

**New Zealand Orange Roughy Trawl Footprint and
Coral Interaction Analysis 2005/06 to 2019/20**

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EXECUTIVE SUMMARY

We undertake a spatial analysis of trawl footprint and coral habitat in three New Zealand fisheries. Analysis is carried out against two habitat types: Underwater Topographic Features (UTF) and 'flats' habitat.

The main study period is the most recent three-year period for which data are available (01/10/17 to 30/09/20), with additional analyses undertaken for the period 01/10/05 to 30/09/20 and for 01/10/89 to 30/09/20. The three fisheries are the Marine Stewardship Council (MSC)-certified ORH7A (including Westpac Bank), ORH3B NWCR and ORH3B ESCR Unit of Assessment (UoA) areas.

Trawl footprint for orange roughy, oreo, hake, hoki and ling are analysed and compared against predicted coral habitats and observed coral capture events.

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1.0 INTRODUCTION

The Deepwater Group Ltd (DWG) asked GNS Science to undertake a spatial analysis of trawl footprint and coral interaction to assist with assessment of the three orange roughy fisheries against the Marine Stewardship Council (MSC) standard. Analyses were carried out for tows targeting orange roughy, oreo, hake, hoki and ling in three orange roughy fisheries. Tows were split into two groups; ORH/OEO (orange roughy and oreo) and HOK/HAK/LIN (hoki, hake and ling). The three fisheries are MSC-certified ORH3B North West Chatham Rise (ORH3B NWCR), ORH3B East and South Chatham Rise (ORH3B ESCR) and ORH7A, including Westpac Bank (ORH7A-WB), within the MSC Unit of Assessment (UoA) areas. For the purposes of this study, only the portion of ORH3B ESCR east of 179°30' W is considered. Additional analysis was also carried out where ORH7A and the Westpac Bank Area were treated as two separate regions.

The primary study period is the most recent three years for which trawl data are available (01/10/17 to 30/09/20). Additional analysis was carried out for an extended time period (01/10/05 to 30/09/20) and the full period for which trawl data are available (01/10/89 to 30/09/20).

Data were obtained from Fisheries New Zealand (FNZ) by the DWG in the form of vessel-reported records and observer-reported records.

This study is a continuation of previous studies, including Black (2018) and Clark et al. (2015). Where possible, similar methodology has been applied.

2.0 DATA

2.1 Tow Data

Trawl fishing data were provided by FNZ as RepLog 13629 (fishing years 1989/90 to 2018/19) and RepLog 13723 (fishing year 2019/20). Fishing years start on the 1st of October in one year and end on the 31st of September in the following year. RepLog 13723 does not include tows outside of the Exclusive Economic Zone (EEZ; i.e. on Westpac Bank). Fishing practice observed in RepLog 13723 suggests that hoki, hake and ling are not targeted in Westpac Bank. For orange roughy and oreo, trawls in Westpac Bank are sourced from RepLog 12816, provided by FNZ in 2020.

The analyses are for the purpose of assessment of the three orange roughy fisheries against the MSC standard. The agreed and accepted area of assessment for orange roughy fishing activity is within the depth range of 800–1600 m within each of the UoA areas. The MSC standard requires that fishing effects by other trawl fisheries within this depth range are also considered. These are oreo for its entire depth range and HOK/HAK/LIN fisheries where their footprint occurs within the 800–1600 m range. Therefore, all ORH/OEO tows are used, but HOK/HAK/LIN tows are only considered when some portion of the tow is ≥ 800 m.

Filtering of suspect tows has not been carried out for the tow data, with the following exceptions:

1. A 770-km-long tow that crossed land has been removed.
2. Positions are edited for obvious +/- 180° errors.

The three RepLogs are combined as necessary and the footprint calculated for the two species groups for each UoA area and variably for 2017/18 to 2019/20, 2005/06 to 2019/20, 1989/90 to 2004/05, 1989/90 to 2016/17 and 1989/90 to 2019/20. The trawl footprint is a polygon representing the area of seafloor that has been trawled at least once, regardless of the number of trawl events.

The area of seafloor that was trawled for the first time between 2017/18 and 2019/20 is referred to as the 'new swept area in 2017/18 to 2019/20'. This is calculated by taking the difference between the 2017/18 to 2019/20 and 1989/90 to 2016/17 footprint polygons and is repeated for the two species groups and each UoA area. This is then repeated to calculate the newly swept area for the 2005/06 to 2019/20 period.

2.2 Coral Data

Coral capture data are sourced from three datasets: observer-reported, vessel-reported and the research dataset.

Tows in the observer- and vessel-reported data also exist in the main tow dataset and so require matching. Unfortunately, there is not always a unique identifier, and location data is captured differently in the different datasets. Where possible, they are matched using the unique 'Event Key'; otherwise, they are matched using a combination of tow start date, tow start time and vessel code, using the premise that a vessel can only be in one place at any one time. Approximate start and end locations are used as a check on the matching process. Tow start times are converted as necessary, as observer data are recorded in NZST all year, whereas vessel and tow data are recorded as NZDT during daylight savings.

Where the trawl start and end locations have been reported differently in the tow data compared with the coral capture data, the location reported in the tow dataset is assumed to be superior unless there is a reason to think otherwise (e.g. tow crosses a closed area or is an unreasonably long tow).

2.3 Underwater Topographic Features Data

Analysis is carried out against two habitat types: Underwater Topographic Features (UTF) and 'flats' habitat. UTFs include knolls, hills and true seamounts.

UTF summit locations were taken from Black et al. (2015), supplemented by newer UTFs (Clark 2021).

Basal boundaries for some UTFs were constructed by Black et al. (2015). For the remaining UTFs, a circle is centred on the UTF summit and sized according to UTF type. The mean radius for each basal polygon in Black et al. (2015) is calculated giving a radius of 1.267 km for hills, 2.182 km for knolls and 12.905 km for seamounts. Due to the proximity of some UTFs, some basal polygons include multiple UTF summits.

Each tow is assigned to a specific UTF if the net position at the start of the tow is within 0.5 nautical miles (nm) of the UTF summit position and the tow is less than 4500 m long. All remaining tows are classified as 'flats' tows. Due to the higher precision in the location data compared with previous datasets, tows have not needed to be manually assigned to UTFs in the manner of Black (2018).

2.4 Habitat Data

Predicted habitat data has been supplied by DWG as grids showing the likelihood of the presence of particular species of coral. This is not a percentage or probability but a unit-less relative scale. The GIS is used to turn these grids into shapefiles identifying the regions in the >50th percentile; these are deemed to be areas where that species of coral is predicted to occur (Owen Anderson, NIWA; pers. comm. February 2020).

The best available predicted habitat data varies by region. For the Chatham Rise (ORH3B ESCR and ORH3B NWCR), it is based on the ensemble model abundance grids of Bowden et al. (2019). For the ORH7A – Westpac Bank region, it is based on the relative habitat suitability distributions of Georgian et al. (2019).

Predicted habitat data are used for three coral groups in the three UoA areas:

- Coral reef
- *Goniocorella dumosa* (Order Scleractinia, stony coral)
- Family Stylasteridae (Order Anthoathecata, hydro corals).

Coral reef is the combination of four common reef-forming stony corals (*Enallopsammia rostrata*, *Madrepora oculata*, *Solenosmilia variabilis* and *Goniocorella dumosa*). The shapefile for coral reef is calculated by first taking the mean value of each cell for the four different layers in the group.

An additional analysis is carried out for predicted coral distributions within Benthic Protection Areas (BPAs) in the entire EEZ. For this, the predicted distributions of Georgian et al. (2019) were used for four coral groups as follows:

- Stony corals
- Black corals
- Gorgonian corals
- Combined (this is the area covered by the predicted habitat of at least one of stony, black or gorgonian coral groups).

2.5 Other Data

Areas closed to trawl fishing are BPAs, Seamount Closure Areas (SCAs) and large marine reserves. Trawl tows are assumed to occur in a straight line between tow start and tow end coordinates. This is not always the case, and tows made around area closures may therefore appear to have occurred through the area closures. For this reason, tows that appear to cross area closure boundaries are clipped to the closure boundary.

Contour lines were extracted from the bathymetry grid at 800 and 1600 m (Mitchell et al. 2012). The 1600 m contour lines were used to construct a polygon containing all parts of each UoA area shallower than 1600 m; this is referred to as the 'fishable area' but may contain areas closed to trawl fishing. The 800 m contour line was also used to filter HOK/HAK/LIN tows. Contours were extracted at 200 m intervals for use in maps.

Boundaries for ORH7A, Westpac Bank, ORH3B NWCR and ORH3B ESCR were received from FNZ. The union of ORH7A and Westpac Bank was taken and ORH3B ESCR clipped to contain only the area east of 179°30' W. All three UoA areas were clipped to the coastline.

Although the majority of analyses were carried out for the three UoA areas, some additional analyses were also carried out on the entire EEZ. For these purposes, the EEZ is the area from the coastline to the 200 nm line and includes two enclaves of international water, one on the Chatham Rise and the other on the Campbell Plateau. For the additional analysis, ORH7A and Westpac Bank were treated as two separate UoA areas.

Hard benthic habitat (HBH) constructed using backscatter data was provided by DWG (Patchell 2019) as a shapefile. This layer does not extend beyond the Chatham Rise, so this analysis was only carried out for ORH3B ESCR and ORH3B NWCR.

