Assessment of orange roughy and oreo trawl footprint in relation to protected coral species distribution

MSC P1 2.3.1

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Cover image: Stony branching corals and associated crinoids and sponges on the flanks of a UTF in the Graveyard Hill Complex on the Chatham Rise, with orange roughy to the left of the coral reef matrix (NIWA DTIS image).

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Background summary

Deepwater Group Ltd is undertaking an assessment of several orange roughy (*Hoplostethus atlanticus*) fisheries against Marine Stewardship Council (MSC) fisheries standards as a process of development towards MSC certification. These fisheries are ORH7A & Westpac Bank, ORH3B Northwest Chatham Rise, and ORH3B East & South Chatham Rise. Analyses are required to compare the footprint of trawling operations against the distribution of protected coral species as part of the assessment process to evaluate effects of orange roughy fishing on Endangered, Threatened or Protected (ETP) species, and Habitats.

In this report, we describe the data, methodology, and results of work performed to quantify the overlap of orange roughy, oreo (black oreo *Allocyttus niger*, smooth oreo *Pseudocyttus maculatus* and unspecified oreo species) and combined (orange roughy and oreo) target-trawling with ETP coral species assemblages (Marine Stewardship Council Performance Indicator 2.3.1).

Information on the distribution of selected protected coral species was sourced from a variety of NIWA and MPI databases, as well as records in scientific papers and reports. These included reef-building stony corals (Order Scleractinia), black corals (Order Antipatharia), and gorgonian octocorals (Order Alcyonacea, previously Order Gorgonacea). Point records were scaled up to 1km^2 grids to estimate the areal extent of observed records, and predicted distributions were estimated for each of the coral groups using Boosted Regression Tree habitat suitability modelling.

Trawl footprint data were obtained from the Institute of Geological and Nuclear Science (GNS) for fishing activities that targeted orange roughy and oreo in the New Zealand EEZ, the EEZ portion of the lower bathyal New Zealand Kermadec province of the GOODS classification system, and the three fishery unit of assessment (UoA) areas, between 1989-90 and 2012-13 and separately for the recent five-year period (2008-09 to 2012-13).

For each coral group, maps were generated to display the observed and predicted coral distributions and the overlapping and non-overlapping trawl footprint. This was done for the entire fishery period (1989-90 to 2012-13) and the last 5 fishing years in each of the five areas. The areal extent of both the trawl footprint and coral distributions, footprint overlap metrics and proportions of coral distributions in areas protected from trawling (e.g., Seamount Closures, Benthic Protection Areas) were calculated and tabulated.

The overlap between coral distributions and the combined (orange roughy and oreo) trawl footprint for all years ranged from 40% to 47% between coral groups based on observed data at the scale of the EEZ, and from 13% to over 70% in fishery areas. The ORH7A fishery area had less overlap relative to the two Chatham Rise areas, where the footprint overlap with ETP corals ranged from 27 to72%. Overlap based on predicted modelling (at a 50% likelihood of occurrence threshold) was much lower, and less than 10% for most areas and taxa except for black corals in the two Chatham Rise areas where overlap was around 20%. Overlap in the last 5 years was much less than for the full time period, which was expected due to reduced fishing effort relative to the all-years dataset. Black corals had a higher degree of overlap with the orange roughy and combined orange roughy/oreo footprint than the other coral taxa in most areas. The oreo footprint mainly intersected with gorgonian coral distribution. The results presented here should be interpreted with caution, owing to i) the high degree of overlap between coral sampling and fishery areas (i.e., many records have come from fishing operations); ii) the likely tendency for predictive modelling to overestimate the extent of suitable coral habitat; and iii) the assumption that coral distributions remain constant over time.

True distributions are likely to lie somewhere between the observed and predicted estimations, and are subject to temporal variation.

An account is given of the composition of ETP coral assemblages and this is discussed in the context of generic trawling impacts on such assemblages, their resilience to trawling impact, and the level of overlap between orange roughy and oreo trawling documented in this study.

1 Introduction

The Deepwater Group is undertaking an assessment of three orange roughy (*Hoplostethus atlanticus*) (ORH) fisheries against Marine Stewardship Council (MSC) fisheries standards as a process of development towards MSC certification:

- ORH7A & Westpac Bank
- ORH3B Northwest Chatham Rise
- ORH3B East & South Chatham Rise (East of 179°30'W)

A pre-assessment of the eligibility of four ORH fisheries for MSC certification in 2013 included an Assessment of the Environmental Effects of Fishing, at which NIWA undertook and presented analyses on aspects related to protected coral species (included in the Endangered, Threatened, or Protected (ETP) component), and aspects of the fishery on habitats associated with seamounts, knolls, and hills (referred to here as Underwater Topographical Features (UTFs)). In preparation for a full MSC assessment in 2014, further work was required on two of the MSC Performance Indicators (PIs):

PI 2.3.1	ETP species outcome
PI 2.4.1	Habitats outcome

NIWA was contracted by Deepwater Group Ltd to undertake trawl footprint analyses to provide information for the three fisheries, to enable an MSC Conformance Assessment Body (CAB) to evaluate them against the PIs: This was divided into two projects:

Project 1. The effects of ORH target-trawling on ETP coral species assemblages (PI 2.3.1)

The objective was to carry out analyses of ETP coral distributions and trawl footprint for orange roughy, including:

- Observed and predicted distributions of ETP coral assemblages within the New Zealand EEZ, the EEZ portion of the lower bathyal New Zealand Kermadec province of the GOODS classification system (UNESCO 2009) and the three unit of assessment (UoA) areas - Orange Roughy Fisheries Areas)
- The extent of the ORH fishery trawl footprint in relation to ETP coral distribution
- The proportions of ETP coral assemblages, considered on a regional, bio-regional and UoA basis, that are fished, unfished and closed to fishing; and
- Provide informed commentary on the likely effects of ORH and OEO/SSO/BOE -targeted fishing on ETP species assemblages.

Project 2. A summary of information to inform the effects of ORH and OEO/SSO/BOE target-trawling on habitat structure and function (PI 2.4.1), is the subject of a separate report (Roux et al. 2015).

During the assessment, the CAB requested additional information on the trawl footprint of the oreo (black oreo, smooth oreo and unspecified oreo species) fisheries in relation to ETP coral distribution. This report presents maps and metrics illustrating the overlap of ORH and OEO/SSO/BOE target trawling with the observed and predicted distributions for three ETP coral groups, namely the black corals (Order Antipatharia), gorgonian corals (Order Alcyonacea but previously known as Order Gorgonacea which is how these corals will be referred to in this report) and stony corals (Order Scleractinia).

2 Methods

2.1 Footprint trawl dataset

Trawl footprint data were provided by the Institute of Geological and Nuclear Science (GNS) who processed commercial catch and effort data through a series of operations within a GIS software framework to groom trawl positions, “jitter” them to reduce the extent of the exact overlay because of positional rounding, and add a buffer to each trawl line approximating the area swept using an assumed doorspread of 150 m (see Black et al. 2013 for further details). No adjustments were made to the reported trawl track to account for the difference in position of the vessel and trawl gear. The total footprint corresponds to the surface layer of all the trawls, irrespective of overlap. To create a single area-swept layer representing the area of the seafloor contacted by these trawls, the individual trawl polygons were dissolved into polygons with no internal lines.

No measure of trawling intensity (i.e. ratio of overlapping versus non-overlapping footprint as an index of cumulative impacts) was estated in this study, but is considered later in the Discussion. Note also that tows with similar start/finish positions were excluded from trawl footprint calculations (Black et al. 2013). Such short tows are frequently associated with orange roughy target fishing around the summits of UTFs, regions which provide important habitat for cold water corals (Rowden et al. 2010). Also excluded from the trawl footprint is all effort recorded on Trawl Catch & Effort Return forms (TCERs), as they lack suitable start and finish position information.

For orange roughy and oreo fisheries separately, two sets of trawl footprints were provided by GNS, covering different time periods:

- The total fishery period, covering all years of catch-effort data (1989–90 to 2012–13)
- The most recent 5 years (2008–09 to 2012–13).

2.2 Protected coral dataset

A NIWA dataset of groomed records of protected coral species captures, as used in earlier analyses of coral distributions within the New Zealand EEZ (Baird et al., 2013), formed the basis of the data used in the current analysis. The dataset comprised 3671 presence records.

This dataset included station records that provide location, date, and depth of the sample. It was compiled from several sources:

- historic scientific research surveys (NIWA's *AllSeaBio* database);
- historic and recent scientific research surveys and samples from commercial fishing operations with NIWA staff present (NIWA's invertebrate collection database *Specify*);
- records from the Ministry for Primary Industries (MPI) observer database (*cod*)*:* (this includes verified (specimens confirmed by experts) as well as non-verified coral records, where the identification was made at sea and no sample was returned;
- NIWA Memoir records, other literature, and unpublished voyage reports;
- research trawl and biodiversity survey data held at NIWA in MPI's *trawl* and NIWA's *biods* databases.

A larger NIWA database, with records of benthic invertebrates from a wide area of the South Pacific Ocean outside the New Zealand EEZ, was searched for additional records for the ORH 7A fishery area outside the EEZ (the Westpac Bank), but none were found; coral layers outside the EEZ boundaries have yet to be generated and validated and such tasks were beyond the scope of the current project.A subset of this database also provided the absence data for the predictive models.

The number of presence and absence coral records for each taxon of interest in the final dataset is shown in Table 2.1. The observer (fishery) data used to distinguish presence/absence records are from a selection of trips where observers were especially looking out for corals (Tracey et al. 2011a). These are pseudo-absence data in the sense that the trawl may pass over corals without catching them (as opposed to absence scores resulting from random background selection of data points in *Maxent* and other habitat suitability models) (Anderson et al. 2014).

The selected taxa (families, genera, or species groups) considered were the branching 'reef-like' and 'tree-like' forms as these are the most vulnerable to trawling, being both upright and fragile.

"reef-like":

  - the branching stony coral forms (Order: Scleractinia), including species *Goniocorella dumosa*, *Solenosmilia variabilis*, *Enallopsammia rostrata*, *Madrepora oculata* and other reef-forming stony coral records (i.e., combined Scleractinia (SIA) and branching coral (CBR).

"tree-like":

  - Combined gorgonian octocoral (Order: Alcyonacea previously known as Gorgonacea, referred to in this report as Gorgonacea to avoid confusion with unprotected soft corals that belong to Order Alcyonacea), including families Acanthogorgiidae, Chrysogorgiidae, Coralliidae, Isididae, Paragorgiidae, Plexauridae and Primnoidae.

- black coral (Order Antipatharia), all species combined (COB), including the genera *Bathypathes*, *Dendrobathypathes*, *Dendropathes*, *Leiopathes*, *Lillipathes*, *Parantipathes*, and *Triadopathes* commonly found >200 m (Opresko & Tracey 2014).

Table 2-1: Number of coral presence/absence records in selected observations of protected coral groups in the NZ EEZ (plus Westpac Bank. Fishery presence = number of presence records from fisheries sampling/monitoring (observer data). Non-fishery presence= number of presence records from fisheries-independent sampling (research trawl and/or biodiversity surveys). Total absence = total number of absence records available.

Order	Taxon (and 3 letter code)	Description	Total Absence	Total Presence	Fishery presence	Non-fishery presence
Scleractinia	Species combined: SIA and CBR (code used for reef-like formers) and also including species *Enallopsammia rostrata* *Solenosmilia variabilis* *Goniocorella dumosa* *Madrepora oculata*	All reef-forming corals	42682	796	327	469
Gorgonacea (now known as Alcyoncaea)	Families combined: GOC Acanthogorgiidae Chrysogorgiidae Coralliidae Isididae Paragorgiidae Plexauridae Primnoidae	Tree-like corals	41854	2129	1101	1028
Antipatharia	All species combined: COB Genera listed above in text	Black corals, tree-like	42746	746	409	337

2.2.1 Observed coral distribution

The position of each coral record in the dataset was expanded onto a grid of 1 km x 1 km cells spanning the extent of the study area, to represent the likely distribution based on the point sample. This is a somewhat arbitrary approximation but is considered a realistic area (based on experience of NIWA scientists) rather than simply a point, and puts the data on a scale similar to that of the length of the trawl or research sled sample from which the record was obtained.

For each coral taxon in turn, for the EEZ as a whole and for each of the UoAs, the total area of coral distribution was estimated as the sum of individual 1km^2 cells with coral presence.

2.2.2 Predicted coral distribution

In addition to producing distributions based on presence records alone, the results of habitat suitability modelling being carried out for the Department of Conservation (Anderson et al. 2014) were used. This applied Boosted Regression Tree (BRT) methods to presence data for the four branching stony coral taxa combined (i.e., the reef-forming scleractinians SIA-CBR), gorgonian corals GOC, and antipatharian (black) corals COB (see Table 2.1), to estimate their likely distribution based on a set of ten environmental predictive variables. These were *dynoc*, mean sea surface height; *tempbot*, temperature of the seawater at the seabed; *vgpm*, surface water primary productivity; *dom*, dissolved organic matter; *tidalcurr*, tidal current velocity; *sstgrad*, sea surface temperature gradient; *seamount* (=UTF), yes/no; *aragonite*, seafloor aragonite saturation state; *calcite*, seafloor calcite saturation state; *slope*, seafloor slope (see Tracey et al. 2011b, Baird et al. 2013, Bostock et al. 2013). Aragonite saturation was used only for scleractinians, and calcite only for gorgonian and black corals.

Habitat suitability modelling with BRT uses recursive binary splits within a tree structure to explain the relationship between the response variable and the predictor variables, with "boosting" improving the model performance through a combination of many simple models (Elith et al. 2008). This approach provides a way of predicting coral habitat and potential distribution of corals in areas where knowledge of coral distribution is lacking.

The analysis was carried out using R (R Core Team, 2012) and methods described by Ridgeway (2006) and Elith & Leathwick (2011). Model fitting and parameter setting followed the general procedures described in Baird et al. (2013). The analysis was based on the same set of environmental variables in Baird et al. (2013) with the inclusion of two additional ocean carbonate chemistry variables, estimated seafloor aragonite and calcite saturation values (Bostock et al., 2013; Anderson et al., 2014).

The modelled distribution data were clipped (cut-out) for each of the UoAs, the EEZ and the EEZ bioregion. Distribution layers at each probability of occurrence threshold (0-25%, 25-50%, 50-75% and 75-100%) were illustrated on maps. A layer of >50% probability occurrence was calculated and used in footprint analyses.

