (Clark & Roberts 2008; SC02-10). These considerations may be relevant to the observation that tows targeting orange roughy had the second highest ratio of VME indicator taxa (16.67%), after bluenose (25%), suggesting that bottom contact may occur more frequently than for tows targeting alfonsino. However, the low number of tows targeting orange roughy (n = 6) prevents us from drawing further conclusions. The difference in targeted species between midwater and bottom trawl is also reflected in the amount of fishing effort and its spatial distribution. While most of the analysed midwater trawl tows are concentrated within the North Lord Howe FMA, bottom trawling has historically occurred in all FMAs within the SPRFMO Evaluated Area (SC10-DW03), as well as in other areas within the SPRFMO Convention Area prior to 2008.

None of the recorded bycatch weights of VME indicator taxa from midwater trawl tows (n = 18, or 2.94% of all tows) exceeded any of the taxon-specific or the biodiversity thresholds specified in Annex 6A and Annex 6B of CMM 03-2023. Therefore, the Encounter Protocol would have not been triggered if the current management measures had been in place when these fishing events occurred. Benthic bycatch records from the Australian midwater trawl fishery are not included in the analysis, adding uncertainty to the results. Significant fishing effort occurred in the North Lord Howe Rise from Australian trawl vessels using midwater trawl gear between 2002 and 2009, mainly targeting alfonsino (representing > 70% of the total catch), but occasionally also targeting rudderfish (*Centrolophus niger*) and boarfish (Family Pentacerotidae), among others (Williams, 2011).

Standardised VME indicator taxa bycatch rates for midwater trawl (mainly targeting alfonsino) were generally lower than those calculated for the New Zealand bottom trawl fleet (excluding species not targeted by midwater trawl, providing a fair comparison). While the VME indicator taxa bycatch metrics presented here for midwater trawling are relatively low, there is a need to consider cumulative impacts, particularly from other forms of bottom-contact fishing (e.g., bottom trawl) that occur (or have occurred) in the same areas. Cumulative bottom impacts are accounted for in benthic impact assessments (SC08-DW07_rev1, SC11-DW01_rev1), with the area estimated to have been impacted by midwater trawling several orders of magnitude smaller than by bottom trawling. Additionally, we acknowledge that there is a certain degree of uncertainty regarding the relationship between the amount of bycatch landed on deck and the amount of taxa that may have been impacted on the seafloor (known as 'catchability'), with catchability likely to differ between taxa, depending on their morphology and susceptibility to the gear. Previous analyses (e.g., SC10-DW04) indicate that in general, the catchability of VME indicator taxa by bottom trawl is low (< 5%) although for some taxa can be higher (> 20%), and rates can vary by geographical area, depth and fishing gear. Therefore, the results presented here may not reflect the full impacts of the gear used when midwater trawling for bentho-pelagic species (particularly alfonsino) on the benthic environment, although they are likely to be a good indicator.

While records of benthic bycatch indicate that the fishing gear contacted the seabed, the present analysis provides a complementary approach to further estimate rates of seabed contact based on the gear events associated with each tow (SC02-10). Unequivocal evidence (e.g., net caught) and strong evidence (e.g., torn net) along with recorded benthic bycatch suggest relatively low rates of the midwater gear contacting the benthos. The results were similar to those presented in SC02-10. Similarly to the VME indicator taxa bycatch metrics, results for midwater trawl tows targeting alfonsino were considered representative of the fishery, given they were the main target species for most tows. For the years where effort targeting alfonsino was deemed relevant (n ≥ 15 tows), the estimated rate of the gear potentially contacting the seabed was ≤ 25%.

The proportion of tows with benthic bycatch (including VME indicator taxa bycatch) were generally lower than the estimated rates of the gear contacting the seabed in the North Lord Howe FMA. The North Lord Howe - East MTMA was identified as the Management Area with highest fishing effort across the 2008–2024 period (n = 237 tows), making it the best candidate to infer conclusions from. For example, the North Lord Howe – East MTMA had the largest percentage of tows having benthic bycatch in 2011 (11.76%), which matched the minimum and potential rates of seabed contact. However, for that same year and MTMA (2011 and North Lord Howe – East MTMA), the percentage of tows that had VME indicator taxa bycatch was approximately half (5.88%) of the minimum rate of seabed contact (11.76%).