3.0 ANALYSIS

3.1 Trawl Footprint Analysis

Two maps are constructed for each UoA, one showing trawl footprint for all years with trawl data (1989/90 to 2019/20) and one showing data for the three most recent fishing years (2017/18, 2018/19 and 2019/20). The map for the 1989/90 to 2019/20 period also distinguishes the region trawled for the first time in 2017/18 to 2019/20. Maps also show the areas of hard benthic habitat, closures and bathymetry contours at 400 m spacing. See Figures A1.1 to A1.6.

No tows targeting HOK/HAK/LIN meet the depth criteria in the 2017/18 to 2019/20 period in the ORH7A – Westpac Bank region.

Metrics for these trawl footprints are calculated for each UoA area; see Tables A1.1 to A1.3.

A subset of these metrics was also calculated for the time period 2005/06 to 2019/20, being the baseline year for MSC assessment of the environmental effects of trawling. See Table A1.4.

3.2 Coral Interaction Analysis

The spatial extent of the predicted habitat of each of the three coral groups in each of the three UoA areas is calculated. The overlap between this and the trawl footprint between 2017/18 and 2019/20 is also calculated and used to show the percentage of each predicted coral distribution potentially impacted by trawling. See Table A2.1.

The overlap between the predicted habitats for the three coral groups and the BPAs in the three UoA areas has been calculated to determine the extent to which the BPAs serve as refuge areas for coral habitat. See Tables A2.2 to A2.4.

A similar process is carried out using the EEZ-wide coral data for the four coral groups. Again, the overlap of predicted coral habitat and BPAs is provided. See Table A2.5.

Observed coral distribution is mapped for four coral groups (Table 3.1). This uses observer-reported coral captures (2017/18 to 2019/20), vessel-reported coral captures (2017/18 to 2019/20) and research coral dataset (2004/05 to 2018/19), where coral capture localities are expressed as 1 x 1 km squares centred at the reported locations/tows. For tows with only a recorded start position and no end location, the square is positioned at the start of the tow. These results are presented in Figures A2.1 to A2.12 and Table A2.6.

Table 3.1 Coral grouping.

Group Name	Scientific Name	Coral Reporting Codes
Hydrocorals	F. Stylasteridae	CRE, COO, COR, CRY, ERR, HDR, LPT, STL
Black corals	O. Antipatharia	ATP, BTP, CIP, COB, DEN, LEI, LIL, LSE, PTP, STI, TPT
Stony corals	O. Scleractinia	CAY, CBR, COF, CUP, DDI, ERO, FUG, GDU, MOC, SIA, STP, SVA
Gorgonian corals	O. Alcyonacea	ACN, BOO, CHR, CLG, CLL, CPT, GOC, IRI, ISI, LLE, MIN, MTL, NAR, PAB, PLE, PMN, PNA, PRI, THO

3.3 Unit of Assessment Fishery Metrics

Metrics for tows in each of the three UoA are compiled using data from the three most recent fishing years (2017/18 to 2019/20); see Appendix 3. ORH/OEO are considered separately to HOK/HAK/LIN. A small number of tows have been excluded from this analysis due to suspected errors. Tows outside of recognised fishing grounds were disregarded (two tows in Tasman Bay in ORH7A-WB and one tow in NWCR). It is suspected that the species code was wrongly reported on these tows. One tow in ORH3B ESCR is excluded from the depth metrics as it has a reported depth of 120 m. Due to the location of the trawl, this is likely to be a typographic error for 1020 m or 1200 m.

Metrics for UTF and flats tows are calculated using the assignment described above and the full list of UTF locations (including the six UTFS identified as part of this report).

Observer- and vessel-reported data are used to identify whether tows have caught coral. It should be noted that the large coral catch on flats habitat in ORH3B NWCR is due to one tow with a reported coral catch of 25,000 kg. See Tables A3.1 and A3.2.

3.4 Analysis of Trawl Footprint Overlap with Vulnerable Marine Ecosystem Indicator Taxa

Analyses were carried out to investigate the overlap between modelled distributions of Vulnerable Marine Ecosystem (VME) indicator taxa (after Georgian et al. 2019) and trawl footprint for the four UoA areas (Westpac Bank was considered a separate region to ORH7A), and the entire EEZ. The modelled VME indicator taxa are:

- Stony corals (GDU, SVA, MOC and ERO)
- Black corals – Antipatharia (COB)
- Alcyonacea – soft corals (SOC)
- Stylasteridae – hydrocorals (COR)
- Desmospongiae – desmosponges (DSO)
- Hexactinellidae – glass sponges (GLS)
- Pennatulacea – sea pens (PTU).

These results are presented in Table A4.1.

3.5 Analysis of Area Closures as Refuge Areas for Vulnerable Marine Ecosystem Indicator Taxa

The proportions of the predicated distributions of VME indicator taxa occurring in the BPAs and SCAs in the EEZ was determined for the UoA areas and for the entire EEZ. See Table A4.2.

4.0 ACKNOWLEDGEMENTS

The authors thank FNZ and, in particular, Peta Abernathy for timely provision of data, Paul Viskovic and David Heron for providing GNS Science reviews, Rob Tilney of DWG for his input, and the GNS Science Admin Team for formatting the report.

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APPENDICES

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APPENDIX 1 TRAWL FOOTPRINT BY UNIT OF ASSESSMENT AREA

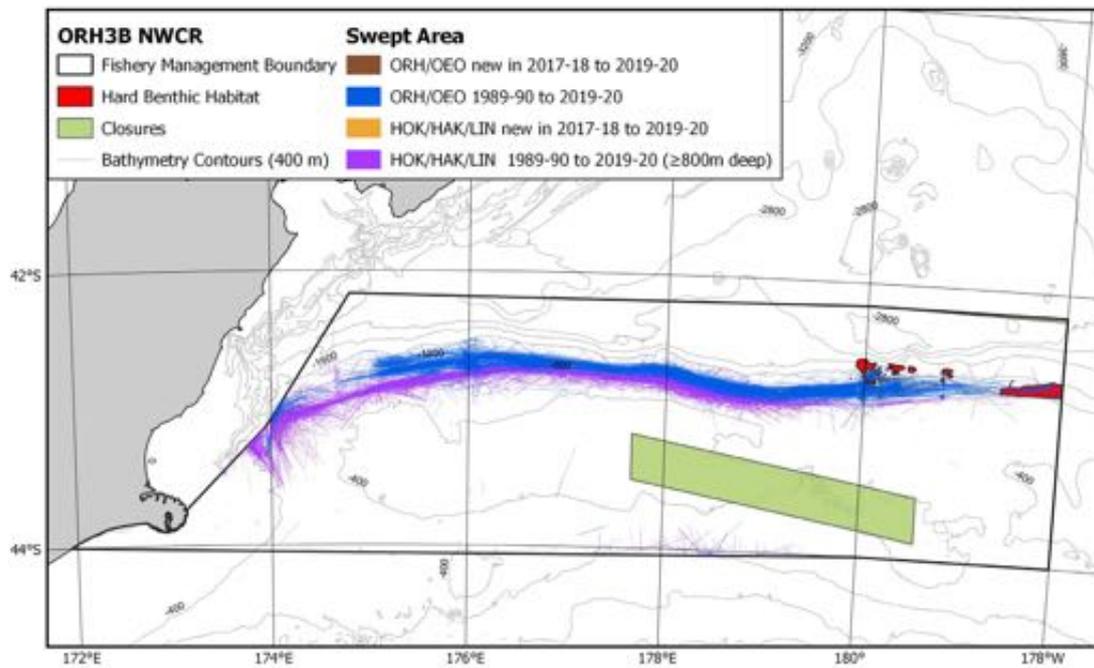


Figure A1.1 Trawl footprint in ORH3B NWCR for ORH/OEO and HOK/HAK/LIN from 1989/90 to 2019/20.

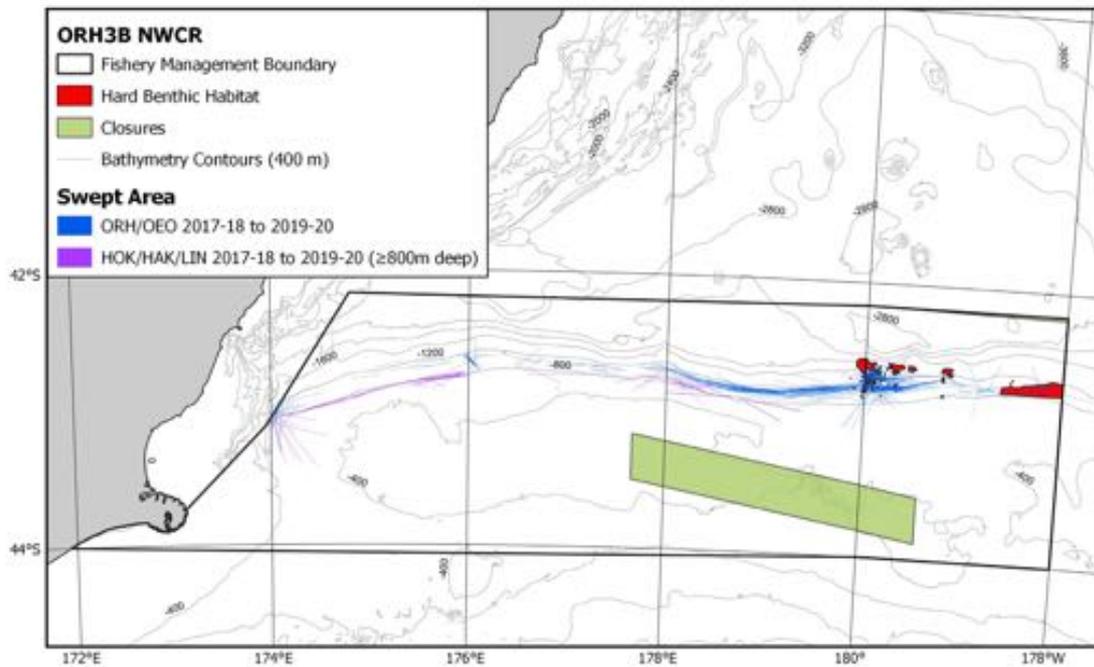


Figure A1.2 Trawl footprint in ORH3B NWCR for ORH/OEO and HOK/HAK/LIN from 2017/18 to 2019/20.