2.3 Trawl footprint overlain with distribution plots of ETP coral assemblages

To determine the relationship between the fishery trawl footprint and coral distributions, the orange roughy (ORH), oreo (OEO/SSO/BOE) and combined (ORH/OEO/ SSO/BOE) trawl footprints from all years (1989-90 to 2012-13) and the last five years (2008-09 to 2012-13) were overlain with observed and predicted coral distributions projected onto a 1 km^2 grid for the New Zealand EEZ as a whole, the New Zealand-Kermadec bioregion within the EEZ (referred to herafter as EEZ bioregion), and the three UoAs (ORH7A and 'Westpac Bank', ORH3B NWCR and ORH3B ESCR (East of 179°30'W).).

Footprint and coral distribution areas were calculated in ArcGIS (ESRI 2014) using a sinusoidal projection centred on 185° (Central Meridian of 175°W). The underlying datum was WGS 1984. Similarly, the area of observed and predicted (>50% probability occurrence) coral distributions located within protected areas boundaries (Benthic Protection Areas (BPAs), closed seamounts and large marine reserves (LMRs)) was calculated for each of the coral groups in each area (UoAs, EEZ, and Kermadec Bioregion within the EEZ), and used to estimate proportions of coral distribution in areas closed to fishing.

Maps of coral observations, predicted distributions and the most recent (five-year) trawl footprints were produced for each of the three ETP coral groups in each of the five areas. For mapping purposes, 1km^2 coral observations were magnified approximately 16 times (in UoAs) and about 324 times (at the scale of the EEZ).

2.4 Calculating fished and unfished proportions of ETP coral distributions

An area of overlap between observed and predicted (>50% probability occurrence) coral distributions and ORH, OEO/SSO/BOE and combined ORH/ OEO/SSO/BOE footprints was calculated for each ETP coral group for the entire fishery period (1989-90 to 2012-13) and the last five years (2008-09 to 2012-13). Only the extent of the trawl footprint varied between fishery periods. Coral distributions were assumed to remain constant over time.

Proportions of the area of coral distribution impacted by trawling (% overlap) were estimated as the ratio of the coral-intersecting (overlapping) trawl footprint over the total coral distribution in each of the UoAs, the entire EEZ and the EEZ bioregion.

3 Results

3.1 Observed coral distribution

Coral observations for each of the three ETP coral groups in the New Zealand EEZ and designated Westpac Bank area; for each of the three UoAs, (ORH7A & Westpac, ORH3B NWCR, and ORH3B ESCR (East of 179°30'W); and for the EEZ bioregion, are presented in Appendices A to E (Figures A1-E3). The figures show the locations of coral presence observations along with the total ORH and OEO/SSO/BOE trawl footprint over the last five years (2008-09 to 2012-13), BPAs, LMRs, and Seamount Closures. ETP coral observations have been superimposed on predicted distributions using 0-25%, 25-50%, 50-75% and 75-100% probability of occurrence thresholds. Summary metrics illustrated on the Figures are:

- Area of predicted coral distribution (>50% probability occurrence),
- Area of predicted coral distribution in protected areas
- Total area of the combined (ORH/OEO/SSO/BOE) trawl footprint for the period 2008-09 to 2012-13.
- Impacted area (i.e. area of overlap between the combined footprint and predicted coral distributions)
- Percent overlap (between the combined footprint and predicted coral distribution)

3.2 Predicted coral distribution

The relative importance of each explanatory variable in the three BRT models is summarised in Figure 3-1. The variable with the most influence in the Scleractinia and Antipatharia models was dynamic topography (*dynoc*). The *dynoc* variable represents sea surface height i.e., the shape of the seafloor which describes changes in topography such as seamounts, canyons, hills, basins, etc. (AVISO http://www.aviso.oceanobs.com). Bottom temperature (*tempbot*) and primary productivity (*vgpm*) were the next most informative in the scleractinia model but each of the other variables also had an influence. In the Antipatharia model dissolved organic matter (*dom*) and calcite were also important, but far less so than *dynoc*. For the Gorgonacea model, no variable stood out above the others, with *dynoc*, *dom*, and *calcite* all of similar importance. The new calcium carbonate variables (aragonite for scleractinians and calcite for gorgonians, according to their mineralogy – as described by Tracey et al. 2013) were important in each model, but did not dominate in any of them.

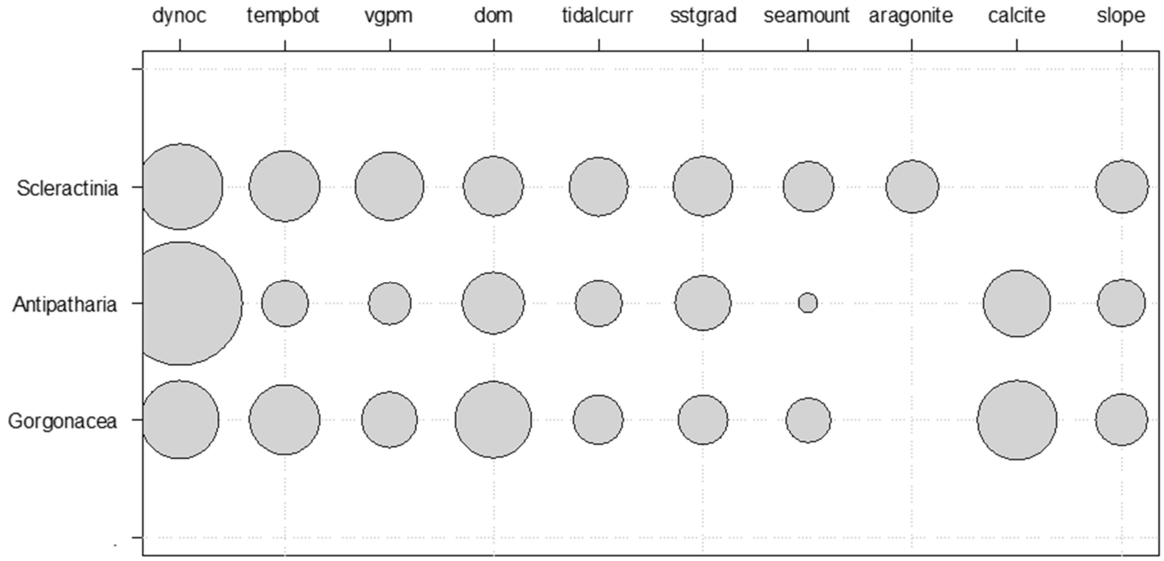

Figure 3-1: Bubble plot showing the relative influence of each explanatory variable in the BRT predictive models for each protected coral taxon.

3.3 Extent of the ORH and OEO/SSO/BOE fishery trawl footprint in relation to ETP coral distribution

Coral distributions, protected corals and fishery trawl footprint metrics (for 1989-90 to 2012-13 and 2008-09 to 2012-13) are presented by coral group and area (EEZ,EEZ Bioregion and UoAs) in Tables 3-1 to 3-5 (observed distributions) and in Tables 3.-6 to 3-10 (predicted distributions):

3.3.1 Coral distributions

Coral observations extrapolated onto 1km^2 cells indicated that gorgonian corals had a broader distribution relative to other taxa in the New Zealand EEZ, the EEZ bioregion, and each of the three fishery regions (Tables 3-1, 3-2, 3-3, 3-4 and 3-5). Habitat suitability modelling suggested a more widespread distribution of scleractinian corals in all areas (Table 3-6, 3-7, 3-8, 3-9 and 3-10). Antipatharia corals had a comparatively narrow distribution under both observed and predicted scenarios, except at the scale of the EEZ bioregion, where its distribution exceeded that of scleractinian (observed) or gorgonian (predicted) taxa (Table 3-2, Table 3-7).

Within the fishery regions, the extent of observed coral distributions was generally greater in the South and East Chatham Rise (ORH3B ESCR) and lower in ORH7A (Tables 3-3, 3-4 and 3-5). Predictive modelling indicated a more widespread distribution of antipatharian corals in ORH3B ESCR and a broader range for scleractinian and gorgonian taxa in ORH7A (Tables 3-8, 3-9 and 3-10).

There were no coral records from the Westpac Bank area.

Proportions of coral distributions located inside protected areas at the scale of the New Zealand EEZ were equivalent to 11% (Gorgonacea), 12% (Antipatharia), and 17% (Scleractinia) for observed distributions (Table 3-1); and varied from 13% (Gorgonacea) to 21% (Scleractinia) and 27% (Antipatharia) for predicted distributions (Table 3-6).

The north-west Chatham Rise (ORH3B NWCR) had comparatively higher proportions of coral observations within protected areas (Table 3-4). Only a few corals were observed inside protected areas in the south-east Chatham Rise (ORH3B ESCR) and ORH7A (Table 3-3, Table 3-5). In contrast, higher proportions (18%-25%) of predicted coral distributions were located inside protected areas in ORH7A (Table 3-8) and lower proportions of predicted Antipatharia and Gorgonacea distributions were in areas closed to fishing in ORH3B NWCR (Table 3-9).

3.3.2 Extent of the ORH, OEO/SSO/BOE and combined ORH/OEO/SSO/BOE trawl footprints in relation to coral distributions

The extent of protected coral-fisheries interactions differed depending on whether observed or predicted coral distributions were considered. Proportions of coral distributions that overlapped with the combined ORH/OEO/SSO/BOE trawl footprint in the EEZ (all years) ranged from 40% (Scleractinia), 42% (Gorgonacea) and 47% (Antipatharia) for observed distributions (Table 3-1) and from 2% (Scleractinia and Gorgonacea) to 6% (Antipatharia) for predicted distributions (Table 3-6). Over the recent 5 year (2009-2013) period, the same proportions varied from 17% (Scleractinia) to 19% (Gorgonacea) and 21% (Antipatharia) (observed distributions (Table 3-1)) and from 0.3% (Gorgonacea), 0.4% (Scleractinia) to 1.7% (Antipatharia) (predicted distributions (Table 3-6)).

A similar pattern was observed in the EEZ bioregion, where antipatharian corals (both observed and predicted distributions) had a higher degree of overlap with the combined ORH/OEO footprint, relative to scleractinian and gorgonian corals. Antipatharian corals also had a higher degree of overlap with combined ORH/OEO fishing activities within each of the UoAs (Table 3-1, Table 3-2), with the exception of ORH7A, where a greater overlap with the predicted Scleractinia distribution was observed (Table 3-8), a pattern that differed from actual coral observations (Table 3-3).Over the entire fishery period (1989-90 to 2012-13), the combined trawl footprint overlapped with between 19% (ORH3B NWCR) and 22% (ORH3B ESCR) of the predicted range for Antipatharia on the Chatham Rise, several times higher than other taxa (Tables 3-9 and 3-10).

Overlap between the ORH and OEO/SSO/BOE trawl footprints was observed at the scale of the EEZ (Figures A1-A3), the EEZ bioregion (Figures E1-E3), and within the ORH3B ESCR UoA (Figures D1-D3). Only limited trawling for oreo species occurred in ORH3B NWCR and ORH7A & Westpac over time, and none over the last five years (Tables 3-3, 3-4, 3-8, 3-9). Overlap metrics between coral distributions and the ORH footprint were similar to those observed for the combined footprint. The OEO/SSO/BOE footprint however, had a higher degree of overlap with observed Gorgonacea distributions at the scale of the EEZ, the EEZ bioregion, and in the ORH3B ESCR UoA (Tables 3-1, 3-2, 3-5), and a higher degree of overlap with predicted distributions of Scleractinia and/or Gorgonacea corals in the same areas (Tables 3-6, 3-7, 3-10). The results suggest greater impacts of ORH and OEO/SSO/BOE trawling on Antipatharia and Gorgonacea corals, respectively.

Proportions of observed coral distributions that were ‘unfished’ at the scale of the EEZ varied from 53% (Antipatharia), 58% (Gorgonacea) and 60% (Scleractinia) over the entire fishery period, and increased to 79% (Antipatharia), 81% (Gorgonacea) and 83% (Scleractinia) over the last five years, under the assumption that coral distributions have remained constant over time (Table 3-1). Proportions of predicted coral distributions that were 'unfished' in the EEZ varied from 94% (Antipatharia) to 98% (Gorgonacea and Scleractinia) over the entire fishery period, and from 98% (Antipatharia) to over 99% (Gorgonacea and Scleractinia) over the last five years (Table 3-6). Among the UoAs, higher proportions of 'unfished' corals were generally observed in ORH7A & Wetspac and/or ORH3B NWCR.

The overlap between coral distributions (both observed and predicted) and the fisheries footprints were most pronounced within ORH3B ESCR (Tables 3-15, Table 3-10).

Overall, there was a contraction in the area of overlap of the trawl footprint and coral distributions in the most recent 5 year period relative to all years. This is to be expected given the reduced effort levels.

Table 3-1: Observed distributions of protected corals groups within the New Zealand EEZ, including proportional occurrence in protected areas (PAs) and overlapping ORH, OEO/SSO/BOE and combined (ORH/OEO/SSO/BOE) fishery trawl footprint (for fishing years 1989/90-2012/13 and 2008/09-2012/13).

NZ EEZ & Westpac	Black corals Antipatharia	Gorgonian corals Alcyonacea	Stony corals Scleractinia
Observed distribution			
no. observations	746	2129	796
distribution area (km2)	515	1206	547
PAs (km2)	63	134	90
PAs (%)	12.2	11.1	16.5
% unfished (1990-2013)*	52.6	58.0	59.6
% unfished (2009-2013)*	79.2	81.3	83.0
ORH footprint			
Total 1990-2013 (km^2)	39585	39585	39585
Overlapping 1990-2013 (km^2)	209	337	164
% Overlap (all years)	40.6	27.9	30.0
Total 2009-2013 (km2)	6507	6507	6507
Overlapping 2009-2013 (km^2)	83	109	61
% Overlap (five-year)	16.1	9.0	11.2
OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	16614	16614	16614
Overlapping 1990-2013 (km^2)	61	266	94
% Overlap (all years)	11.8	22.1	17.2
Total 2009-2013 (km2)	3070	3070	3070
Overlapping 2009-2013 (km^2)	27	126	35
% Overlap (five-year)	5.2	10.4	6.4
Combined ORH/OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	53503	53503	53503
Overlapping 1990-2013 (km^2)	244	507	221
% Overlap (all years)	47.4	42.0	40.4
Total 2009-2013 (km2)	9490	9490	9490
Overlapping 2009-2013 (km^2)	107	226	93
% Overlap (five-year)	20.8	18.7	17.0

Table 3-2: Observed distributions of protected corals groups within the EEZ bioregion, including proportional occurrence in protected areas (PAs) and overlapping ORH, OEO/SSO/BOE and combined (ORH/OEO/SSO/BOE) fishery trawl footprint (for fishing years 1989/90-2012/13 and 2008/09-2012/13).