The percentage of tows estimated to be near the seabed (≤ 10 m) at the start and at the end of each tow (~8% and ~%6 respectively) were in the same range (< 10%) as the minimum and potential rates of seabed contact, although the height of the net relative to the seabed during each fishing event (tow) remains uncertain. The number of tows with missing recorded depths at the start and/or end positions (Table 4), which were replaced by estimates of depth from the GEBCO bathymetry grid (GEBCO, 2021), add uncertainty to the estimation of the position of the net relative to the seabed. Additionally, in occasions when the net may be in close proximity to the seabed (without contacting it), seabed and net depths may be recorded with the same values (Andy Smith, HSFG, pers. comm.).

Considering the low percent of midwater trawl tows targeting alfonsino that contact the benthos (SC02-10, SPRFMO trawl impact workshop in July 2017), and the low levels of VME indicator taxa bycatch in midwater tows that do contact the benthos (none of which would have triggered the Encounter Protocol during the entire period represented in the data), the benthic impacts of the midwater fishery targeting alfonsino can be described as low compared to those associated with bottom trawling. This may also be the case for midwater trawl tows targeting other species such as orange roughy, but the low levels of effort prevent us from extrapolating our conclusions beyond the alfonsino fishery. Thus, when assessing the effects of the New Zealand midwater trawl fishery targeting alfonsino within the SPRFMO Evaluated Area, the risk of causing significant adverse effects (SAIs) is much less than that for the bottom trawling fishery. Recognising differences between fisheries in the likelihood that they will impact the benthos, future management actions intending to avoid or limit the adverse effects of bottom trawling on VMEs (e.g., spatial closures) may need to be fishery-specific given the results presented here.

6. Recommendations

It is recommended that the Scientific Committee:

- **Notes**:
  - That metrics describing the frequency and spatial distribution of historic bycatch of VME indicator taxa have been updated with reference to the midwater trawl fishery (targeting bentho-pelagic species) from New Zealand flagged vessels within the SPRFMO Evaluated Area;
  - That none of the analysed midwater trawl tows would have triggered the Encounter Protocol had measures been in place at the time that fishing took place;
  - That levels of VME indicator taxa bycatch in the New Zealand midwater trawl fishery for alfonsino are lower than those from the New Zealand bottom trawl fishery within the SPRFMO Evaluated Area.
- **Agrees**:
  - That the impact from the New Zealand midwater trawl fishery targeting alfonsino on the benthic environment, and particularly VMEs, is lower than that from bottom trawling;
  - That any future management actions (e.g. spatial closures) that aim to avoid or limit bottom fishing impacts on the benthos (and VMEs in particular) within the SPRFMO Evaluated Area should be fishery specific (i.e., not apply broadly to all bottom fisheries).

7. Acknowledgements

We are grateful for comments and advice from members of the New Zealand South Pacific Working Group. We thank Andy Smith from the High Seas Fishing Group (HSFG) for the useful comments on fishers' behaviour and gear technicalities when targeting alfonsino using midwater trawl gear in the high seas. We thank the Fisheries Data Management Team at Fisheries New Zealand, especially Ann Cristobal and John Moriarty, for providing us with the data extract from the Centralised Observer Database (*cod*) used in the analysis.

8. References

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Annex 1 – Fishery Management Areas (FMAs)