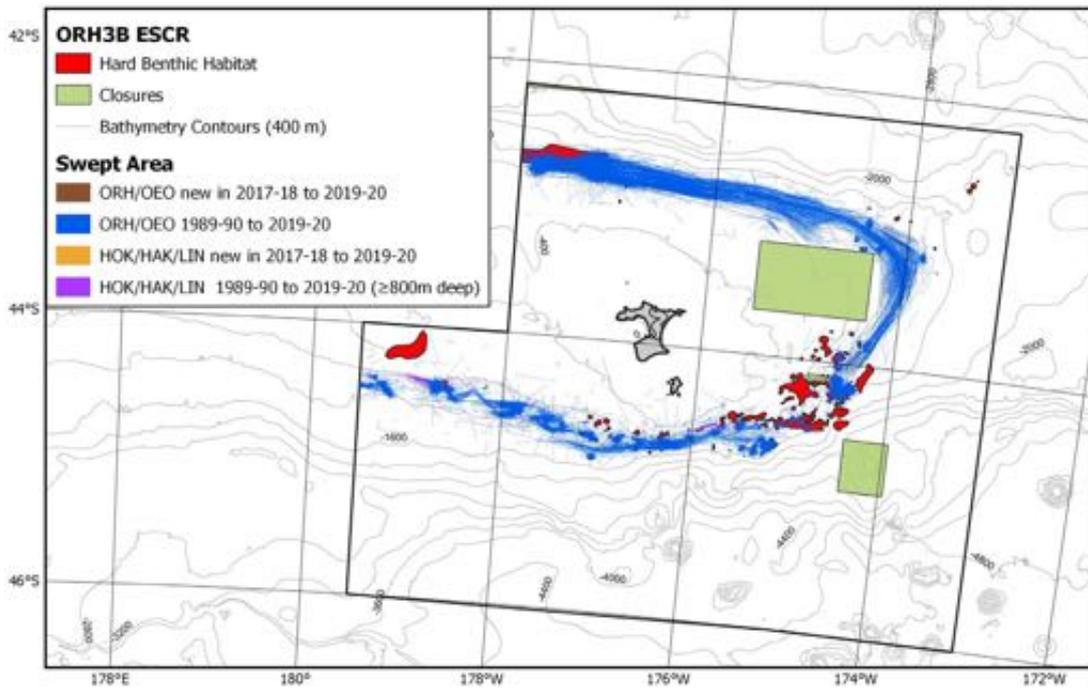


Figure A1.3 Trawl footprint in ORH3B ESCR for ORH/OEO and HOK/HAK/LIN from 1989/90 to 2019/20.

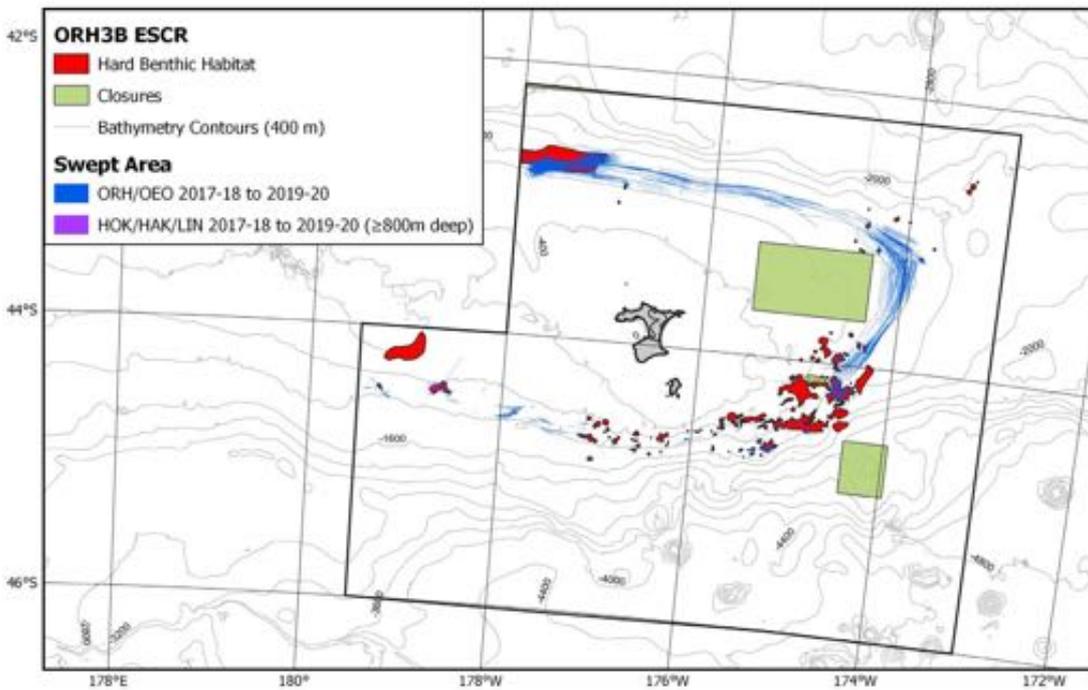


Figure A1.4 Trawl footprint in ORH3B ESCR for ORH/OEO and HOK/HAK/LIN from 2017/18 to 2019/20.

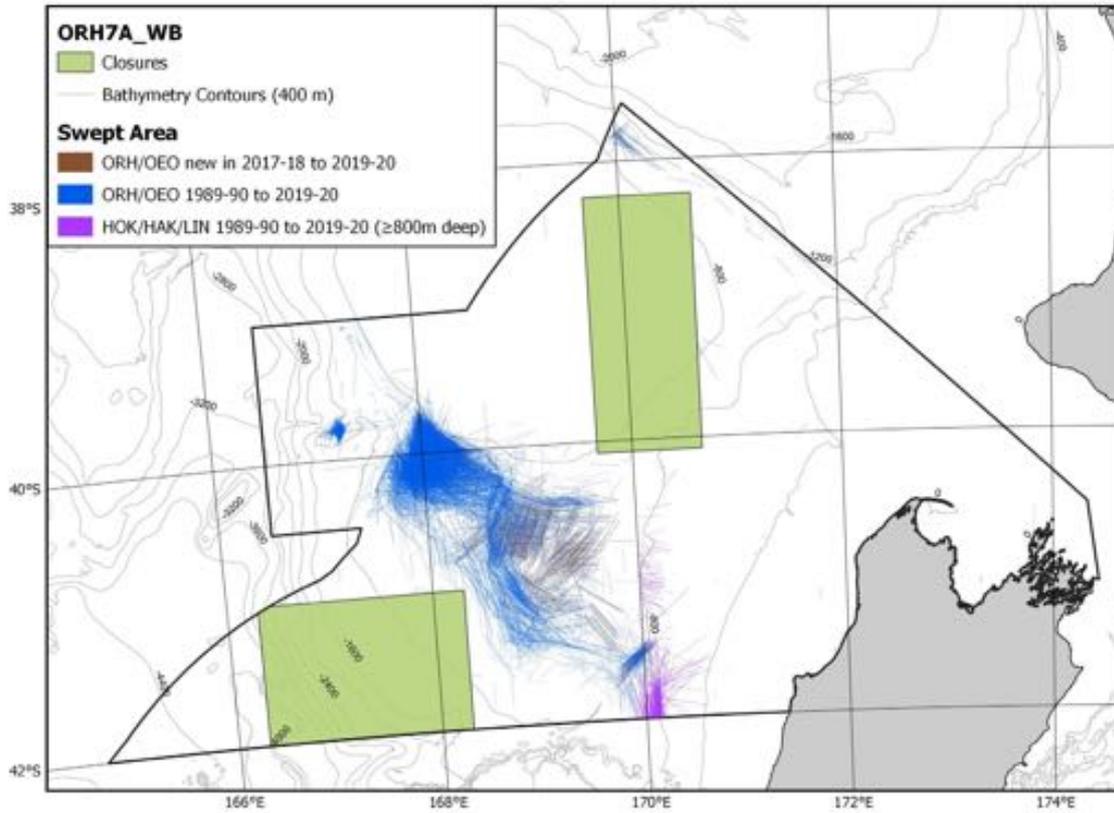


Figure A1.5 Trawl footprint in ORH7A – Westpac Bank for ORH/OEO and HOK/HAK/LIN from 1989/90 to 2019/20.