EEZ_Bioregion	**Black corals Antipatharia**	**Gorgonian corals Alcyonacea**	**Stony corals Scleractinia**
Observed distribution			
no. observations	540	1648	549
distribution area (km2)	363	851	340
PAs (km2)	34	85	44
PAs (%)	9.4	10.0	12.9
% unfished (1990-2013)*	36.9	44.8	39.4
% unfished (2009-2013)*	72.2	75.9	75.3
ORH footprint			
Total 1990-2013 (km^2)	36670	36670	36670
Overlapping 1990-2013 (km^2)	199	315	154
% Overlap (all years)	54.8	37.0	45.3
Total 2009-2013 (km2)	6211	6211	6211
Overlapping 2009-2013 (km^2)	80	100	57
% Overlap (five-year)	22.0	11.8	16.8
OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	14638	14638	14638
Overlapping 1990-2013 (km^2)	55	240	85
% Overlap (all years)	15.2	28.2	25.0
Total 2009-2013 (km2)	2786	2786	2786
Overlapping 2009-2013 (km^2)	23	110	29
% Overlap (five-year)	6.3	12.9	8.5
Combined ORH/OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	49387	49387	49387
Overlapping 1990-2013 (km^2)	229	470	206
% Overlap (all years)	63.1	55.2	60.6
Total 2009-2013 (km2)	9011	9011	9011
Overlapping 2009-2013 (km^2)	101	205	84
% Overlap (five-year)	27.8	24.1	24.7

**% unfished relative to the combined (ORH/OEO) footprint*

Table 3-3: Observed distributions of protected corals groups within the ORH7A & Westpac Bank UoA, including proportional occurrence in protected areas (PAs) and overlapping ORH, OEO/SSO/BOE and combined (ORH/OEO/SSO/BOE) fishery trawl footprint (for fishing years 1989/90-2012/13 and 2008/09-2012/13).

OR7A_Westpac	**Black corals Antipatharia**	**Gorgonian corals Alcyonacea**	**Stony corals Scleractinia**
Observed distribution			
no. observations	5	22	21
distribution area (km2)	5	18	13
PAs (km2)	0	1	0
PAs (%)	0.0	5.6	0.0
% unfished (1990-2013)*	72.0	86.1	86.9
% unfished (2009-2013)*	90.0	95.6	93.1
ORH footprint			
Total 1990-2013 (km^2)	7534	7534	7534
Overlapping 1990-2013 (km^2)	1.4	2.5	1.7
% Overlap (all years)	28.0	13.9	13.1
Total 2009-2013 (km2)	277	277	277
Overlapping 2009-2013 (km^2)	0.5	0.8	0.9
% Overlap (five-year)	10.0	4.4	6.9
OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	1.8	1.8	1.8
Overlapping 1990-2013 (km^2)	0	0	0
% Overlap (all years)	0.0	0.0	0.0
Total 2009-2013 (km2)	0	0	0
Overlapping 2009-2013 (km^2)	0	0	0
% Overlap (five-year)	0.0	0.0	0.0
Combined ORH/OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	7535	7535	7535
Overlapping 1990-2013 (km^2)	1.4	2.5	1.7
% Overlap (all years)	28.0	13.9	13.1
Total 2009-2013 (km2)	277	277	277
Overlapping 2009-2013 (km^2)	0.5	0.8	0.9
% Overlap (five-year)	10.0	4.4	6.9

**% unfished relative to the combined (ORH/OEO) footprint*

Table 3-4: Observed distributions of protected corals groups within the ORH3B_NWCR UoA, including proportional occurrence in protected areas (PAs) and overlapping ORH, OEO/SSO/BOE and combined (ORH/OEO/SSO/BOE) fishery trawl footprint (for fishing years 1989/90-2012/13 and 2008/09-2012/13).

ORH3B_NWCR	**Black corals Antipatharia**	**Gorgonian corals Alcyonacea**	**Stony corals Scleractinia**
Observed distribution			
no. observations	34	228	174
distribution area (km2)	27	119	101
PAs (km2)	1.2	19.5	32
PAs (%)	4.4	16.4	31.7
% unfished (1990-2013)*	38.9	73.1	61.4
% unfished (2009-2013)*	85.6	94.7	92.0
ORH footprint			
Total 1990-2013 (km^2)	6298	6298	6298
Overlapping 1990-2013 (km^2)	16.4	32	39
% Overlap (all years)	60.7	26.9	38.6
Total 2009-2013 (km2)	740	740	740
Overlapping 2009-2013 (km^2)	3.9	6.3	8.1
% Overlap (five-year)	14.4	5.3	8.0
OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	165	165	165
Overlapping 1990-2013 (km^2)	1.6	3	3.2
% Overlap (all years)	5.9	2.5	3.2
Total 2009-2013 (km2)	0	0	0
Overlapping 2009-2013 (km^2)	0	0	0
% Overlap (five-year)	0.0	0.0	0.0
Combined ORH/OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	6349	6349	6349
Overlapping 1990-2013 (km^2)	16.5	32	39
% Overlap (all years)	61.1	26.9	38.6
Total 2009-2013 (km2)	740	740	740
Overlapping 2009-2013 (km^2)	3.9	6.3	8.1
% Overlap (five-year)	14.4	5.3	8.0

**% unfished relative to the combined (ORH/OEO) footprint*

Table 3-5: Observed distributions of protected corals groups within the ORH3B_ESCR UoA, including proportional occurrence in protected areas (PAs) and overlapping ORH, OEO/SSO/BOE and combined (ORH/OEO/SSO/BOE) fishery trawl footprint (for fishing years 1989/90-2012/13 and 2008/09-2012/13).

ORH3B_ESCR	**Black corals Antipatharia**	**Gorgonian corals Alcyonacea**	**Stony corals Scleractinia**
Observed distribution			
no. observations	134	282	186
distribution area (km2)	103	181	111
PAs (km2)	1	3.5	3.1
PAs (%)	1.0	1.9	2.8
% unfished (1990-2013)*	28.2	40.9	35.1
% unfished (2009-2013)*	59.2	66.3	61.3
ORH footprint			
Total 1990-2013 (km^2)	9766	9766	9766
Overlapping 1990-2013 (km^2)	73	100	71
% Overlap (all years)	70.9	55.2	64.0
Total 2009-2013 (km2)	2939	2939	2939
Overlapping 2009-2013 (km^2)	40	46	40
% Overlap (five-year)	38.8	25.4	36.0
OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	2269	2269	2269
Overlapping 1990-2013 (km^2)	9.4	40	13.5
% Overlap (all years)	9.13	22.10	12.16
Total 2009-2013 (km2)	705	705	705
Overlapping 2009-2013 (km^2)	4	22	4.8
% Overlap (five-year)	3.88	12.15	4.32
Combined ORH/OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	10950	10950	10950
Overlapping 1990-2013 (km^2)	74	107	72
% Overlap (all years)	71.8	59.1	64.9
Total 2009-2013 (km2)	3580	3580	3580
Overlapping 2009-2013 (km^2)	42	61	43
% Overlap (five-year)	40.8	33.7	38.7

**% unfished relative to the combined (ORH/OEO) footprint*

Table 3-6: Predicted distributions (>50% probability of occurrence) of protected corals groups within the New Zealand EEZ, including proportional occurrence in protected areas (PAs) and overlapping ORH, OEO/SSO/BOE and combined (ORH/OEO/SSO/BOE) fishery trawl footprint (for fishing years 1989/90-2012/13 and 2008/09-2012/13).

NZ EEZ and WESTPAC	Black corals Antipatharia	Gorgonian corals Alcyonacea	Stony corals Scleractinia
Predicted distribution			
>50% occurrence (km^2)	116616	223056	1065177
PAs (km^2)	31459	29496	221329
PAs (%)	27.0	13.2	20.8
% unfished (1990-2013)*	93.6	98.1	98.1
% unfished (2009-2013)*	98.3	99.7	99.6
ORH footprint			
Total 1990-2013 (km^2)	39585	39585	39585
Overlapping 1990-2013 (km^2)	6996	3177	15198
% Overlap (all years)	6.0	1.4	1.4
Total 2009-2013 (km2)	6507	6507	6507
Overlapping 2009-2013 (km^2)	1886	475	2590
% Overlap (five-year)	1.6	0.2	0.2
OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	16614	16614	16614
Overlapping 1990-2013 (km^2)	586	1267	6402
% Overlap (all years)	0.5	0.6	0.6
Total 2009-2013 (km2)	3070	3070	3070
Overlapping 2009-2013 (km^2)	69.6	297	1569
% Overlap (five-year)	0.1	0.1	0.1
Combined ORH/OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	53503	53503	53503
Overlapping 1990-2013 (km^2)	7411	4330	20335
% Overlap (all years)	6.4	1.9	1.9
Total 2009-2013 (km2)	9490	9490	9490
Overlapping 2009-2013 (km^2)	1952	761	4090
% Overlap (five-year)	1.7	0.3	0.4

**% unfished relative to the combined (ORH/OEO) footprint*

Table 3-7: Predicted distributions (>50% probability of occurrence) of protected corals groups within the EEZ Bioregion, including proportional occurrence in protected areas (PAs) and overlapping ORH, OEO/SSO/BOE and combined (ORH/OEO/SSO/BOE) fishery trawl footprint (for fishing years 1989/90-2012/13 and 2008/09-2012/13).

EEZ BIOREGION	Black corals Antipatharia	Gorgonian corals Alcyonacea	Stony corals Scleractinia
Predicted distribution			
>50% occurrence (km^2)	91122	55951	573933
PAs (km^2)	26588	10069	134408
PAs (%)	29.2	18.0	23.4
% unfished (1990-2013)*	92.4	93.9	96.8
% unfished (2009-2013)*	98.0	98.9	99.4
ORH footprint			
Total 1990-2013 (km^2)	36670	36670	36670
Overlapping 1990-2013 (km^2)	6559	2537	14097
% Overlap (all years)	7.2	4.5	2.5
Total 2009-2013 (km2)	6211	6211	6211
Overlapping 2009-2013 (km^2)	1801	390	2440
% Overlap (five-year)	2.0	0.7	0.4
OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	14638	14638	14638
Overlapping 1990-2013 (km^2)	532	976	5434
% Overlap (all years)	0.6	1.7	0.9
Total 2009-2013 (km2)	2786	2786	2786
Overlapping 2009-2013 (km^2)	58.7	220	1324
% Overlap (five-year)	0.1	0.4	0.2
Combined ORH/OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	49387	49387	49387
Overlapping 1990-2013 (km^2)	6926	3428	18379
% Overlap (all years)	7.6	6.1	3.2
Total 2009-2013 (km2)	9011	9011	9011
Overlapping 2009-2013 (km^2)	1857	603	3715
% Overlap (five-year)	2.0	1.1	0.6

**% unfished relative to the combined (ORH/OEO) footprint*

Table 3-8: Predicted distributions (>50% probability of occurrence) of protected corals groups within the ORH7A & Westpac UoA, including proportional occurrence in protected areas (PAs) and overlapping ORH, OEO/SSO/BOE and combined (ORH/OEO/SSO/BOE) fishery trawl footprint (for fishing years 1989/90-2012/13 and 2008/09-2012/13).

ORH7A_WESTPAC	Black corals Antipatharia	Gorgonian corals Alcyonacea	Stony corals Scleractinia
Predicted distribution			
>50% occurrence (km^2)	3951	50115	117085
PAs (km^2)	702	10827	29091
PAs (%)	17.8	21.6	24.8
% unfished (1990-2013)*	99.3	97.9	95.2
% unfished (2009-2013)*	100.0	99.9	99.8
ORH footprint			
Total 1990-2013 (km^2)	7534	7534	7534
Overlapping 1990-2013 (km^2)	27	1048	5584
% Overlap (all years)	0.7	2.1	4.8
Total 2009-2013 (km2)	277	277	277
Overlapping 2009-2013 (km^2)	0.67	25.8	265
% Overlap (five-year)	0.0	0.1	0.2
OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	1.8	1.8	1.8
Overlapping 1990-2013 (km^2)	0	0	0.32
% Overlap (all years)	0.0	0.0	0.0
Total 2009-2013 (km2)	0	0	0
Overlapping 2009-2013 (km^2)	0	0	0
% Overlap (five-year)	0.0	0.0	0.0
Combined ORH/OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	7535	7535	7535
Overlapping 1990-2013 (km^2)	27	1048	5584
% Overlap (all years)	0.7	2.1	4.8
Total 2009-2013 (km2)	277	277	277
Overlapping 2009-2013 (km^2)	0.67	25.8	265
% Overlap (five-year)	0.0	0.1	0.2

**% unfished relative to the combined (ORH/OEO) footprint*

Table 3-9: Predicted distributions (>50% probability of occurrence) of protected corals groups within the ORH3B_NWCR UoA, including proportional occurrence in protected areas (PAs) and overlapping ORH, OEO/SSO/BOE and combined (ORH/OEO/SSO/BOE) fishery trawl footprint (for fishing years 1989/90-2012/13 and 2008/09-2012/13).