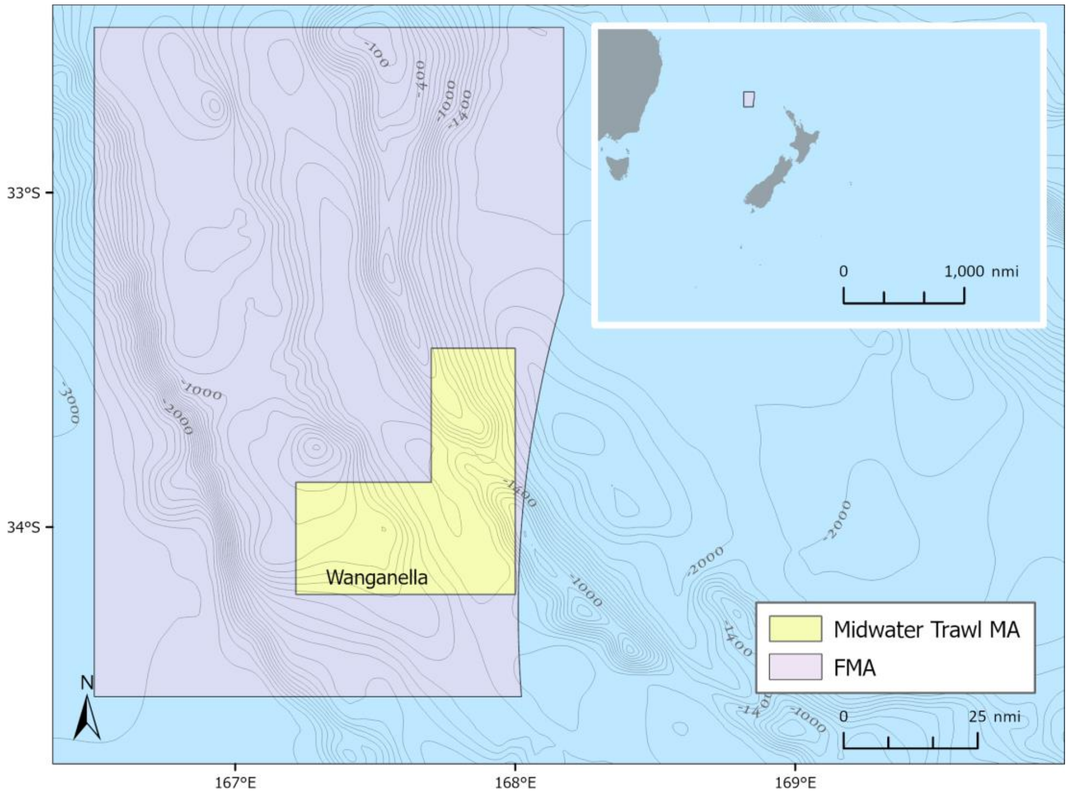

Figure A1 | West Norfolk FMA (pink box) and the Wanganella Midwater Trawl Management Area open to fishing under CMM03-2023 (yellow boxes). Depth contours are shown at 100m intervals.

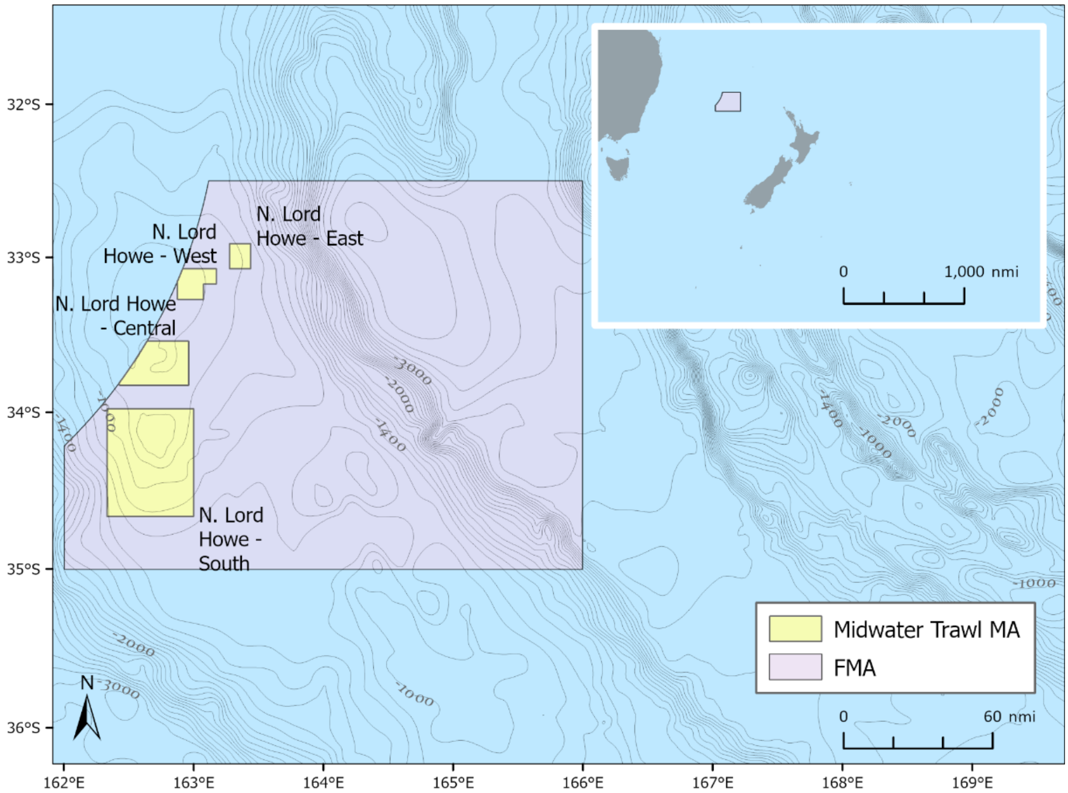

Figure A2 | North Lord Howe Rise FMA (pink box) and the Midwater Trawl Management Areas open to fishing under CMM03-2023 (yellow boxes). Depth contours are shown at 100m intervals.