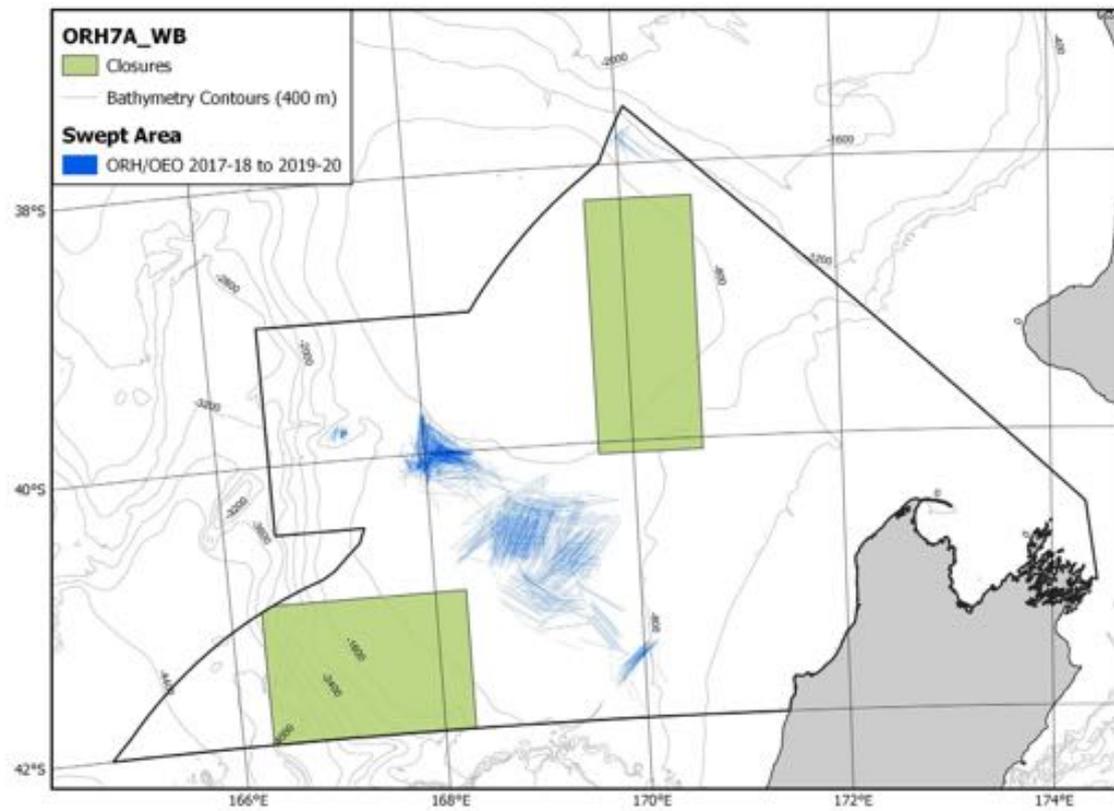


Figure A1.6 Trawl footprint in ORH7A – Westpac Bank for ORH/OEO from 2017/18 to 2019/20.

Table A1.1 Trawl footprint metrics in ORH3B NWCR: 2017/18 to 2019/20 and 1989/90 to 2019/20.

ORH3B NWCR	
Category	km ² / %
UoA area (km ²)	137,929
0–800 m area (km ²)	92,364
800–1600 m area (km ²)	17,398
>1600 m area (km ²)	28,167
Fishable Area (0–1600 m) (km ²)	109,762
Hard Benthic Habitat (HBH) (km ²)	772
HBH in Fishable Area (km ²)	685
HBH in Fishable Area (%)	0.6%
UTF area within HBH area (km ²)	20
UTF area within HBH area (%)	2.6%
Closures within UoA (km ²)	8,998
Closures within UoA (%)	6.5%
Closures within Fishable Area (km ²)	8,778
Closures within Fishable Area (%)	8.0%

ORH3B NWCR Swept Areas				
Category	ORH/OEO Targeted		HOK/HAK/LIN Targeted	
	1989/90 to 2019/20	2017/18 to 2019/20	1989/90 to 2019/20	2017/18 to 2019/20
Swept Area in UoA (km ²)	7127	1331	7377	475
Swept Area in UoA (%)	5.2%	1.0%	5.3%	0.3%
Swept Area in Fishable Area (km ²)	7125	1326	7372	470
Swept Area in Fishable Area (%)	6.5%	1.2%	6.7%	0.4%
Swept area in HBH (km ²)	167	86	11	-
Swept area in HBH (%)	21.7%	11.2%	1.4%	0.0%
New swept area in UoA (km ²)	-	332	-	88
New swept area in UoA (%)	-	0.2%	-	0.1%
New swept area in Fishable Area (km ²)	-	332	-	83
New swept area in Fishable Area (%)	-	0.3%	-	0.1%
Number of tows	12,955	811	3955	73

Table A1.2 Trawl footprint metrics in ORH3B ESCR: 2017/18 to 2019/20 and 1989/90 to 2019/20.

ORH3B ESCR	
Category	km ² / %
UoA area (km ²)	195,884
0–800 m area (km ²)	50,184
800–1600 m area (km ²)	38,148
>1600 m area (km ²)	107,552
Fishable Area (0–1600 m) (km ²)	88,332
Hard Benthic Habitat (HBH) (km ²)	3517
HBH in Fishable Area (km ²)	3349
HBH in Fishable Area (%)	3.8%
UTF area within HBH area (km ²)	230
UTF area within HBH area (%)	6.5%
Closures within UoA (km ²)	7092
Closures within UoA (%)	3.6%
Closures within Fishable Area (km ²)	5338
Closures within Fishable Area (%)	6.0%

ORH3B ESCR Swept Areas				
Category	ORH/OEO Targeted		HOK/HAK/LIN Targeted	
	1989/90 to 2019/20	2017/18 to 2019/20	1989/90 to 2019/20	2017/18 to 2019/20
Swept Area in UoA (km ²)	11,625	2440	520	35
Swept Area in UoA (%)	5.9%	1.2%	0.3%	0.0%
Swept Area in Fishable Area (km ²)	11,622	2439	520	35
Swept Area in Fishable Area (%)	13.2%	2.8%	0.6%	0.0%
Swept area in HBH (km ²)	1358	557	94	13
Swept area in HBH (%)	38.6%	15.8%	2.7%	0.4%
New swept area in UoA (km ²)	-	630	-	18
New swept area in UoA (%)	-	0.3%	-	0.0%
New swept area in Fishable Area (km ²)	-	629	-	18
New swept area in Fishable Area (%)	-	0.7%	-	0.0%
Number of tows	56,449	4122	1059	100

Table A1.3 Trawl footprint metrics in ORH7A – Westpac Bank: 2017/18 to 2019/20 and 1989/90 to 2019/20.

ORH7A Westpac Bank	
Category	km ² / %
UoA area (km ²)	212,351
0–800 m area (km ²)	108,688
800–1600 m area (km ²)	78,870
>1600 m area (km ²)	24,793
Fishable Area (0–1600 m) (km ²)	187,558
Closures within UoA (km ²)	36,114
Closures within UoA (%)	17.0%
Closures within Fishable Area (km ²)	26,704
Closures within Fishable Area (%)	14.2%

ORH7A Westpac Bank Swept Areas				
Category	ORH/OEO Targeted		HOK/HAK/LIN Targeted	
	1989/90 to 2019/20	2017/18 to 2019/20	1989/90 to 2019/20	2017/18 to 2019/20
Swept Area in UoA (km ²)	10,296	3332	893	-
Swept Area in UoA (%)	4.8%	1.6%	0.4%	0.0%
Swept Area in Fishable Area (km ²)	10,296	3332	893	-
Swept Area in Fishable Area (%)	5.5%	1.8%	0.5%	0.0%
New swept area in UoA (km ²)	-	1785	-	-
New swept area in UoA (%)	-	0.8%	-	0.0%
New swept area in Fishable Area (km ²)	-	1785	-	-
New swept area in Fishable Area (%)	-	1.0%	-	0.0%
Number of tows	10,687	1587	405	-

Table A1.4 Baseline trawl footprint 2005/06 to 2019/20 and newly trawled area 2017/18 to 2019/20 in the 800–1600 m depth range in ORH7A, Westpac Bank, ORH3B NWCR and ORH3B ESCR Unit of Assessment areas.

	Category	ORH7A	Westpac Bank	ORH3B NWCR	ORH3B ESCR
	Unit of Assessment area 800–1600 m (km ²)	69,161.56	9709.57	17,398.27	38,155.41
ORH/OEO	Trawl footprint (km ²) 2005/06 to 2019/20	5999.09	111.27	3267.04	7440.45
	Trawl footprint (%) 2005/06 to 2019/20	8.67%	1.15%	18.78%	19.50%
	Newly trawled area (km ²) 2017/18 to 2019/20 compared to 2005/06 to 2016/17	2302.13	27.07	616.95	920.17
	Newly trawled area (%) 2017/18 to 2019/20 compared to 2005/06 to 2016/17 (%)	3.33%	0.28%	3.55%	2.41%
HOK/HAK/LIN	Trawl footprint (km ²) 2005/06 to 2019/20	74.75	-	1279.58	103.06
	Trawl footprint (%) 2005/06 to 2019/20	0.11%	NA	7.35%	0.27%
	Newly trawled area (km ²) 2017/18 to 2019/20 compared to 2005/06 to 2016/17	-	-	101.47	13.24
	Newly trawled area (%) 2017/18 to 2019/20 compared to 2005/06 to 2016/17	NA	NA	0.58%	0.03%

APPENDIX 2 PREDICTED AND OBSERVED CORAL-TRAWL INTERACTION

Table A2.1 Overlap of the combined ORH/OEO and HOK/HAK/LIN trawl footprint with the predicted coral distributions of Georgian et al. (2019), 2017/18 to 2019/20.

Unit of Assessment	Coral Group	Predicted Coral Distribution (km ²)	Trawl Footprint in Predicted Coral Area (km ²)	Overlap (%)
ORH3B NWCR	Coral Reef	38,738.39	587.40	1.52
	<i>Goniocorella dumosa</i> (GDU)	20,184.11	18.27	0.09
	Family Stylasteridae (COR)	5134.98	20.04	0.39
ORH3B ESCR	Coral Reef	34,756.21	533.90	1.54
	<i>Goniocorella dumosa</i> (GDU)	15,383.23	125.46	0.82
	Family Stylasteridae (COR)	42,698.81	1079.65	2.53
ORH7A WB	Coral Reef	102,038.41	2654.66	2.60
	<i>Goniocorella dumosa</i> (GDU)	104,559.05	2208.21	2.11
	Family Stylasteridae (COR)	98,311.59	1683.04	1.71

Table A2.2 Predicted coral distribution overlap with Benthic Protection Areas (BPA) in ORH3B NWCR.