ORH3B_NWCR	Black corals Antipatharia	Gorgonian corals Alcyonacea	Stony corals Scleractinia
Predicted distribution			
>50% occurrence (km^2)	5053	22290	34480
PAs (km^2)	42	1512	4459
PAs (%)	0.8	6.8	12.9
% unfished (1990-2013)*	80.8	99.2	99.5
% unfished (2009-2013)*	98.1	99.9	100.0
ORH footprint			
Total 1990-2013 (km^2)	6298	6298	6298
Overlapping 1990-2013 (km^2)	970	171	152
% Overlap (all years)	19.2	0.8	0.4
Total 2009-2013 (km2)	740	740	740
Overlapping 2009-2013 (km^2)	97	19	11
% Overlap (five-year)	1.9	0.1	0.0
OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	165	165	165
Overlapping 1990-2013 (km^2)	15	5.8	7.2
% Overlap (all years)	0.3	0.0	0.0
Total 2009-2013 (km2)	0	0	0
Overlapping 2009-2013 (km^2)	0	0	0
% Overlap (five-year)	0.0	0.0	0.0
Combined ORH/OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	6349	6349	6349
Overlapping 1990-2013 (km^2)	972	175	158
% Overlap (all years)	19.2	0.8	0.5
Total 2009-2013 (km2)	740	740	740
Overlapping 2009-2013 (km^2)	97	19	11
% Overlap (five-year)	1.9	0.1	0.0

**% unfished relative to the combined (ORH/OEO) footprint*

Table 3-10: Predicted distributions (>50% probability of occurrence) of protected corals groups within the ORH3B_ESCR UoA, including proportional occurrence in protected areas (PAs) and overlapping ORH, OEO/SSO/BOE and combined (ORH/OEO/SSO/BOE) fishery trawl footprint (for fishing years 1989/90-2012/13 and 2008/09-2012/13).

ORH3B_ESCR	Black corals Antipatharia	Gorgonian corals Alcyonacea	Stony corals Scleractinia
Predicted distribution			
>50% occurrence (km^2)	9436	28227	71346
PAs (km^2)	1911	3904	5308
PAs (%)	20.3	13.8	7.4
% unfished (1990-2013)*	77.9	96.1	90.0
% unfished (2009-2013)*	92.9	99.1	96.9
ORH footprint			
Total 1990-2013 (km^2)	9766	9766	9766
Overlapping 1990-2013 (km^2)	2086	1047	6486
% Overlap (all years)	22.1	3.7	9.1
Total 2009-2013 (km2)	2939	2939	2939
Overlapping 2009-2013 (km^2)	669	227	1854
% Overlap (five-year)	7.09	0.80	2.60
OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	2269	2269	2269
Overlapping 1990-2013 (km^2)	16	87	1365
% Overlap (all years)	0.2	0.3	1.9
Total 2009-2013 (km2)	705	705	705
Overlapping 2009-2013 (km^2)	0.8	19.1	372
% Overlap (five-year)	0.0	0.1	0.5
Combined ORH/OEO/SSO/BOE footprint			
Total 1990-2013 (km^2)	10950	10950	10950
Overlapping 1990-2013 (km^2)	2090	1102	7164
% Overlap (all years)	22.1	3.9	10.0
Total 2009-2013 (km2)	3580	3580	3580
Overlapping 2009-2013 (km^2)	670	240	2177
% Overlap (five-year)	7.1	0.9	3.1

**% unfished relative to the combined (ORH/OEO) footprint*

4 Discussion

This work has involved a large amount of data sorting, manipulation, plotting, and the calculation of overlap metrics. As such, there are many figures and tables to digest. As the fishery is being assessed against current rather than historical performance, the proportions of observed and predicted coral distributions in protected areas, and the proportions overlapped by trawl footprint over the most recent 5-year period, are summarised in Table 4-1.

Table 4-1: Summary of the proportion of predicted and observed ETP coral distributions in protected areas and overlapped by the trawl footprint in the most recent 5-year period (2008-09 to 2012-13).

Area & Parameter	Predicted Coral Distribution (≥50% prob. occur.)			Observed Coral Distribution (extrapolated to 1 km^2 cells)		
	Black Corals Antipatharia	Gorgonian Corals Alcyonacea	Stony Corals Scleractinia	Black Corals Antipatharia	Gorgonian Corals Alcyonacea	Stony Corals Scleractinia
NZ EEZ and Westpac						
Coral in Protected Areas (%)	27%	13%	21%	12.2%	11.1%	16.5%
Trawl-Coral Overlap (%)	1.7%	0.3%	0.4%	20.8%	18.7%	17.0%
EEZ Bioregion						
Coral in Protected Areas (%)	29%	18%	23%	9.4%	10.0%	12.9%
Trawl-Coral Overlap (%)	2.0%	1.1%	0.6%	27.8%	24.1%	24.7%
UoA ORH7A & Westpac						
Coral in Protected Areas (%)	18%	22%	25%	0.0%	5.6%	0.0%
Trawl-Coral Overlap (%)	0.0%	0.1%	0.2%	10.0%	4.4%	6.9%
UoA ORH3B NWCR						
Coral in Protected Areas (%)	1%	7%	13%	4.4%	16.4%	31.7%
Trawl-Coral Overlap (%)	1.9%	0.1%	0.0%	14.4%	5.3%	8.0%
UoA ORH3B ESCR						
Coral in Protected Areas (%)	20%	14%	7%	1.0%	1.9%	2.8%
Trawl-Coral Overlap (%)	7.1%	0.9%	3.1%	40.8%	33.7%	38.7%

Beyond the production of these results, NIWAs brief was to “provide informed commentary, based on available information, on the likely effects of orange roughy and oreo on ETP coral assemblages”. We address that part of the project in the sections below, which work through a sequence describing coral assemblages, discussing their distribution, detailing some of the main impacts of bottom trawling on such benthic communities, including consideration of the intensity of trawling, and then evaluating the resilience and potential recovery of such impacted assemblages.

4.1 ETP coral assemblages

4.1.1 Composition

The protected coral species considered in this study are often associated with a rich and diverse invertebrate community. The reef-building scleractinian matrix is home to brisingid seastars, urchins, feather stars, anemones, and sponges that use the upper surface of the coral colony as place that is clear of sediment for filter-feeding on particulate matter in the water column. Internally there can be high densities of eunicid worms, brittle stars and squat lobsters. Over 1000 fish and invertebrate species have been found in association with *Lophelia* reefs in the North Atlantic (Freiwald et al. 2004), and although it is uncertain how many of these utilise the coral habitat specifically, biodiversity is about 3 times higher on the reef than on adjacent regions of soft sediment slope. On southern hemisphere UTFs with *Solenosmilia* reefs, species richness associated with corals is reported to be 4 times higher than in areas without coral (e.g., Althaus et al. 2009).

Most of the species of coral and associated communities are widely distributed throughout the New Zealand region, and beyond. However, several species of antipatharian black corals, gorgonian bubblegum corals (*Paragorgia* spp.), and 8 species of *Errina* red hydrocoral (Anthoathecata) are endemic to the New Zealand region (Gordon 2009). None are thought endemic on the scale of a single orange roughy fishing area.

4.1.2 Distribution

The distribution of coral records, and especially the predicted habitat suitability range, cover large areas. Nevertheless, the distribution of high densities of corals is often patchy. Scleractinian corals are commonly found on UTFs, where they can form high densities on the summit and upper flank areas (Rowden et al. 2010). Typically, species of the genera *Solenosmilia*, *Madrepora*, and *Enallopsammia* are found deep and on UTFs, whereas *Goniocorella* is shallower and forms thickets on hard rocky outcrops on the slope (Tracey et al. 2011b). Hence their susceptibility to trawling differs, as the UTF species can be subject to repeated and intense trawling activity in situations where fishers target the summit of a UTF to stabilise the gear before towing downslope. In contrast, the more widely dispersed *Goniocorella* may be subject to lower intensity trawling over wide areas.

Results have been presented for two approaches to defining the distribution of corals: actual known records, and then predictive modelling based on the habitat suitability. It is important to bear in mind that both these are based on **presence of corals**, and they do not relate to abundance. Both distribution methods have their advantages and disadvantages. The actual observed records are a minimum estimate of the distribution, although the 1km^2 binning of records increases the assumed area of their distribution over the actual sampled area. The key advantage is that the record is a known occurrence position, and makes no assumptions about environmental drivers of their distribution. The latter is a key element of habitat suitability modelling. The method is able to extend the distribution into likely areas that have not been sampled, but the accuracy of this depends upon whether the “right” environmental variables have been selected, and whether the spatial scale of such variables is relevant to the patchy distribution of coral assemblages. The 10 variables used in the modelling are all potentially biologically meaningful, but a key missing factor is substrate. It is fundamental that if the seafloor is thick soft sediment, most ETP (but not all) coral species will not occur, because their holdfasts require hard substrate for attachment. This is illustrated by the high predicted occurrence of stony corals over the top of the Challenger Plateau in ORH7A. However, it is known that much of the plateau is soft sediment, and unlikely to support reef-building scleractinian corals. The model does the best it can given the input data, but it is perhaps telling that for some taxa the 50% predicted range does not include a number of actual observed locations-implying that the environmental data are not fully describing the drivers of coral distribution. It is likely that the true distribution lies somewhere between the two approaches.

4.1.3 Assemblage scale

The maps of coral distributions presented in this report are relatively large scale. An occurrence is scaled up to a 1km^2 cell, and predictive modelling results are continuous. However, corals are often patchy in their distribution, and in their densities. Antipatharia and Gorgonacea tend to be solitary growth forms, although they can cluster together, but it is primarily the Scleractinia that have the potential to cover appreciable expanses of seafloor. There is limited quantitative information available on the "patchiness" of corals and stony coral habitat around New Zealand, and carrying out such analyses was beyond the scope of this work. Nevertheless, it has been documented that on unfished UTFs, where stony corals are dominant, the coverage of corals over the seafloor is variable. Clark & Rowden (2009) and Clark et al. (2010a) include plots of the density of stony coral matrix along camera transects on "Gothic" and "Ghoul" hills in the Graveyard complex. Densities of *Solenosmilia variabilis* in individual still camera images range from 0 to 100%. The scale of this patchiness can be in the order of metres rather than kilometres. On the slope, the distribution of *Goniocorella dumosa* extends over larger areas than on UTFs, but is still variable in density of thicket-type structures on the scale of metres to kilometres (Bowden et al. 2013).

4.2 Trawling impacts

The impacts of bottom trawling on ETP coral assemblages depends on several factors:

- The type of trawl gear, its configuration, and weight
- The nature of the impacts from the gear
- The extent of the trawl footprint relative to the distribution of the species
- The intensity of trawl effort
- The resilience of the species to trawling impacts
- The recovery potential of the species

Below we briefly cover each of these aspects to give a feel for their importance for the New Zealand ETP coral species, and then refer back to results of the work presented earlier on interaction between the footprint and coral distributions to draw some conclusions about the likely impact of orange roughy and oreo -targeted trawling on the ETP coral assemblages.

Bottom trawling for orange roughy and oreo typically involves relatively heavy and robust trawl gear, capable of running over rough seafloor. Steel bobbin rigs were common in the past, but more vessels now use rock-hopper groundgear. The trawl gear may weigh several tonnes in water at 1000 m depth (Clark & Rowden 2009), and the vertical penetration of various parts of the gear into the seabed can be significant. These effects differ between gear types and substrate composition, but in soft sediment trawl doors can gouge up to 30 cm depth, and 3-4 cm for bobbin-type ground gear (Eigaard et al. 2014). On gravel or rock substrate, penetration into the seafloor may be negligible, but these indicators of downwards pressure clearly suggest that coral matrix structures fixed on hard substrate will likely be significantly impacted. Recent concern in Europe is whether heavier bobbins have less impact than lighter rock-hopper gear because the bobbins rotate and have a rolling effect, whereas the rockhopper discs are fixed and therefore apply a constant dragging force on the seabed (L. Teal, IMARES, Norway, pers. comm).

The weight of the trawl gear, and penetration into the seabed, is probably the main difference between shallow-water and deep-water trawling operations. The nature of impacts is likely to be similar, with the key effects relevant to ETP communities comprising direct physical damage to species (e.g., ploughing, scraping effects of the gear), and indirect impacts from the resuspension of soft sediment that can clog the filter-feeding mechanisms of corals and sponges, and prevent settlement of larvae (e.g., reviews by Jennings & Kaiser 1998, Hall 1999, Gage et al. 2005, Clark & Koslow 2007). In comparison with shelf environments, deeper waters have seen few studies, but patterns with erect epifauna are the same, in particular:

Reduced abundance

e.g., Tasmanian UTFs (Koslow et al. 2001) heavily fished, average species number 9, average biomass 1 kg

lightly fished, average species number 20, average biomass 7 kg

e.g., Gulf of Alaska sponge gardens (Freese et al. 1999)

trawled, average density of finger sponges 71, vase sponges 1/100m^2

untrawled, average density of finger sponges 119, vase sponges 4/100m^2

e.g., Norwegian slope, *Lophelia* reefs (Buhl-Mortenson et al. 2013)

Lopphavet reef: trawled colony height *Paragorgia* 17cm, *Lophelia* 20cm

Lopphavet reef: untrawled colony height *Paragorgia* 55cm, *Lophelia* 30cm

Reduced extent of coral cover

e.g., New Zealand UTFs (Clark & Rowden 2009)

coral cover on trawled UTFs, average in images 4%

coral cover on untrawled UTFs, average in images 25%

e.g., Tasmanian UTFs (Althaus et al. 2009)

coral cover on trawled UTFs, average in images 0%

coral cover on untrawled UTFs, average in images 50%

e.g., *Lophelia* reefs, Norway (Fossa et al. 2002)

4 reefs, damaged areas up to 450km^2, ranging from 5% to 50% of total reef area

These compare and contrast studies clearly indicate that trawling is likely to have a substantial impact on deep-sea coral communities in fished areas. This is hardly surprising given the ecological traits that most ETP coral species exhibit. Characteristics of an erect growing habit (liable to breakage), being sedentary (unable to move away), living on the sediment surface (hence disturbed by gear on the seabed), and being fragile (hence damaged or killed if disturbed) make this type of fauna highly sensitive to disturbance (e.g., Hewitt et al. 2011). Nevertheless, there is always some uncertainty about “cause-and-effect” with this type of study compared with before and after experiments. However, a strong clue that trawling is a major cause comes from remnant areas of corals that can occur in areas that are too rough to trawl. An example of this is on “Morgue Seamount” on the Chatham Rise, where dense scleractinian corals occurred down a spur that, from commercial records, and talking with skippers, had not been fished (Clark et al. 2010a).

Evaluating the extent of impacts depends not just on the overlap of the total footprint, but understanding also the direction of tows, length of tow, and frequency of trawling. The aspects of direction and length of tow are particularly important on UTFs, where there is considerable variability in both. This will be dealt with more extensively in the habitats section, but Figure 4-1 shows a frequency plot of tow distance by direction for 2 features, Hegerville in the southern Chatham Rise showing widespread trawling over much of the UTF, whereas with Megabrick on the Challenger Plateau it is more restricted and tows are shorter.