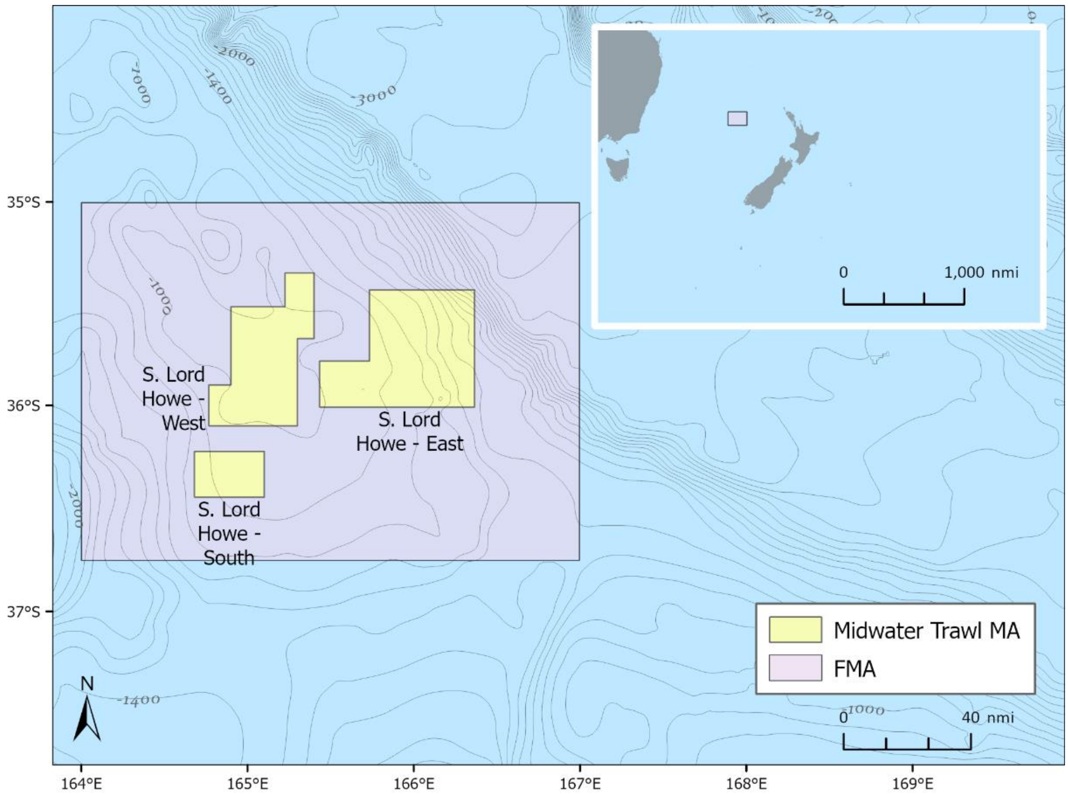

Figure A3 | Central Lord Howe Rise FMA (pink box) and the Midwater Trawl Management Areas open to fishing under CMM03-2023 (yellow boxes). Depth contours are shown at 100m intervals.