Unit of Assessment	Coral Group	BPA: Mid Chatham Rise		
		BPA Area (km ²)	Overlap (km ²)	Overlap (%)
ORH3B NWCR	Coral Reef	8732.4	6567.9	75.21
	<i>Goniocorella dumosa</i> (GDU)	8732.4	6522.8	74.70
	Family Stylasteridae (COR)	8732.4	160.7	1.84

Table A2.3 Predicted coral distribution overlap with Benthic Protection Areas (BPA) in ORH3B ESCR.

Unit of Assessment	Coral Group	BPA: Mid Chatham Rise			BPA: Blink		
		BPA Area (km ²)	Overlap (km ²)	Overlap (%)	BPA Area (km ²)	Overlap (km ²)	Overlap (%)
ORH3B NWCR	Coral Reef	5248.7	2930.6	55.83	0.3	0.3	100.00
	<i>Goniocorella dumosa</i> (GDU)	5248.7	1515.8	28.88	0.3	-	0.00
	Family Stylasteridae (COR)	5248.7	1898.9	36.18	0.3	-	0.00

Table A2.4 Predicted coral distribution overlap with Benthic Protection Areas (BPA) in ORH7A-WB.

Unit of Assessment	Coral Group	BPA: Challenger North			BPA: Challenger South		
		BPA Area (km ²)	Overlap (km ²)	Overlap (%)	BPA Area (km ²)	Overlap (km ²)	Overlap (%)
ORH3B NWCR	Coral Reef	17,589.2	13,191.6	75.00	18,525.1	7498.5	40.48
	<i>Goniocorella dumosa</i> (GDU)	17,589.2	14,954.4	85.02	18,525.1	3205.7	17.30
	Family Stylasteridae (COR)	17,589.2	14,053.8	79.90	18,525.1	6988.2	37.72

Table A2.5 Predicted coral distribution overlap with Benthic Protection Areas (BPA) in the entire EEZ.

BPA	BPA Area (km ²)	Stony Coral Overlap		Black Coral Overlap		Gorgonian Coral Overlap		Combined Coral Overlap	
		km ²	%	km ²	%	km ²	%	km ²	%
Antipodes Transect	109,487.2	17,223.3	15.73	16,728.8	15.28	19,043.5	17.39	19,152.2	17.49
Arrow Plateau	64,472.5	3309.0	5.13	10,579.2	16.41	592.3	0.92	10,596.2	16.44
Blink	0.3	-	0.00	-	0.00	0.3	100.00	0.3	100.00
Bounty Heritage	1806.3	224.5	12.43	-	0.00	-	0.00	224.5	12.43
Campbell East	22,609.3	113.1	0.50	-	0.00	-	0.00	113.1	0.50
Campbell Heritage	3003.2	-	0.00	-	0.00	-	0.00	-	0.00
Challenger North	17,589.2	3501.0	19.90	5182.5	29.46	-	0.00	8147.6	46.32
Challenger South	30,731.5	10,441.2	33.98	5940.6	19.33	158.2	0.51	10,745.2	34.96
East Chatham Rise	5248.7	85.6	1.63	57.5	1.10	-	0.00	143.1	2.73
Fiordland Transect	40,395.3	164.4	0.41	31.8	0.08	9.4	0.02	184.1	0.46
Hikurangi Deep	54,025.2	181.0	0.34	199.3	0.37	181.8	0.34	209.1	0.39
Kermadec	621,828.8	50,203.0	8.07	94,444.3	15.19	6166.6	0.99	99,540.3	16.01
Mid Chatham Rise	8732.4	5049.9	57.83	-	0.00	-	0.00	5049.9	57.83
Norfolk Deep	43,944.9	6070.9	13.81	6853.4	15.60	255.3	0.58	8143.3	18.53
Puysegur	187.4	115.5	61.64	27.3	14.57	6.8	3.62	115.8	61.83
Sub-Antarctic Deep	99,843.3	38,800.2	38.86	6934.3	6.95	33,753.4	33.81	42,831.9	42.90
Tectonic Reach	13,659.4	2318.4	16.97	2419.9	17.72	903.9	6.62	2869.8	21.01

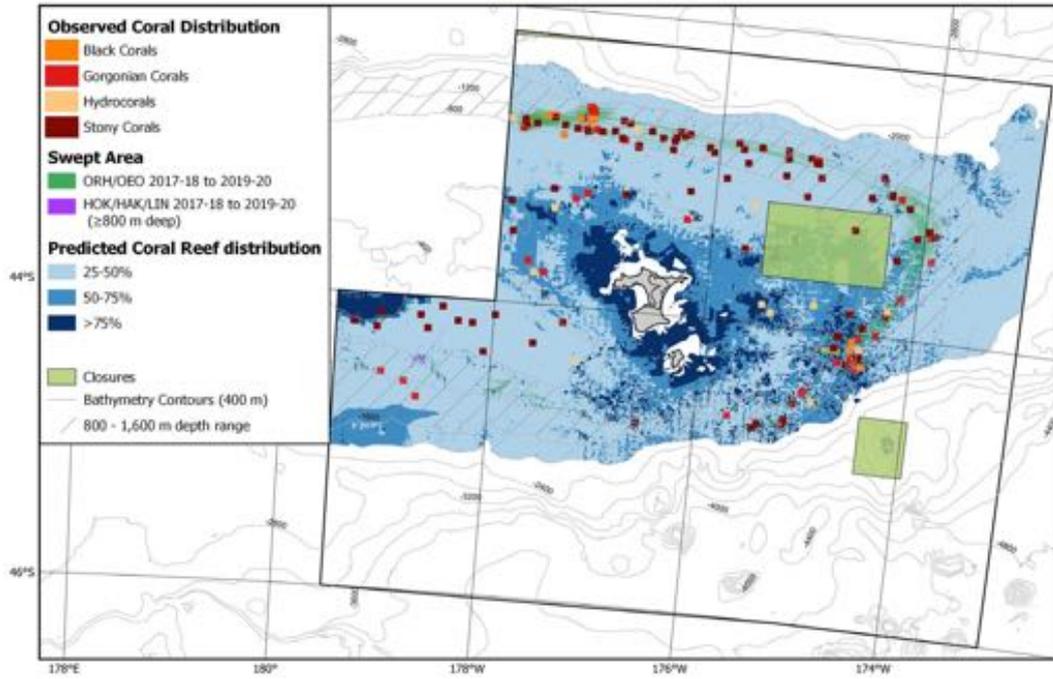


Figure A2.1 Observed coral distribution, predicted coral reef distribution and trawl footprint in ORH3B ESCR.



Figure A2.2

[Redacted text]

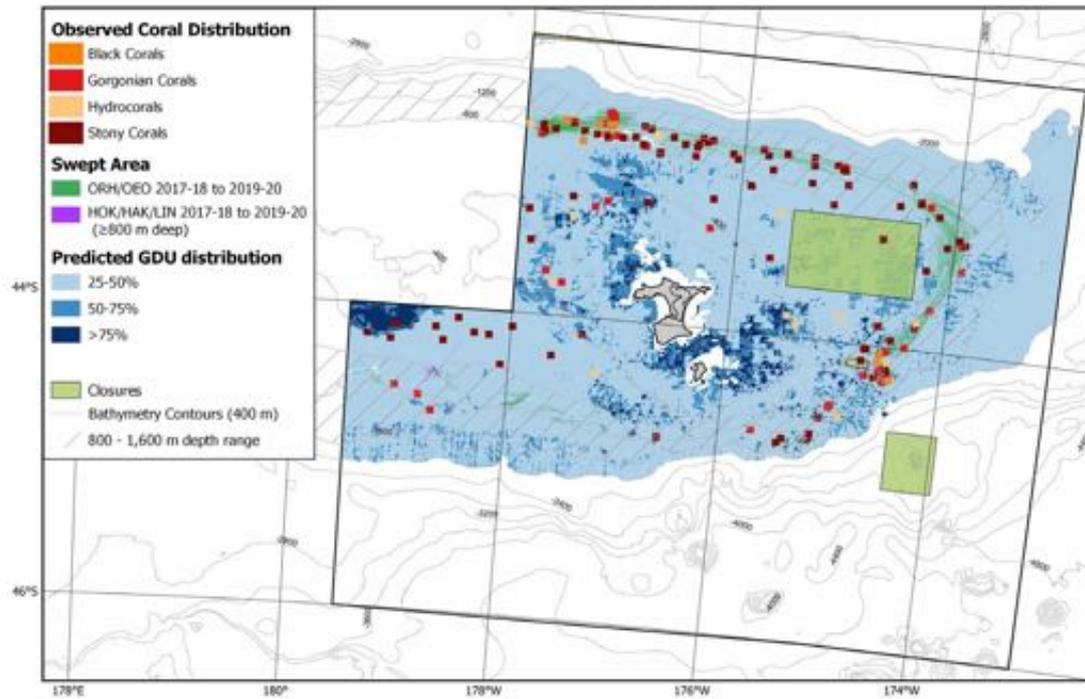


Figure A2.3 Observed coral distribution, predicted *Goniocorella dumosa* (GDU) distribution and trawl footprint in ORH3B ESCR.