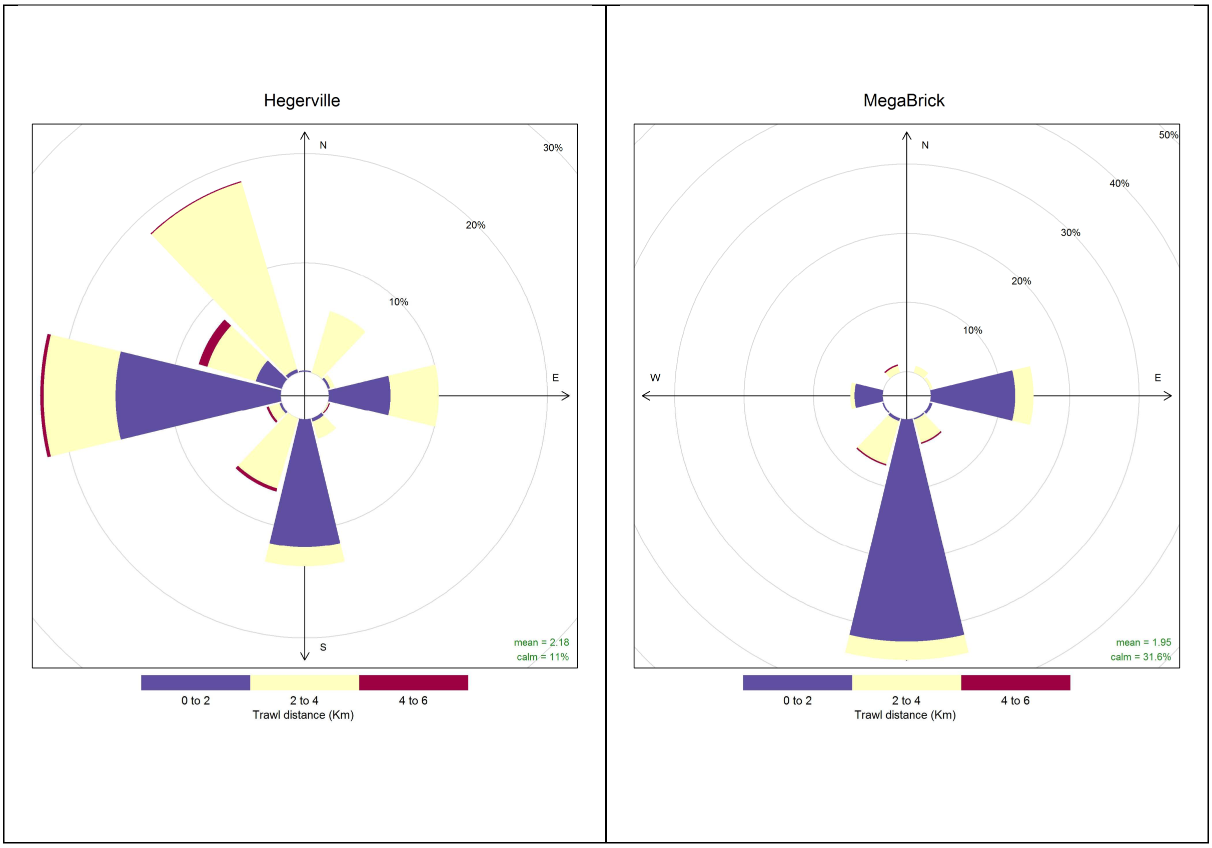

Figure 4-1: "Windrose" plots of tow distance, direction and frequency for two UTFs, Hegerville on the southern Chatham Rise, and Megabrick in ORH7A, (Clark & Anderson 2013).

Intensity metrics are not presented in Section 3 in this version of the report but some parts of the footprint are repeatedly-trawled very frequently, others less so. Cumulative trawl impacts are important to consider, as variable trawl gear performance and selectivity means that not all benthic fauna are impacted with a single trawl pass.

As mentioned above, there have been few specific deep-sea studies on trawling impact. However, several have occurred at shelf depths that give an indication of what might be expected with similar taxa in the deep sea. Table 4-2 summarises several studies that describe the incidence of damage to the numbers or density of some coral and sponge taxa that are similar in form and size to the New Zealand ETP coral species.

Table 4-2: Summary of relevant studies documenting damage to sponge and coral taxa from trawling experiments.

Location	Depth	Gear	Effort	Taxon	Damage	Reference
USA	20 m	Fish trawl	1 trawl	Barrel sponges	32%	Van Dolah et al. 1987
Alaska	200-300m	Fish trawl	8 x 1 trawl	Sponges gorgonians	67% 55%	Freese et al. 1999
NW Australia	50-200m	Fish trawl	1 trawl	Sponges	90%	Sainsbury et al. 1997
NE Australia	20-35m	Prawn trawl	6 x13 trawls	Sponges gorgonians	80%	Burridge et al. 2003

Results from these studies differ, but in general suggest that a single trawl may not necessarily damage everything in its path, but repeated trawling can reduce populations to low levels. The experimental trawling on the Great Barrier Reef (reported in Pitcher et al. 2000 and Burridge et al. 2003) was perhaps one of the best studies, as it involved good methodology and replicated events. Results showed between 10 and 20% of gorgonian corals and large sponges were removed with each trawl event. Studies on the "Graveyard Hills" on the Chatham Rise suggest that a change from 15-25% coral cover to 0 can occur after as few as 10 trawls on the UTF (Clark et al. 2010a).

Indirect trawling impacts are more difficult to quantify. The key aspect here is that trawling can create a substantial sediment plume, that in low-current deep-sea environments can disperse very slowly, over large distances (e.g., Bluhm 2001, Rolinski et al. 2001), and potentially affect areas well beyond, and deeper than the area of the fishery (e.g., Martin et al. 2014). There have been no specific studies examining sediment mobilisation by fishing gear in deep-sea fisheries, but European research has quantified the effects of individual gear components on various substrate types (O'Neill & Summerbell 2011). Trawling on muddy sand seafloor can generate over 100 tonnes of sediment per kilometre towed. This has impacts on ETP coral species through potential smothering of small individuals (e.g., Glover & Smith 2003) and preventing settlement of juveniles (e.g., Rogers et al. 1999) with deposition of mm to cm depth. Impacts on coral feeding and metabolic function are uncertain, although shallow-water stony corals can actively shed sediment (e.g., Riegl 1995) and potentially cope with a sediment plume (within limits), but deep-sea sponge respiration has been reported as largely shutting down when subjected to heavy sedimentation loads (Tjensvoll et al. 2013). These impact are likely to be higher on *Goniocorella dumosa* communities, as they are distributed on slopes of the Chatham Rise dominated by soft sediment with hard substrate patches. There are also longer trawl tows on the slope. The effects will be less on UTFs with coral assemblages than on the slope, as UTF substrate is typically rocky, with only small patches of interspersed soft sediment.

Some species of protected corals are more resilient to the impacts of trawling than others, because of their size, shape, or habitat. For example, hydrocorals (Stylasteridae) are generally small relative to other orders of coral, and they aggregate in rugged pockets of topography such as under rocky overhangs. Hence they are less accessible to damage by trawls. In contrast, some erect corals of the family Chrysogorgidae (gold corals) are flexible, and may "bounce back" after being knocked down by a trawl (e.g., Clark et al 2010b). However, the reef-building Scleractinia are rigid and fragile, and extend often several metres above the seafloor. Similarly many of the larger gorgonian corals are also highly accessible to trawl gear and easily broken.

Given that orange roughy and oreo trawls are highly likely to cause damage to most ETP coral groups encountered in the footprint, a final consideration for evaluating fisheries impact is whether they are likely to recover if trawling ceases, or is reduced in frequency. There have been several major reviews of recovery potential of benthic fauna (e.g., Collie et al. 2000, Kaiser et al. 2006, Jones & Schmitz 2009), but there are very few examples of deep-sea studies. Many deep-sea invertebrate species, like the fish species, tend to be long-lived and slow-growing. It is difficult to generalise about age and growth, as these can be very species and site specific. Rogers et al. (2007) review some of the data available for deep-sea corals, and we update this in Table 4-3 below.

Table 4-3: Summary of some age and growth characteristics of coral species relevant to New Zealand ETP assemblages.

(NZ studies are highlighted in bold).

Faunal group	Age/ growth	Method	Author
Gorgonian corals	67-2377 yo	^{14}C dating	Roark et al. (2006)
Bamboo corals Isididae	75->200 yo 35-197 yo	^{14}C ^{14}C and ^{120}Pb dating	Roark et al. (2005) Rogers et al. (2007)
Bamboo corals ***Lepidisis* spp**	**400 yo** **21-57 mm/yr** 400 yo 0.05–0.16 mm/yr	**^{210}Pb dating** ^{14}C dating	**Tracey et al. (2007)** Roark et al. (2006)
Bamboo corals ***Keratoisis* spp**	**400 yo** **21-57 mm/yr** 0.11 mm/yr 0.2 mm/yr	**^{210}Pb dating** ^{210}Pb dting and U/Th dating ^{14}C dating	**Tracey et al. (2007)** Thresher et al. (2004, 2007) Noe et al. (2008)
Bubblegum coral ***Paragorgia* arborea**	**300-500 y** **15-25mm/yr**	**^{14}C dating**	**Tracey et al. (2003)**
Black coral (*Leiopathes*)	2320 yo 4000 yo	^{14}C dating	Careiro-Silva et al. (2012) Roark et al. (2009)
Black coral (*Antipathes*)	140 yo	^{14}C dating	Love et al. (2007)
Stony corals (*Solenosmilia*)	120 yo (47,000 yo colony)	^{14}C dating	Fallon et al. (2014)
Stony corals (*Solenosmilia*)	**150-660 yo (20 cm matrix)** **0.3-1.6 mm/yr**	**^{14}C dating**	**Neil et al. (unpub)**
Stony corals (*Lophelia*)	Various, live possibly <20 yo (9,000 yo colony) 1-35 mm/yr	Various	Review in Roberts et al. (2009)

These data confirm that large colonies can be very old, and potentially date back centuries to thousands of years (especially in the case of Scleractinia where the live part of the colony is often built upon an accumulation of dead matrix (Freiwald et al. 2004). Growth rates are very slow, typically a few mm per year for stony corals, and a few cm per year for gorgonians. Hence any regrowth to the height of the climax colonies will take the order of decades to centuries.

High longevity may be an important component of recovery, as it implies slow growth rates. However, aspects of larval output (potential recruitment magnitude), and dispersal capability (high meaning widespread colonisation is possible) are also important when considering the ability of a coral species to recover. Williams et al. (2010) rated the ETP coral types low to medium recovery potential due mainly to many being broadcast spawners (hence high larval output) and assumed wide dispersal capability in deep ocean currents.

Time series of surveys have been carried out on UTFs off New Zealand and Tasmania. Initially the surveys were compare-and-contrast to determine the likely effect of fishing (e.g., Koslow et al. 2001, Clark & Rowden 2009), but surveys have been repeated (in 1997 and 2006 off Tasmania; in 2001, 2006 and 2009 off New Zealand). These UTFs are often dominated by stony coral reef species and habitats, and so are directly relevant to an evaluation of the impacts of fishing on ETP coral communities. Williams et al. (2010) analysed seafloor image data from the first two surveys of each, and compared changes in benthic invertebrate community composition for three UTF “types”: Fished, and open to fishing over the full time period; Fished previously, but closed to trawling for the period; Not fished, and closed to trawling. The Fished-open, and Unfished-closed combinations represent two extremes of an impact gradient. If rapid recovery was occurring with the Fished-closed UTF, the expectation would be that its community structure would shift from the Fished-open, towards the Unfished-closed situation between the surveys. The Fished-closed type of UTF showed changes in species composition between surveys, with indications of an increase in abundance of resistant or early coloniser species. However, overall there were no clear signs of changes in the faunal assemblages consistent with recovery over the time period. The 3-survey series in New Zealand is currently being analysed, but preliminary results indicate again that, although faunal changes are occurring, there is no indication of any recovery of stony corals, or their associated communities. Such reversal-type shifts, as with many terrestrial forest systems, may take at least several decades or even centuries.

The capacity of ETP coral species to recover from impact depends upon population connectivity-the dispersal distances of coral larvae, and the suitability of sites at depth for settlement. Miller et al (2010) examined 9 species of deepwater coral from Australia and New Zealand, and assessed their genetic composition as a measure of connectivity. They found variable patterns of connectivity between species of both scleractinian and antipatharian corals on the scale of 100s to 1000s of km, suggesting isolation may occur between UTFs for some coral species, but not others. Recent genetic work in Australia gives further insight into expectations about recovery of scleractinian communities.Recent genetic studies of populations of *Solenosmilia variabilis* on several UTFs separated by 10s to 100s km off southern Tasmania show that the UTF populations are genetically isolated, which suggests there are only low levels of larval dispersal, of the order of only several kilometres, among them, and that the corals are largely self-recruiting (http://www.apscience.org.au/projects/APSF_11_6/apsf_11_6.html). This means that populations on one feature may not be replenished from adjacent features. Hence, even though the same study found that genetic diversity on fished UTFs was as high as on non-fished features, it is not clear that this ensures their resilience in the long term.

4.3 Conclusions

The results of the 5-year interaction of orange roughy and oreo target trawls and the extent of ETP coral distribution show that, over all five regions, the overlap of the trawl footprint can be as high as 41% for the observed distributions but that it is consistently less than 8% for the predicted distributions. Estimates of the proportions of coral distribution in protected areas ranges between 0 – 32% for the observed distributions and 1 – 29% for the predicted distributions. At the scale of the EEZ, the combined footprint overlap with coral distribution is estimated to be less than 2% for the predicted distribution and less than 21% for the observed distribution, and proportion of coral in protected areas ranges between 13 - 27% for the predicted distribution and between 11 - 17% for the observed distribution.

Over all years, the overlap of the trawl footprint can be high based on the observed coral locations. At the scale of the EEZ, the combined footprint overlap with coral distribution is estimated to be between 40 and 47%. The overlap is higher (≥60%) for antipatharian corals in both ORH3B NWCR and ORH3B ESCR UoA regions, and for Gorgonacea and Scleractinia in the ORH3B ESCR. Overlap with the predicted 50% occurrence model distribution is much less. As discussed above, it is difficult to know how much confidence to place in the modelled distributions. The experience of the authors is that these models may over-predict the extent of suitable habitat at the 50% level (and in general) due to the combination of the environmental tolerances of several taxa within individual models.