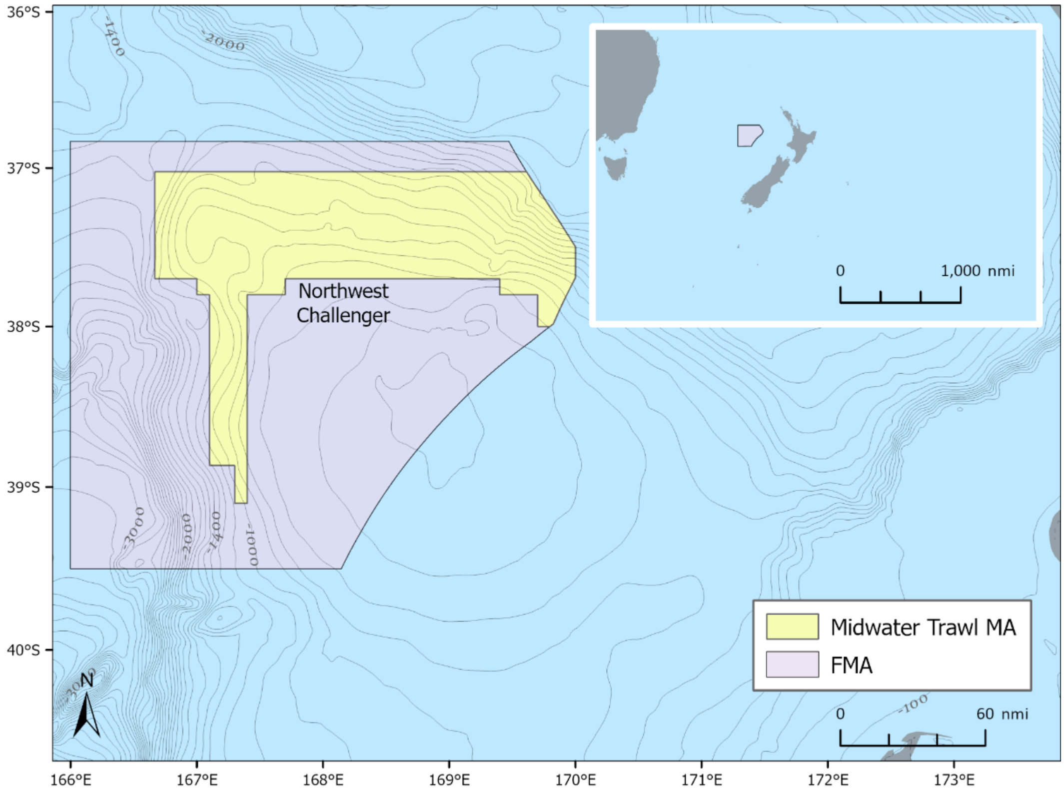

Figure A4 | Northwest Challenger FMA (pink box) and the Northwest Challenger Midwater Trawl Management Area open to fishing under CMM03-2023 (yellow boxes). Depth contours are shown at 100m intervals.

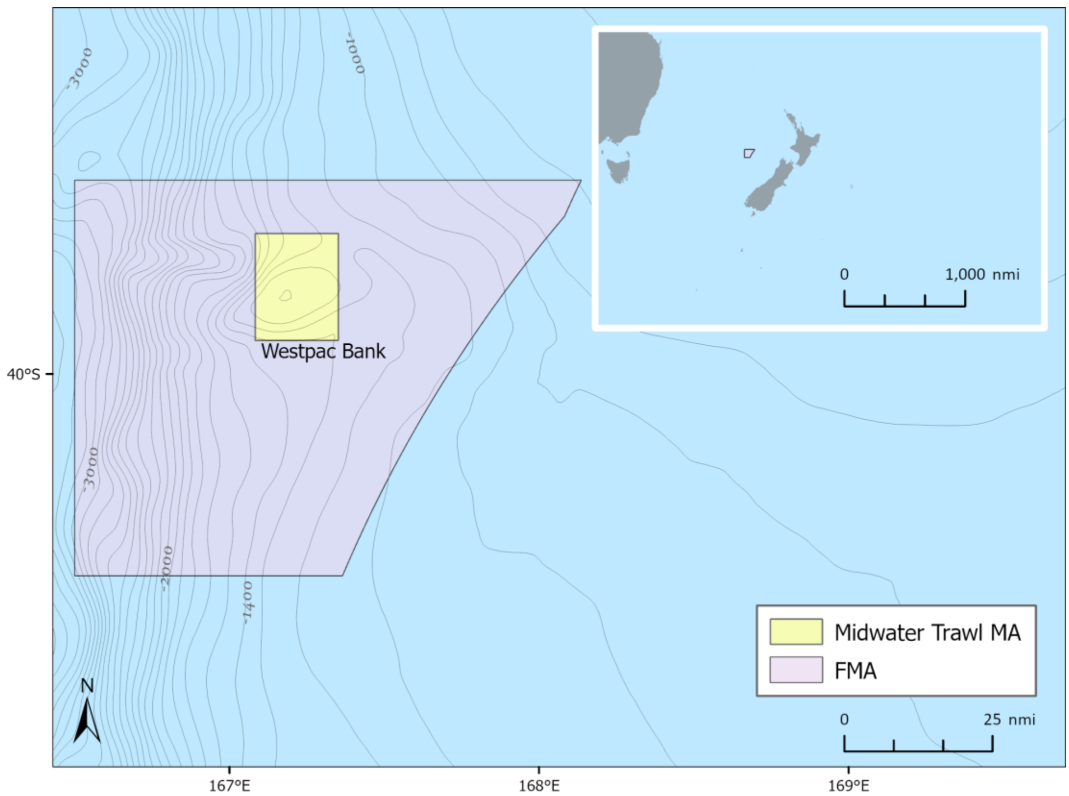

Figure A5 | Westpac Bank FMA (pink box) and the Westpac Bank Midwater Trawl Management Area open to fishing under CMM03-2023 (yellow boxes). Depth contours are shown at 100m intervals.