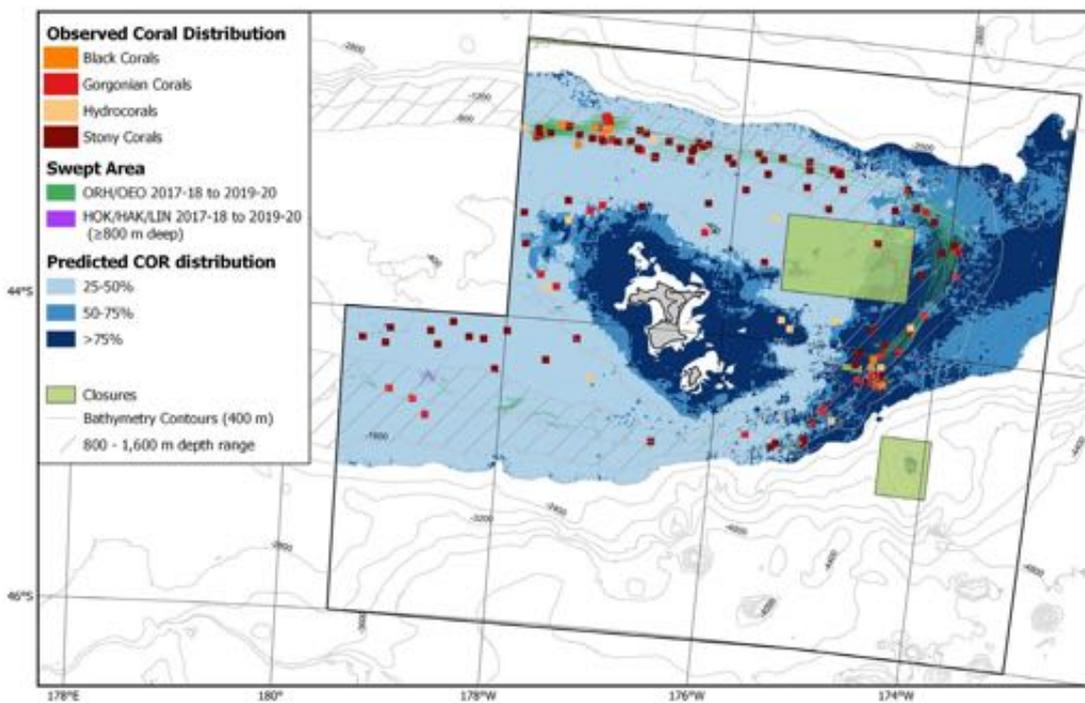


Figure A2.4 Observed coral distribution, predicted Family Stylasteridae (COR) distribution and trawl footprint in ORH3B ESCR.

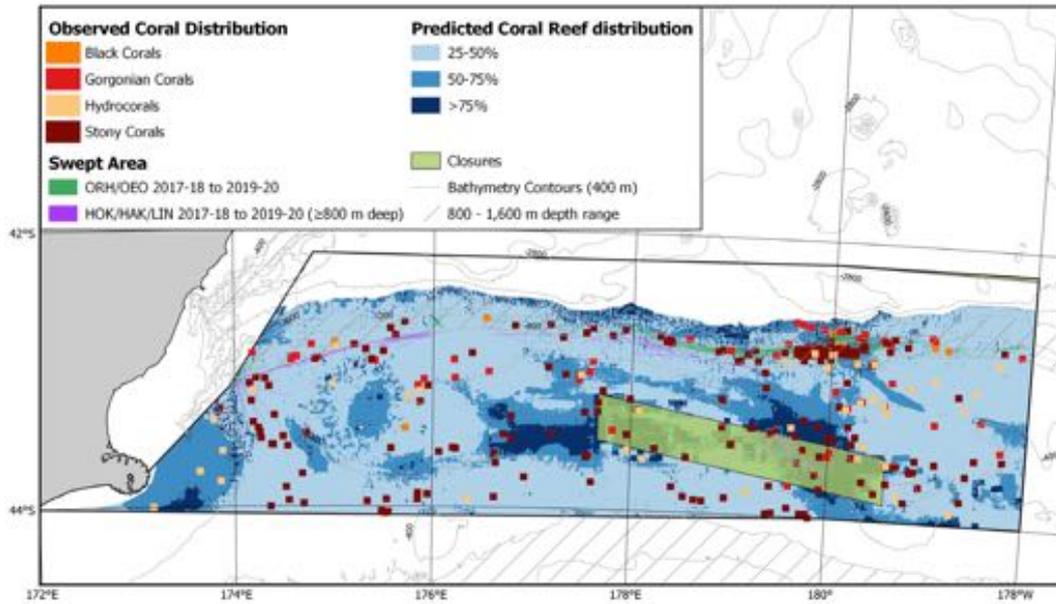


Figure A2.5 Observed coral distribution, predicted coral reef distribution and trawl footprint in ORH3B NWCR.

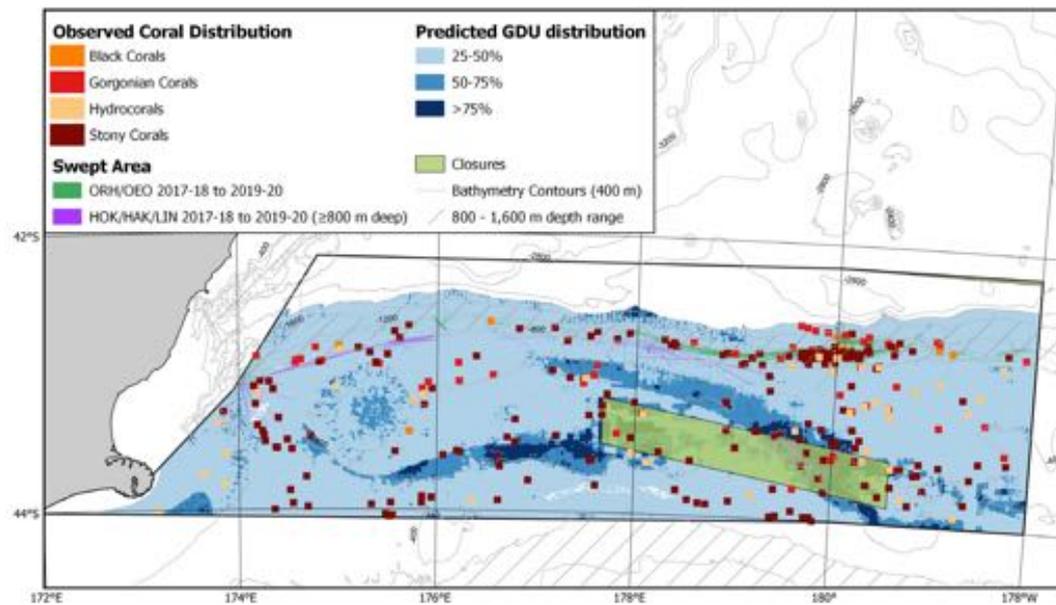


Figure A2.6 Observed coral distribution, predicted *Goniocorella dumosa* (GDU) distribution and trawl footprint in ORH3B NWCR.

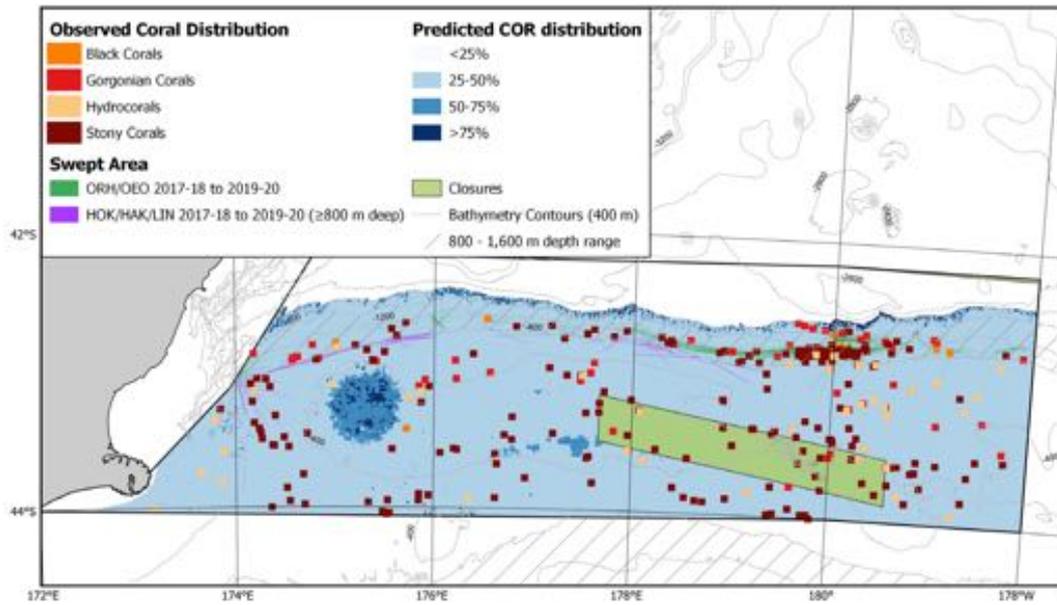


Figure A2.7 Observed coral distribution, predicted Family Stylasteridae (COR) distribution and trawl footprint in ORH3B NWCR.