The footprint has reduced considerably over time and the proportions for the last 5 years are less than for all years. However, given the slow growth rates of almost all ETP coral species, and growing evidence that, at least for UTF populations, the main coral species cannot recover rapidly, the extent of the full footprint is probably more realistic for interpreting the extent of impact. The repetitive nature of much of the trawling footprint implies that where fishing has occurred, damage to the ETP coral assemblages is likely to have been considerable. Genetic work on Australasian corals shows mixed population connectivity, ranging from small-scale population structure (of the order of several kilometres only), to no differences over 100s of kilometres. Possible differences between species is an important aspect for assessing damage to localised populations.

It is unknown how much of a coral population can be damaged before the viability of the coral communities/ecosystem is impaired. Shallow-water studies associated with protected area design have tended to average around maintaining at least 30–50% of a community to ensure its survival (e.g., Botsford et al. 2001, Airame et al. 2003). The spatial extent of coral populations is unknown. If it is assumed that the fishery stock area reflects also the coral population distribution, then the fishing pressure on the Chatham Rise may be approaching, or at, such levels. However, this is a key area of uncertainty when interpreting the significance of overlap between fishing and corals.

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Appendix A: Distribution maps for Protected (ETP) coral species groups – EEZ

Predicted and observed distribution maps for Protected (ETP) coral species (actual records on a 1km^2 grid) for the New Zealand region shown relative to the combined orange roughy and oreo, smooth oreo, black oreo target trawl footprint between 500 and 1600 m, and for the last 5 year period (2008-09 to 2012-13). Also shown are the ORH Management Areas, Seamount Closures, Benthic Protection Areas, and Large Marine Reserves. Figures A1-A3. ETP observed coral distributions (1 km^2 grid), are superimposed as red squares on predicted distributions, together with the trawl footprint. The predicted distributions are illustrated using a 0-25%, 25-50%, 50-75% and 75-100% probability of occurrence scale. Summary metrics are illustrated on the figures.

List of Figures A1 to A3: Predicted distribution maps for the New Zealand region EEZ:

A1. SIA - CBR Scleractinian stony branching corals *(Goniocorella dumosa*, *Solenosmilia variabilis*, *Enallopsammia rostrata*, *Madrepora oculata*) combined

A2. GOC Gorgonacea (all records, selected genera include the Precious coral Corallidae (*Corallium* and *Hemicorallium)* and selected Primnoids and Plexaurids (sea fans)

A3. COB Antipatharia (Order level, all records)

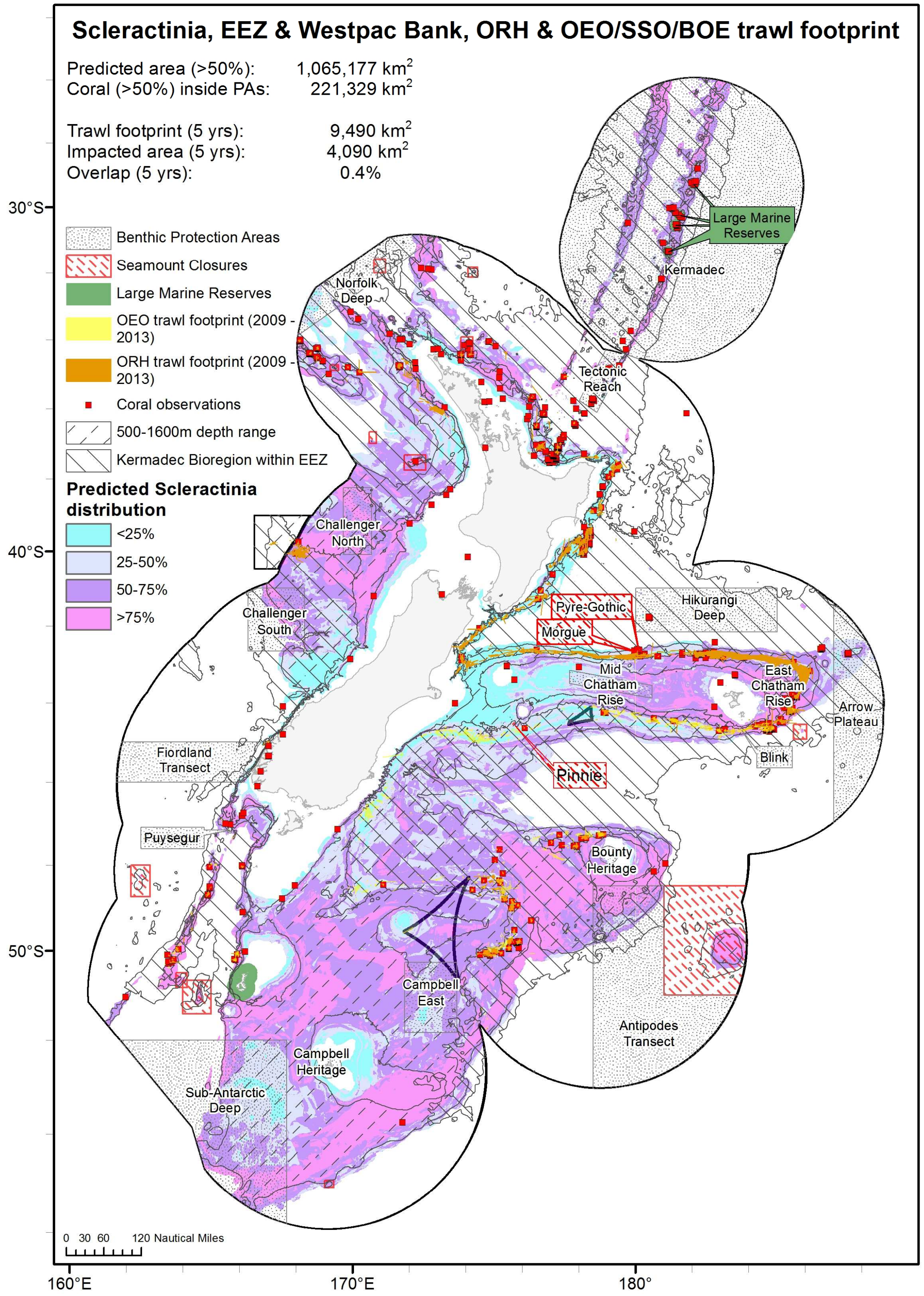

Figure A1: SIA – CBR Scleractinian stony branching corals *(Goniocorella dumosa*, *Solenosmilia variabilis*, *Enallopsammia rostrata*, *Madrepora oculata*) combined.

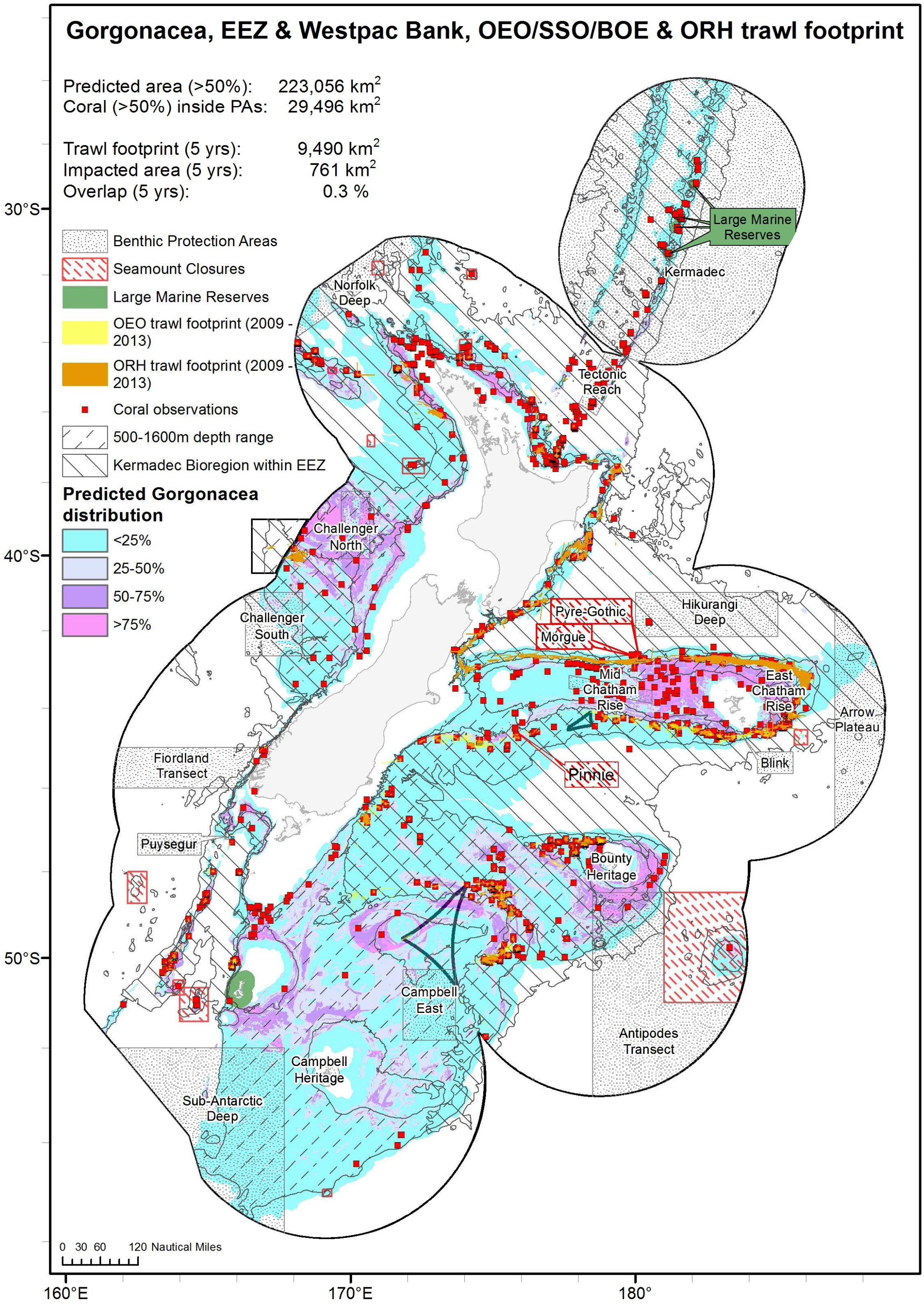

Figure A2: GOC Gorgonacea (all records, selected genera include the Precious coral Corallidae (*Corallium* and *Hemicorallium)* and selected Primnoids and Plexaurids (sea fans).

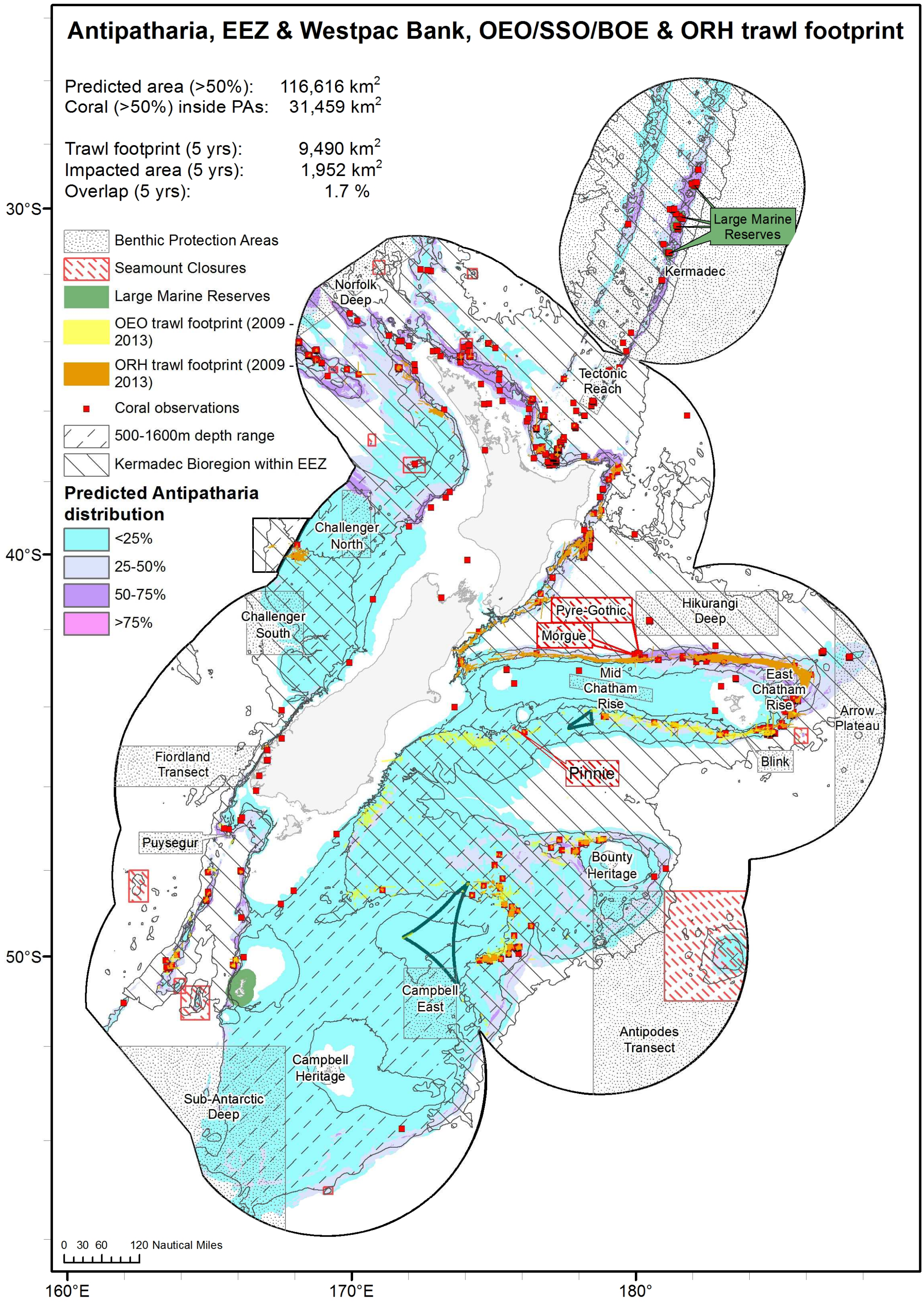

Figure A3: **COB Antipatharia (Order level, all records).**

Appendix B: Distribution maps for Protected (ETP) coral species – ORH7A & Westpac Bank

Predicted and observed distribution maps for Protected (ETP) coral species for the ORH fishery region ORH7A & Westpac Bank shown relative to the combined orange roughy and oreo, smooth oreo, black oreo target trawl footprint between 500 and 1600 m, and for the last 5 year period (2008-09 to 2012-13). Also shown are the Seamount Closures, Benthic Protection Areas, and Large Marine Reserves. ETP observed coral distributions (1 km^2 grid), are superimposed as red squares on predicted distributions, together with the trawl footprint. The predicted distributions are illustrated using a 0-25%, 25-50%, 50-75% and 75-100% probability of occurrence scale. Summary metrics are illustrated on the figures. Figures B1-B3.