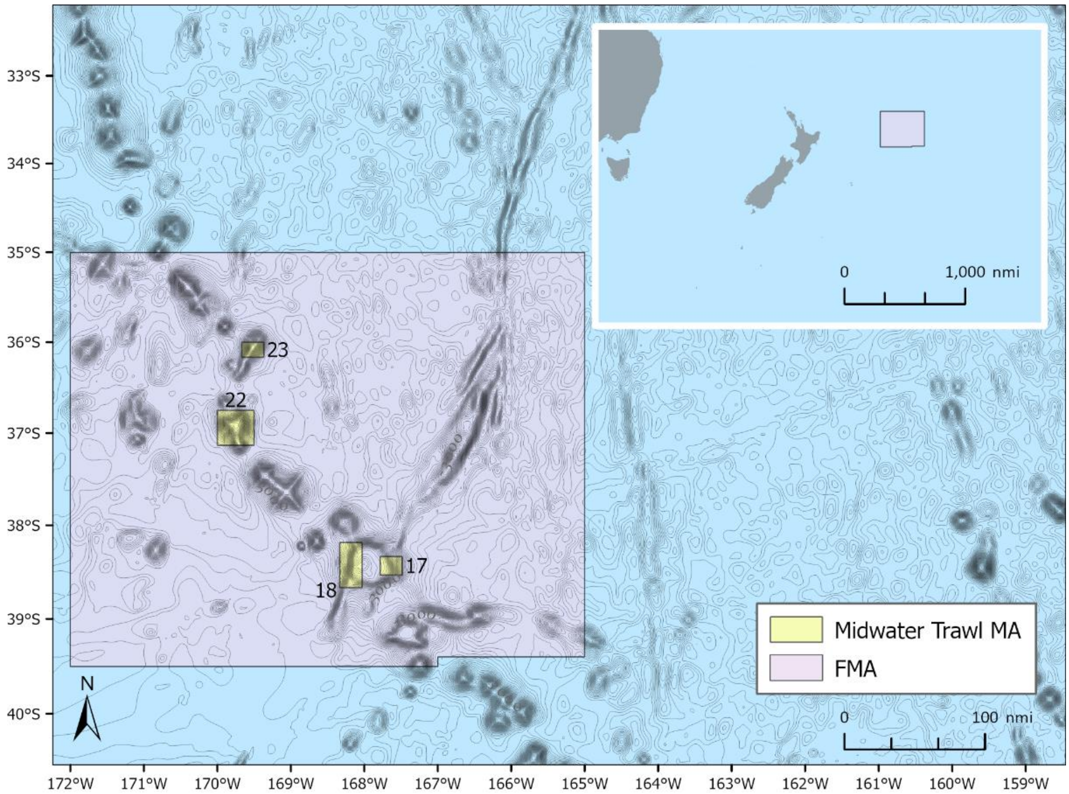

Figure A6 | North Louisville Ridge FMA (pink box) and the Midwater Trawl Management Areas open to fishing under CMM03-2023 (yellow boxes). Depth contours are shown at 100m intervals.