Figure A2.8

[Redacted text]

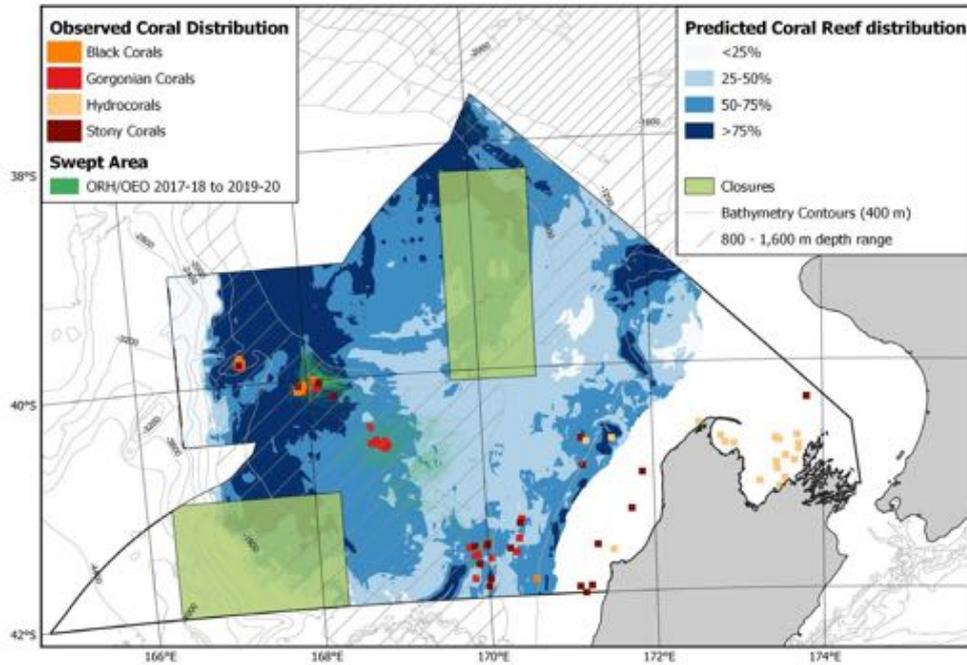


Figure A2.9 Observed coral distribution, predicted coral reef distribution and trawl footprint in ORH7A – Westpac Bank.

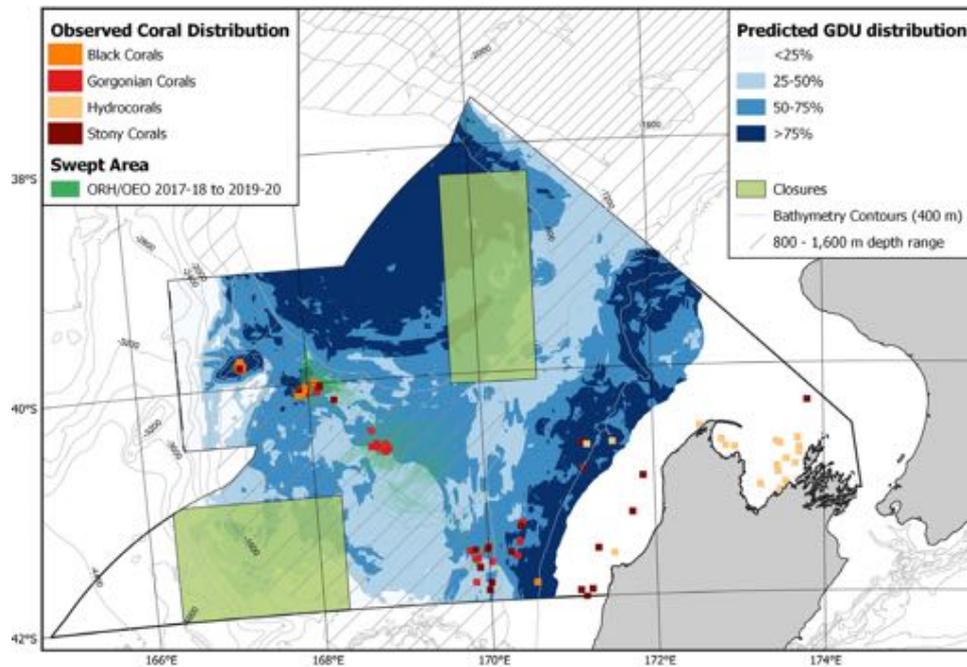


Figure A2.10 Observed coral distribution, predicted *Goniocorella dumosa* (GDU) distribution and trawl footprint in ORH7A – Westpac Bank.



Figure A2.11

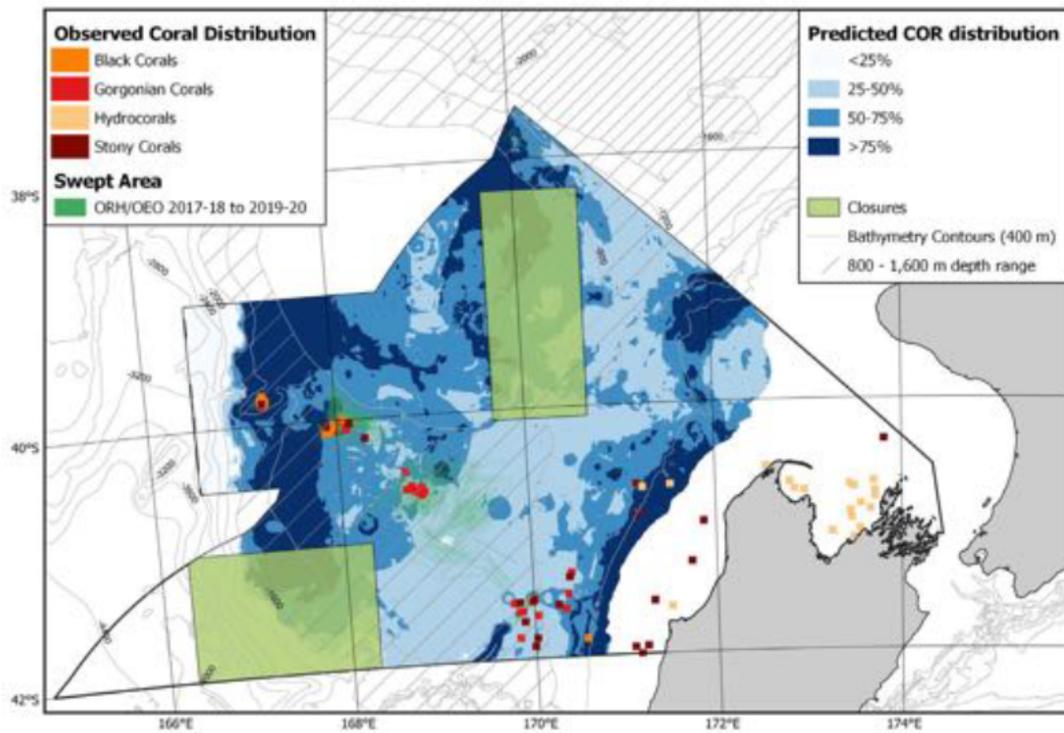


Figure A2.12 Observed coral distribution, predicted Family Stylasteridae (COR) distribution, and trawl footprint in ORH7A – Westpac Bank.

Table A2.6 Trawl footprint overlap with the observed coral distribution (i.e. observer-reported [2017/18 to 2019/20], vessel-reported [2017/18 to 2019/20]) and research coral dataset [2004/05 to 2018/19] expressed as 1 x 1 km squares.

	Coral Group	Observed Coral Distribution (km²)	Overlap with 2017/20 Trawl Footprint (km²)	Overlap (%)
ORH3B NWCR	Black corals	11.00	3.32	30.17
	Gorgonian corals	76.00	7.32	9.63
	Stony corals	227.35	29.25	12.87
	Hydrocorals	39.00	1.20	3.07
ORH3B ESCR	Black corals	16.73	9.88	59.05
	Gorgonian corals	53.06	18.62	35.10
	Stony corals	84.26	20.72	24.59
	Hydrocorals	12.00	1.01	8.43
ORH7A WB	Black corals	19.81	12.54	63.31
	Gorgonian corals	42.63	19.98	46.87
	Stony corals	19.48	3.30	16.92
	Hydrocorals	19.00	-	0.00

APPENDIX 3 UNIT OF ASSESSMENT FISHERY METRICS

Table A3.1 Unit of Assessment metrics for tows targeting ORH/OEO, 2017/18 to 2019/20.

Parameter	Unit of Assessment		
	ORH7A – Westpac Bank	ORH3B NWCR	ORH3B ESCR
Tow depth – minimum	428.73	598.56	560.00
Tow depth – median	894.87	1100.00	1042.02
Tow depth – maximum	1112.19	1503.96	1554.51
Number of tows	1,234	808	4,106
Number of tows on UTF	107	190	2053
Percentage of tows on UTF	9%	24%	50%
Number of tows on flats	1127	618	2053
Percentage of tows on flats	91%	76%	50%
ORH/OEO catch on UTFs	285,775	260,228	5,845,484
ORH/OEO catch on UTF coral tows	11,679	12,203	88,383
ORH/OEO catch on flats	4,450,186	1,600,128	11,639,190
ORH/OEO catch on flats coral tows	184,432	69,817	286,313
Coral Catch on UTFs	8.86	10.00	1047.75
Coral Catch on flats habitat	37.22	25,090.73	485.63
Number of tows that caught coral	74	36	129
Percentage of tows that caught coral	6%	4%	3%
Number of UTF tows that caught coral	8	4	56
Percentage of UTF tows that caught coral	7%	2%	3%
Number of 'flats' tows that caught coral	66	32	73
Percentage of 'flats' tows that caught coral	6%	5%	4%
Number of UTFs with tows	4	12	57
Number of UTFs with coral tows	2	2	26
Basal area of UTFs	15.44	98.93	3889.93
Basal area of UTFs with tows	10.40	47.87	306.98
Footprint of UTF tows inside basal polygon	3.94	6.49	88.54
Percentage footprint on UTFs with tows	2.64	14%	29%

Table A3.2 Unit of Assessment metrics for tows targeting HOK/HAK/LIN, 2017/18 to 2019/20.