List of Figures B1-B3: Distribution maps for ORH7A & Westpac Bank

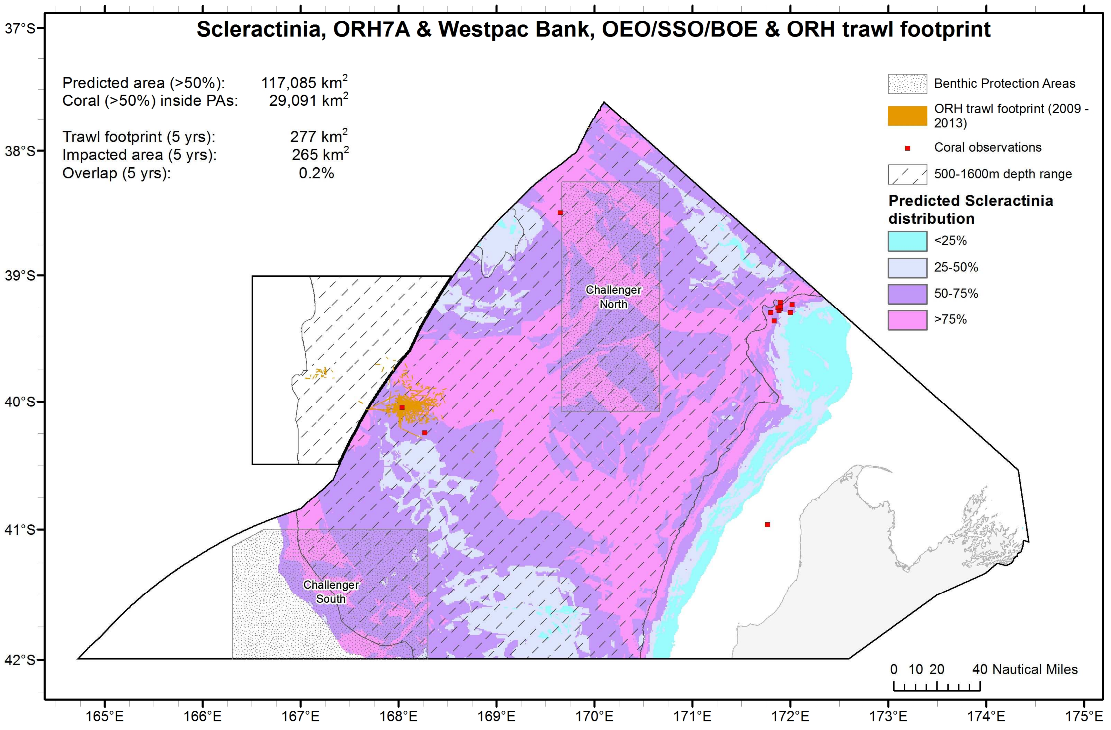

Figure B1: SIA – CBR Scleractinian stony branching corals (*Goniocorella dumosa*, *Solenosmilia variabilis*, *Enallopsammia rostrata*, *Madrepora oculata*) combined.

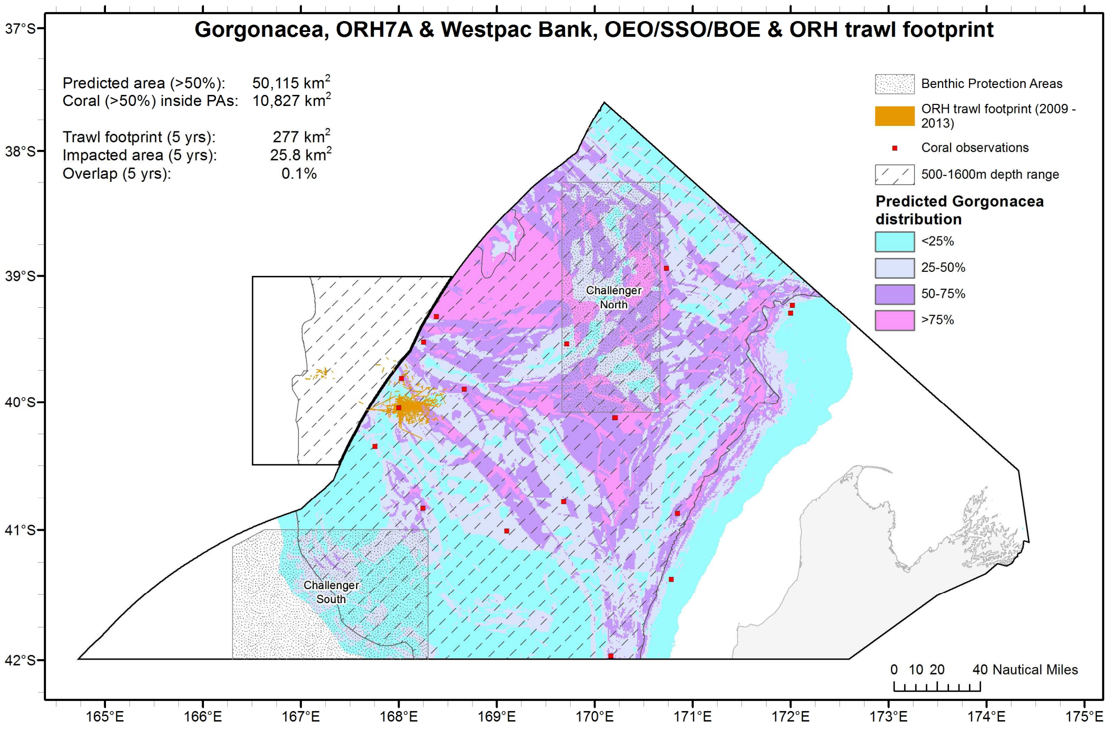

Figure B2: GOC Gorgonacea (all records, selected genera include the Precious coral Corallidae (*Corallium* and *Hemicorallium)* and selected Primnoids and Plexaurids (sea fans).

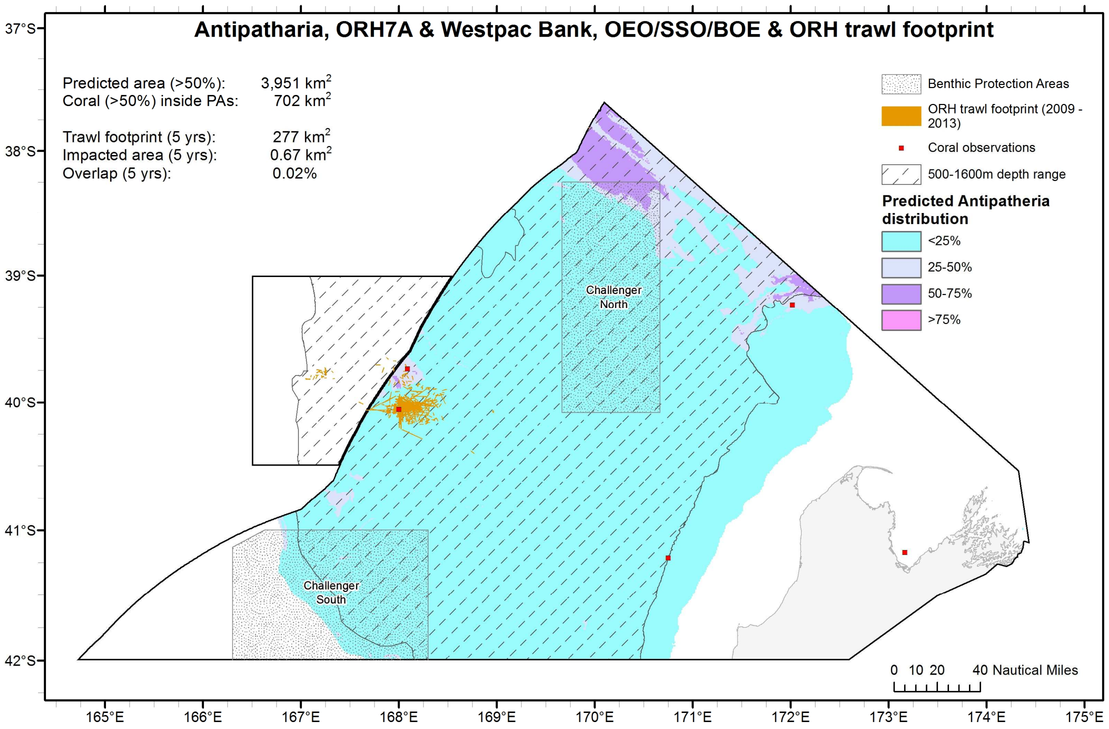

Figure B3: COB Antipatharia (Order level, all records).

Appendix C: Distribution maps for Protected (ETP) coral species – ORH3B NWCR

Predicted and observed distribution maps for Protected (ETP) coral species for the ORH fishery region ORH3B Northwest Chatham Rise (NWCR) sub-area shown relative to the combined orange roughy and oreo, smooth oreo, black oreo target trawl footprint between 500 and 1600 m, and for the last 5 year period (2008-09 to 2012-13). Also shown are the Seamount Closures, Benthic Protection Areas, and Large Marine Reserves. ETP observed coral distributions (1 km^2 grid), are superimposed as red squares on predicted distributions, together with the trawl footprint. The predicted distributions are illustrated using a 0-25%, 25-50%, 50-75% and 75-100% probability of occurrence scale. Summary metrics are illustrated on the figures. Figures C1-C3.

List of Figures C1-C13: Distribution maps for ORH3B NWCR sub-area

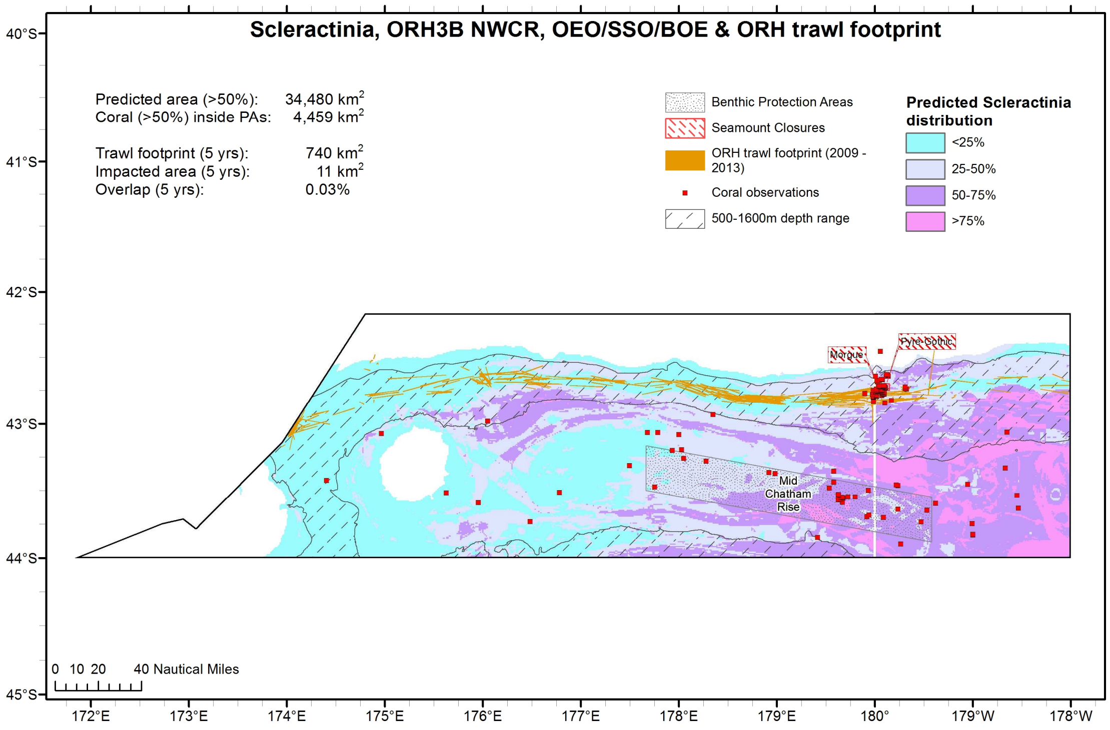

Figure C1: SIA - CBR Scleractinian stony branching corals *(Goniocorella dumosa*, *Solenosmilia variabilis*, *Enallopsammia rostrata*, *Madrepora oculata*) combined.