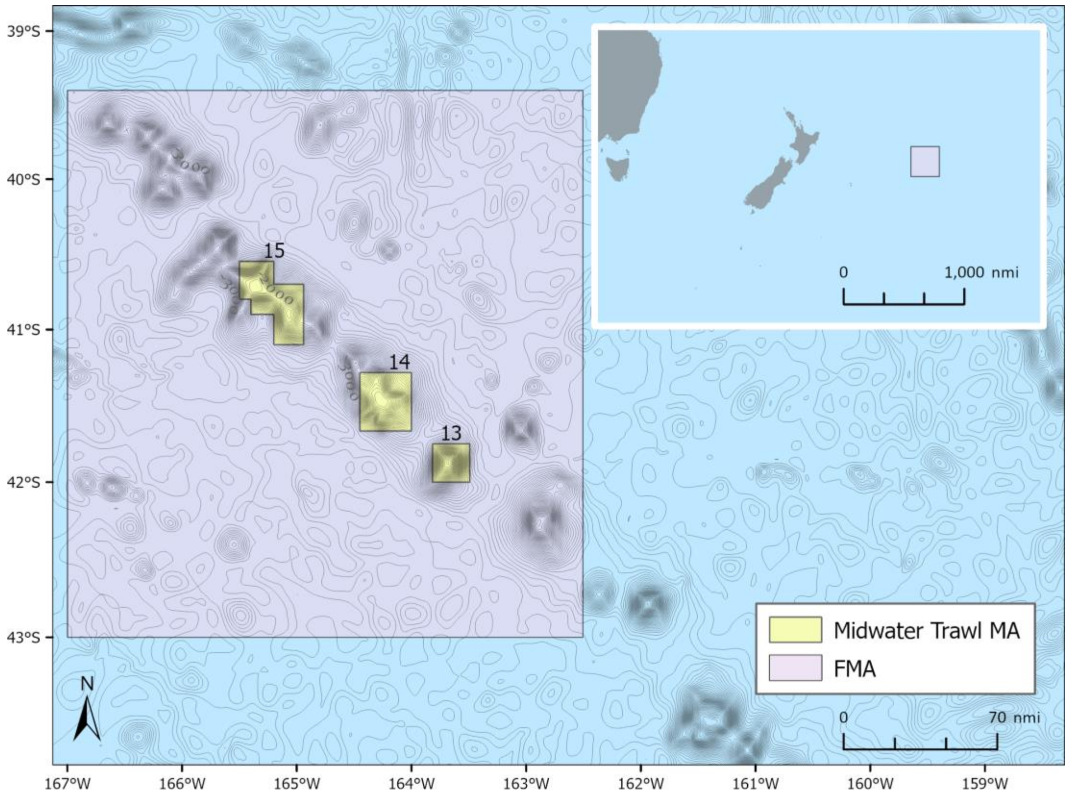

Figure A7 | Central Louisville Ridge FMA (pink box) and the Midwater Trawl Management Areas open to fishing under CMM03-2023 (yellow boxes). Depth contours are shown at 100m intervals.

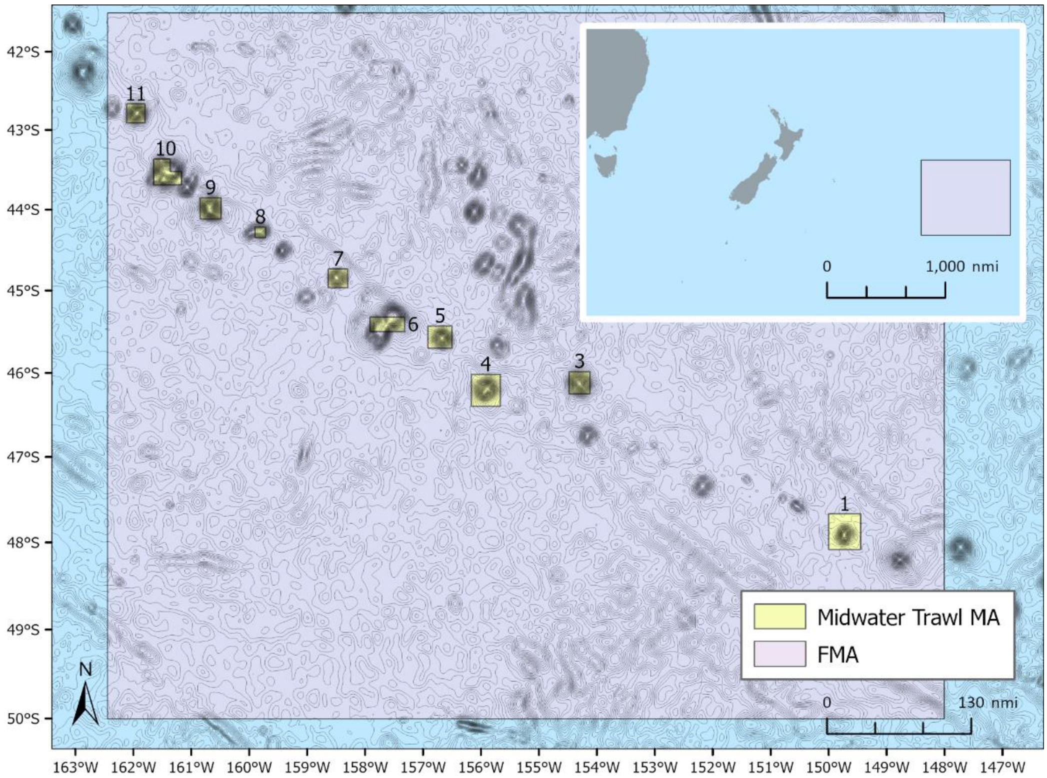

Figure A8 | South Louisville Ridge FMA (pink box) and the Midwater Trawl Management Areas open to fishing under CMM03-2023 (yellow boxes). Depth contours are shown at 100m intervals.