Parameter	Unit of Assessment		
	ORH7A – Westpac Bank	ORH3B NWCR	ORH3B ESCR
Tow depth – minimum	-	225.00	539.461
Tow depth – median	-	796.215	784.907
Tow depth – maximum	-	1113.24	1172.004
Number of tows	0	73	92
Coral catch	-	0.0	0.0
Number of tows that caught coral	-	0	0
Percentage of tows that caught coral	-	0.00%	0.00%
HOK/HAK/LIN catch	-	659,925	1,525,015
HOK/HAK/LIN catch on coral tows	-	0	0

APPENDIX 4 ANALYSES OF AREA CLOSURES AS REFUGE AREAS FOR VULNERABLE MARINE ECOSYSTEM INDICATOR TAXA

Table A4.1 Overlap of Vulnerable Marine Ecosystem indicator taxa predicted distributions with the ORH/OEO and HOK/HAK/LIN trawl footprint, 2005/06 to 2019/20 and 2017/18 to 2019/20.

Unit of Assessment	Coral Group and Non-Corals	Predicted Coral Distribution (km ²)	2005/06 to 2019/20		2017/18 to 2019/20	
			Trawl Footprint in Predicted Coral Area (km ²)	Overlap (%)	Trawl Footprint in Predicted Coral Area (km ²)	Overlap (%)
ORH3B NWCR	Stony Corals (GDU, SVA, MOC and ERO)	100,596	5882.07	5.85	2334.77	2.32
	Black corals – Antipatharia (COB)	101,523	5932.02	5.84	2356.26	2.32
	Alcyonacea – soft corals (SOC)	106,552	5948.72	5.58	2366.70	2.22
	Stylasteridae – hydrocorals (COR)	101,910	5941.28	5.83	2363.43	2.32
	Desmospongiae – desmosponges (DEM)	102,326	5938.85	5.80	2363.00	2.31
	Hexactinellidae – glass sponges (HEX)	103,185	5944.10	5.76	2363.66	2.29
	Pennatulacea – sea pens (PTU)	101,258	5928.67	5.86	2362.91	2.33
ORH3B ESCR	Stony Corals (GDU, SVA, MOC and ERO)	81,986	7643.61	9.32	2466.34	3.01
	Black corals – Antipatharia (COB)	81,067	7641.49	9.43	2466.32	3.04
	Alcyonacea – soft corals (SOC)	83,354	7644.64	9.17	2467.24	2.96
	Stylasteridae – hydrocorals (COR)	80,468	7643.63	9.50	2466.34	3.06
	Desmospongiae – desmosponges (DEM)	80,660	7639.84	9.47	2465.88	3.06
	Hexactinellidae – glass sponges (HEX)	78,658	7642.92	9.72	2466.52	3.14
	Pennatulacea – sea pens (PTU)	88,926	7602.47	8.55	2443.10	2.75
ORH7A	Stony Corals (GDU, SVA, MOC and ERO)	133,250	3283.09	2.46	5457.18	4.10
	Black corals – Antipatharia (COB)	141,321	3283.09	2.32	5457.18	3.86
	Alcyonacea – soft corals (SOC)	142,413	3283.09	2.31	5457.18	3.83

Unit of Assessment	Coral Group and Non-Corals	Predicted Coral Distribution (km ²)	2005/06 to 2019/20		2017/18 to 2019/20	
			Trawl Footprint in Predicted Coral Area (km ²)	Overlap (%)	Trawl Footprint in Predicted Coral Area (km ²)	Overlap (%)
	Stylasteridae – hydrocorals (COR)	140,814	3228.08	2.29	5399.97	3.83
	Desmospongiae – desmosponges (DEM)	141,835	3283.09	2.31	5457.18	3.85
	Hexactinellidae – glass sponges (HEX)	141,670	3283.09	2.32	5457.18	3.85
	Pennatulacea – sea pens (PTU)	137,464	2244.28	1.63	4138.68	3.01
Westpac Bank	Stony Corals (GDU, SVA, MOC and ERO)	14,484	113.18	0.78	46.29	0.32
	Black corals – Antipatharia (COB)	14,438	113.18	0.78	46.29	0.32
	Alcyonacea – soft corals (SOC)	13,812	113.18	0.82	46.29	0.34
	Stylasteridae – hydrocorals (COR)	14,096	113.18	0.80	46.29	0.33
	Desmospongiae – desmosponges (DEM)	13,499	113.18	0.84	46.29	0.34
	Hexactinellidae – glass sponges (HEX)	13,766	113.18	0.82	46.29	0.34
	Pennatulacea – sea pens (PTU)	14,624	113.18	0.77	46.29	0.32
EEZ	Stony Corals (GDU, SVA, MOC and ERO)	1,324,412	37,607.58	2.84	11,878.32	0.90
	Black corals – Antipatharia (COB)	1,417,504	37,857.45	2.67	11,944.82	0.84
	Alcyonacea – soft corals (SOC)	1,425,579	37,869.24	2.66	11,957.33	0.84
	Stylasteridae – hydrocorals (COR)	1,350,725	37,559.13	2.78	11,821.13	0.88
	Desmospongiae – desmosponges (DEM)	1,343,035	37,778.40	2.81	11,942.22	0.89
	Hexactinellidae – glass sponges (HEX)	1,355,578	37,671.18	2.78	11,941.79	0.88
	Pennatulacea – sea pens (PTU)	1,268,087	33,057.85	2.61	9724.78	0.77

Table A4.2 The extent of Vulnerable Marine Ecosystem (VME) indicator taxa predicted distributions in the EEZ and their overlaps with Benthic Protection Areas (BPA) and Seamount Closure Areas (SCA) in the EEZ and Unit of Assessment areas.

Region	VME Indicator Taxa	Predicted Coral/ Non-Coral Distribution (km ²)	Proportion of EEZ (%)
EEZ	Stony Corals (GDU, SVA, MOC and ERO)	1,324,412	32.14
	Black corals – Antipatharia (COB)	1,417,504	34.40
	Alcyonacea – soft corals (SOC)	1,425,579	34.59
	Stylasteridae – hydrocorals (COR)	1,350,725	32.78
	Desmospongiae – desmosponges (DEM)	1,343,035	32.59
	Hexactinellidae – glass sponges (HEX)	1,355,578	32.89
	Pennatulacea – sea pens (PTU)	1,268,087	30.77
	Coral and non-corals combined	1,375,247	33.37

Unit of Assessment	VME Indicator Taxa	Area of BPAs and SCAs (km ²)	Predicted Coral/ Non-Coral Distribution (km ²)	Proportion of EEZ (%)
EEZ	Stony Corals (GDU, SVA, MOC and ERO)	1,213,811.59	281,567	23.20
	Black corals – Antipatharia (COB)		258,831	19.54
	Alcyonacea – soft corals (SOC)		266,672	20.14
	Stylasteridae – hydrocorals (COR)		268,381	20.26
	Desmospongiae – desmosponges (DEM)		264,181	19.95
	Hexactinellidae – glass sponges (HEX)		283,165	21.38
	Pennatulacea – sea pens (PTU)		294,557	22.24

Unit of Assessment	Coral Group and Non-Corals	Area of BPAs and SCAs (km ²)	Predicted Distribution of Coral/ Non-Coral in BPAs and SCAs (km ²)	Overlap (%)
ORH3B NWCR	Stony Corals (GDU, SVA, MOC and ERO)	8997.53	8776	97.54
	Black corals – Antipatharia (COB)		8776	97.54
	Alcyonacea – soft corals (SOC)		8776	97.54
	Stylasteridae – hydrocorals (COR)		8776	97.54
	Desmospongiae – desmosponges (DEM)		8776	97.54
	Hexactinellidae – glass sponges (HEX)		8776	97.54
	Pennatulacea – sea pens (PTU)		8601	95.59

Unit of Assessment	Coral Group and Non-Corals	Area of BPAs and SCAs (km ²)	Predicted Distribution of Coral/ Non-Coral in BPAs and SCAs (km ²)	Overlap (%)
ORH3B ESCR	Stony Corals (GDU, SVA, MOC and ERO)	7091.95	5796	81.73
	Black corals – Antipatharia (COB)		5699	80.36
	Alcyonacea – soft corals (SOC)		5655	79.73
	Stylasteridae – hydrocorals (COR)		5717	80.61
	Desmospongiae – desmosponges (DEM)		5778	81.47
	Hexactinellidae – glass sponges (HEX)		5822	82.09
	Pennatulacea – sea pens (PTU)		6069	85.58
ORH7A	Stony Corals (GDU, SVA, MOC and ERO)	36,114.37	26,537	73.48
	Black corals – Antipatharia (COB)		26,241	72.66
	Alcyonacea – soft corals (SOC)		27,070	74.96
	Stylasteridae – hydrocorals (COR)		26,399	73.10
	Desmospongiae – desmosponges (DEM)		26,461	73.27
	Hexactinellidae – glass sponges (HEX)		26,319	72.88
	Pennatulacea – sea pens (PTU)		29,365	81.31
Westpac Bank	Stony Corals (GDU, SVA, MOC and ERO)	-	-	-
	Black corals – Antipatharia (COB)		-	-
	Alcyonacea – soft corals (SOC)		-	-
	Stylasteridae – hydrocorals (COR)		-	-
	Desmospongiae – desmosponges (DEM)		-	-
	Hexactinellidae – glass sponges (HEX)		-	-
	Pennatulacea – sea pens (PTU)		-	-



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