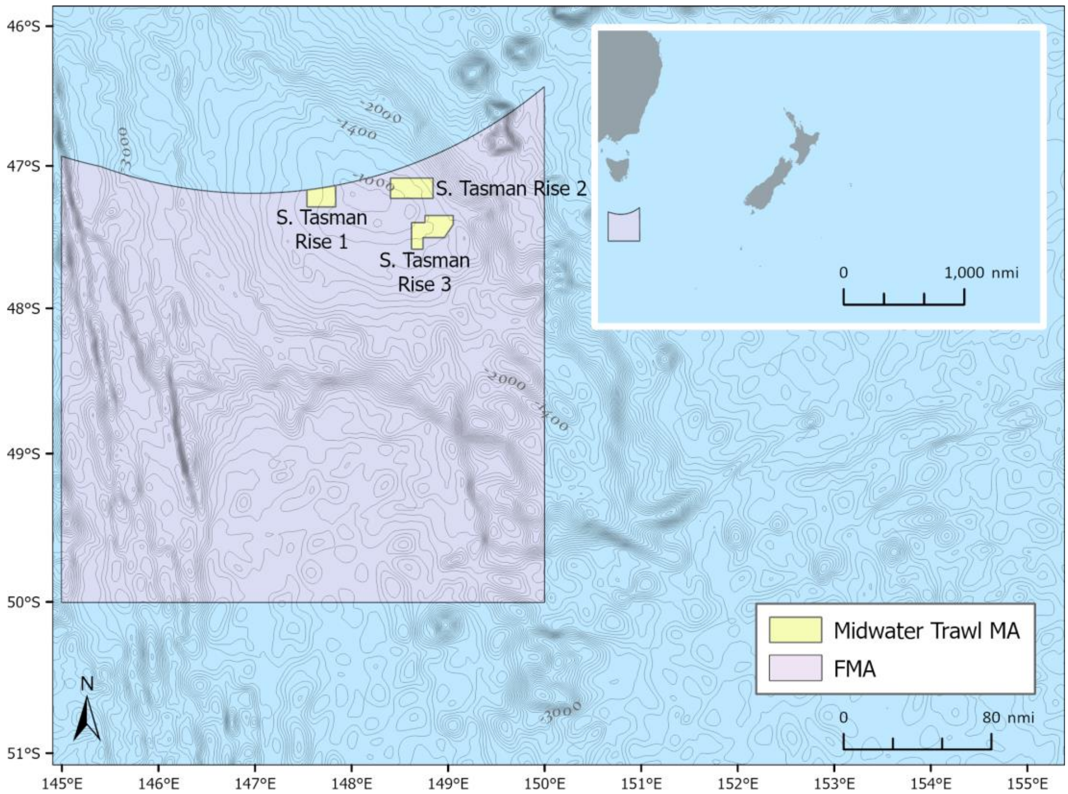

Figure A9 | South Tasman Rise FMA (pink box) and the Midwater Trawl Management Areas open to fishing under CMM03-2023 (yellow boxes).

Annex 2 - Zero Weight Adjustments

Table A2.1 | Number of trawl events, bycatch range (kg), trawl events with zero weights recorded, and the zero-weight adjustment used in the analysis.

VME indicator taxon	No. trawl events	Bycatch range (kg)	N (%) trawl events with zero weight records	Adjusted weight (kg)
PFR - Porifera	1	0.3 – 0.3	0	–
CSS - Scleractinia	4	0.1 – 6.5	1	0.1
AQZ - Antipatharia	4	0.02 – 0.5	1	0.01
AJZ - Alcyonacea	0	–	–	–
GGW - Gorgonacea	9	0.1 – 5.4	0	–
NTW - Pentulacea	0	–	–	–
ATX - Actiniaria	2	0.1 – 3	0	–
ZOT - Zoantharia	0	–	–	–
HQZ - Hydrozoa	0	–	–	–
AXT - Stylasteridae	0	–	–	–
BZN - Bryozoa	0	–	–	–
BHZ - Brisingida	0	–	–	–
CWD - Crinoidea	3	0.04 – 0.54	0	–

Annex 3 – Number of cells omitted from Figures due to release of commercially sensitive data regulations

Table A3.1 | Number of 3 nm x 3nm cells available for inclusion in Figures before (B) and after (A) applying release of commercially sensitive data regulations for each FMA (FMA_avail) and each VME indicator taxa within an FMA.

			VME Indicator Taxa																									
	FMA_avail		Porifera		Scleractinia		Antipatharia		Alcyonacea		Gorgonian Alcyonacea		Pennatulacea		Actiniaria		Zoantharia		Hydrozoa		Stylasteridae		Bryozoa		Brisingida		Crinoidea	
FMA	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Central Lord Howe	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nth Lord Howe	52	6	2	0	3	1	5	2	0	0	5	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	4	0
NW Challenger	16	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Westpac Bank	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Annex 4 – R packages

DPLYR
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