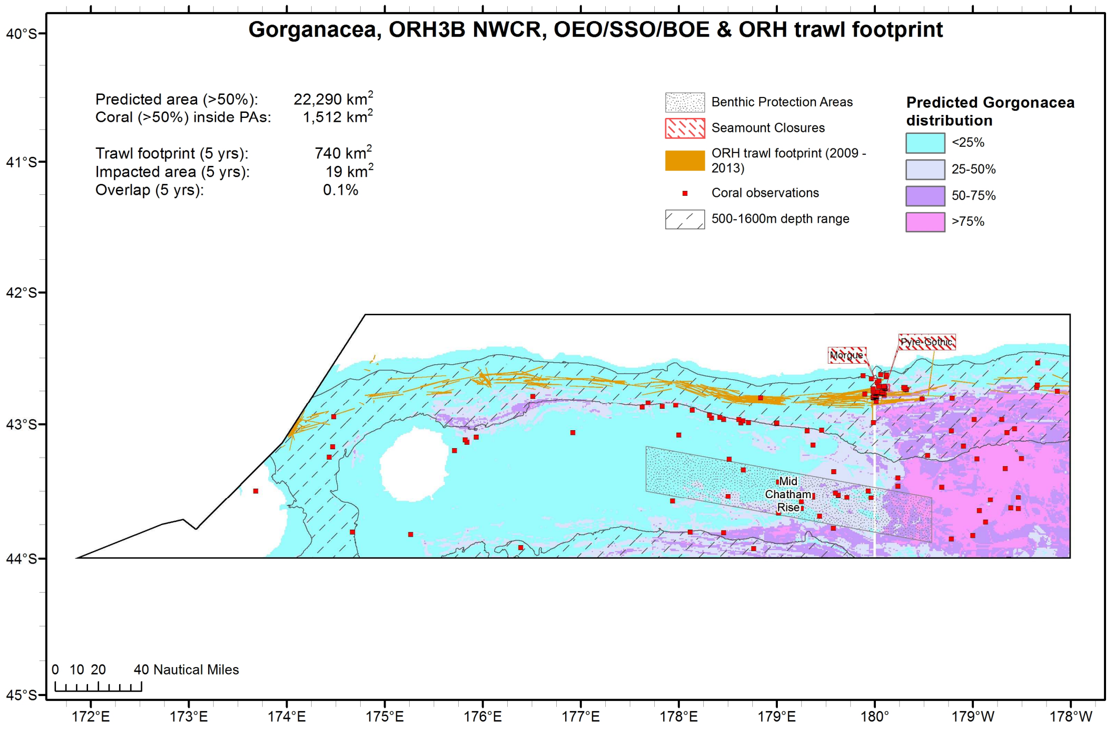

Figure C2: GOC Gorgonacea (all records, selected genera include the Precious coral Corallidae (*Corallium* and *Hemicorallium)* and selected Primnoids and Plexaurids (sea fans).

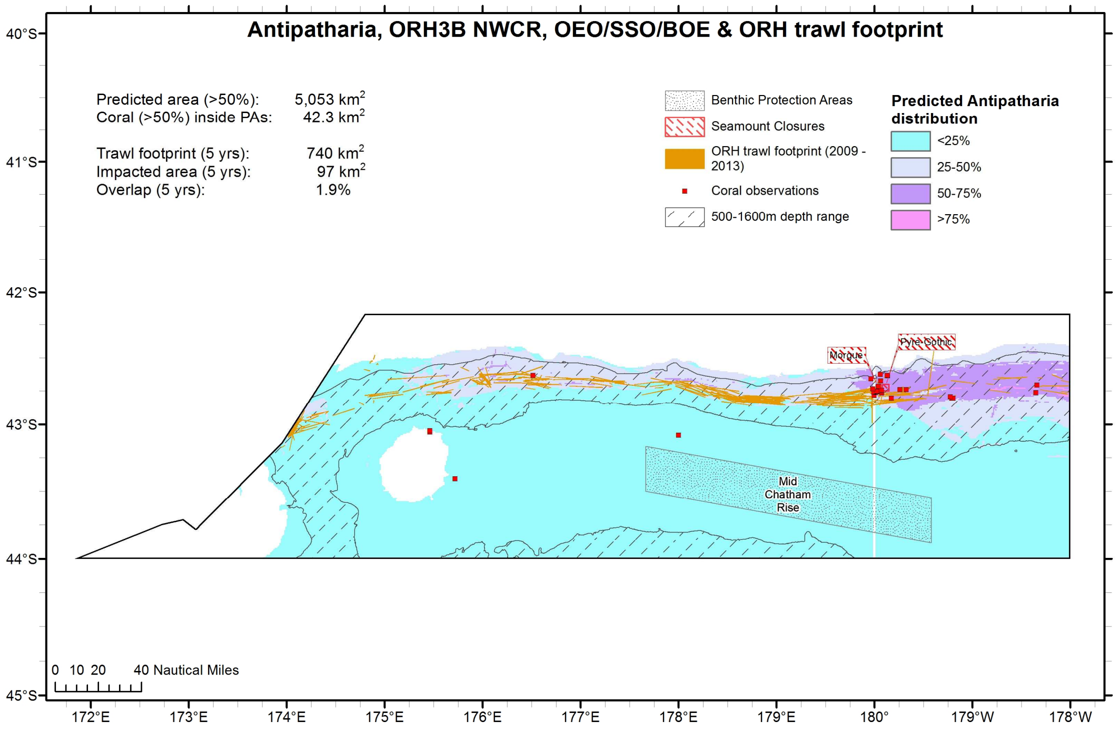

Figure C3: COB Antipatharia (Order level, all records).

Appendix D: Distribution maps for Protected (ETP) coral species – ORH3B ESCR (East of 179°30'W)

Predicted and observed distribution maps for Protected (ETP) coral species for the ORH fishery region ORH3B East & South Chatham Rise (East of 179°30'W)
(ESCR) shown relative to the combined orange roughy and oreo, smooth oreo, black oreo target trawl footprint between 500 and 1600 m, and for the last 5 year period (2008-09 to 2012-13). Also shown are the Seamount Closures, Benthic Protection Areas, and Large Marine Reserves. ETP observed coral distributions (1 km^2 grid), are superimposed as red squares on predicted distributions, together with the trawl footprint. The predicted distributions are illustrated using a 0-25%, 25-50%, 50-75% and 75-100% probability of occurrence scale. Summary metrics are illustrated on the figures. Figures D1-D3.

List of Figures D1-D13: Distribution maps for ORH3B East & South Chatham Rise (East of 179°30'W)

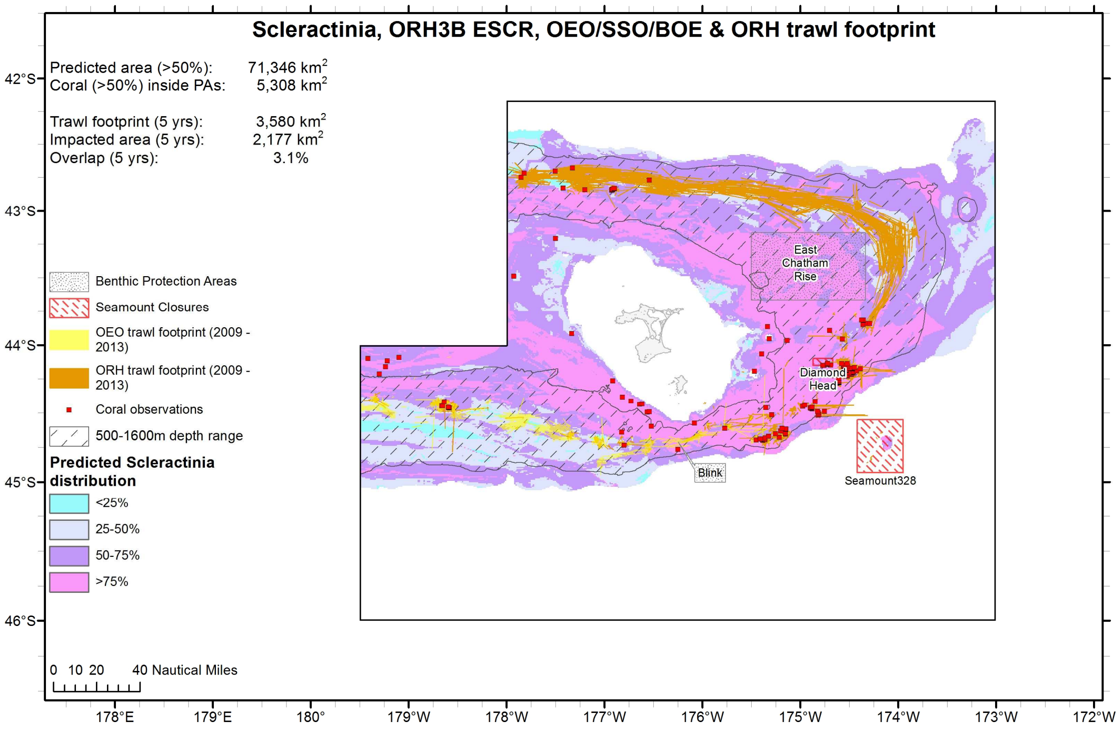

Figure D1. SIA - CBR Scleractinian stony branching corals (*Goniocorella dumosa, Solenosmilia variabilis, Enallopsammia rostrata, Madrepora oculata*) combined.

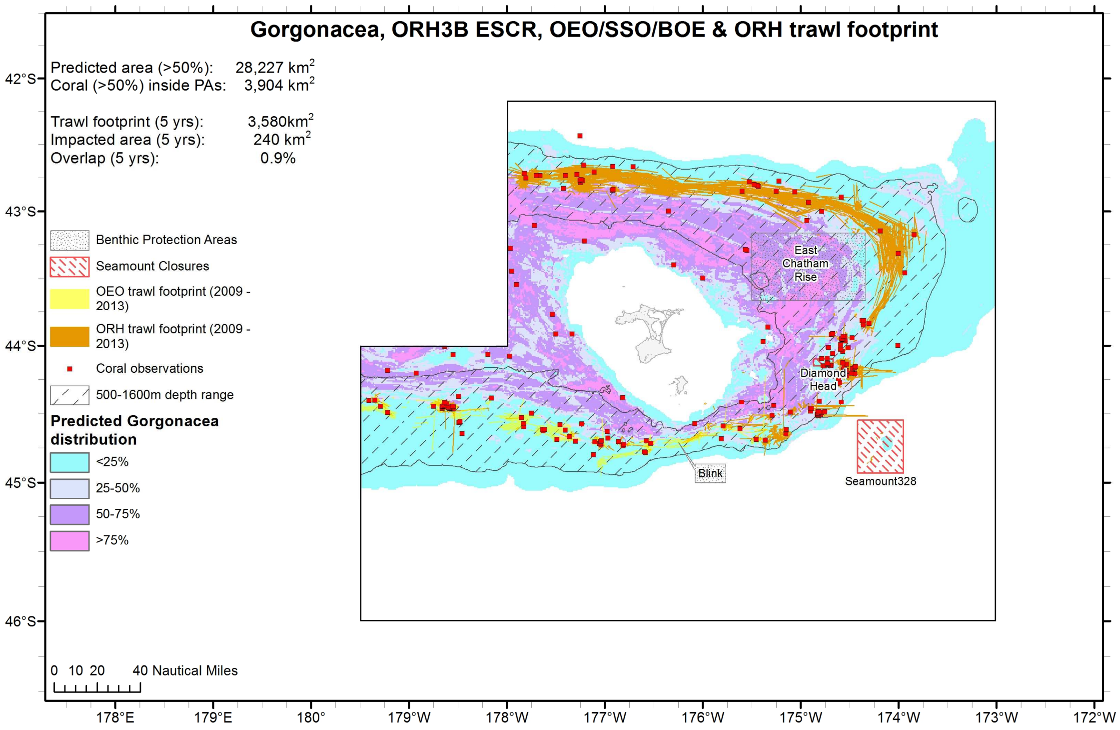

Figure D2. GOC Gorgonacea (all records, selected genera include the Precious coral Corallidae (*Corallium* and *Hemicorallium*) and selected Primnoids and Plexaurids (sea fans).

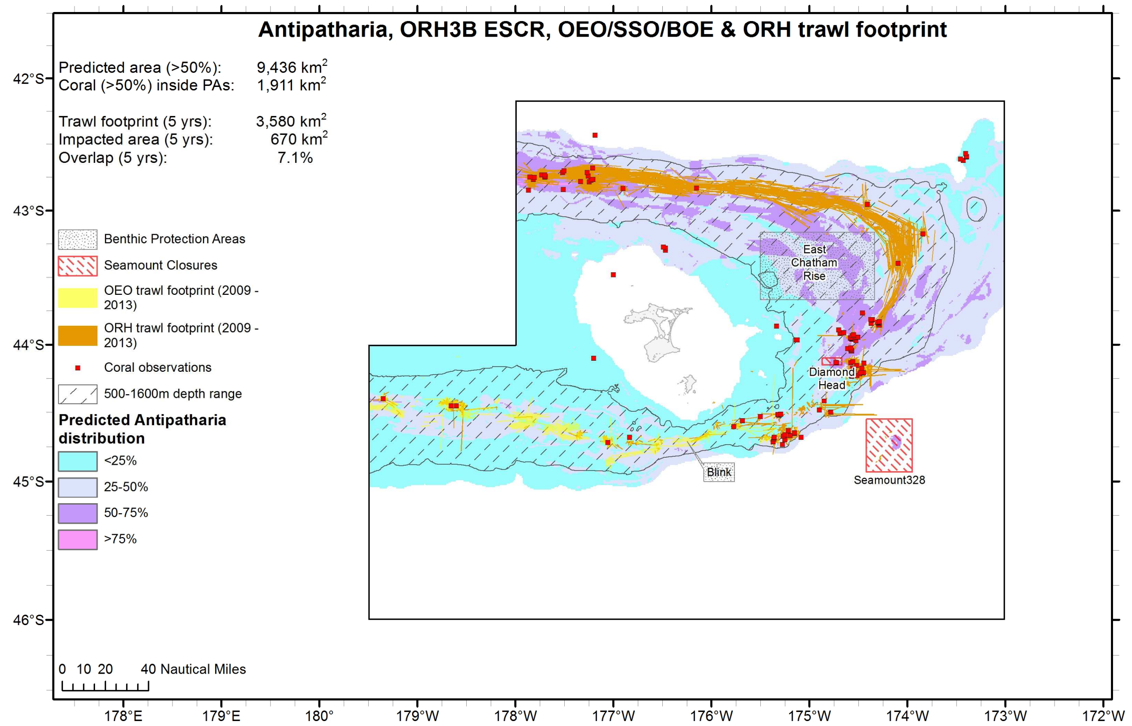

Figure D3. COB Antipatharia (Order level, all records).

Appendix E: Coral distribution plots – Kermadec Bioregion within the EEZ

Predicted and observed distribution maps for Protected (ETP) coral species for the EEZ Bioregion shown relative to the combined orange roughy and oreo, smooth oreo, black oreo target trawl footprint between 500 and 1600 m, and for the last 5 year period (2008-09 to 2012-13). Also shown are the Seamount Closures, Benthic Protection Areas, and Large Marine Reserves. ETP observed coral distributions (1 km^2 grid), are superimposed as red squares on predicted distributions, together with the trawl footprint. The predicted distributions are illustrated using a 0-25%, 25-50%, 50-75% and 75-100% probability of occurrence scale. Summary metrics are illustrated on the figures. Figures E1-E3.

List of Figures E1-E3: distribution maps for EEZ Bioregion

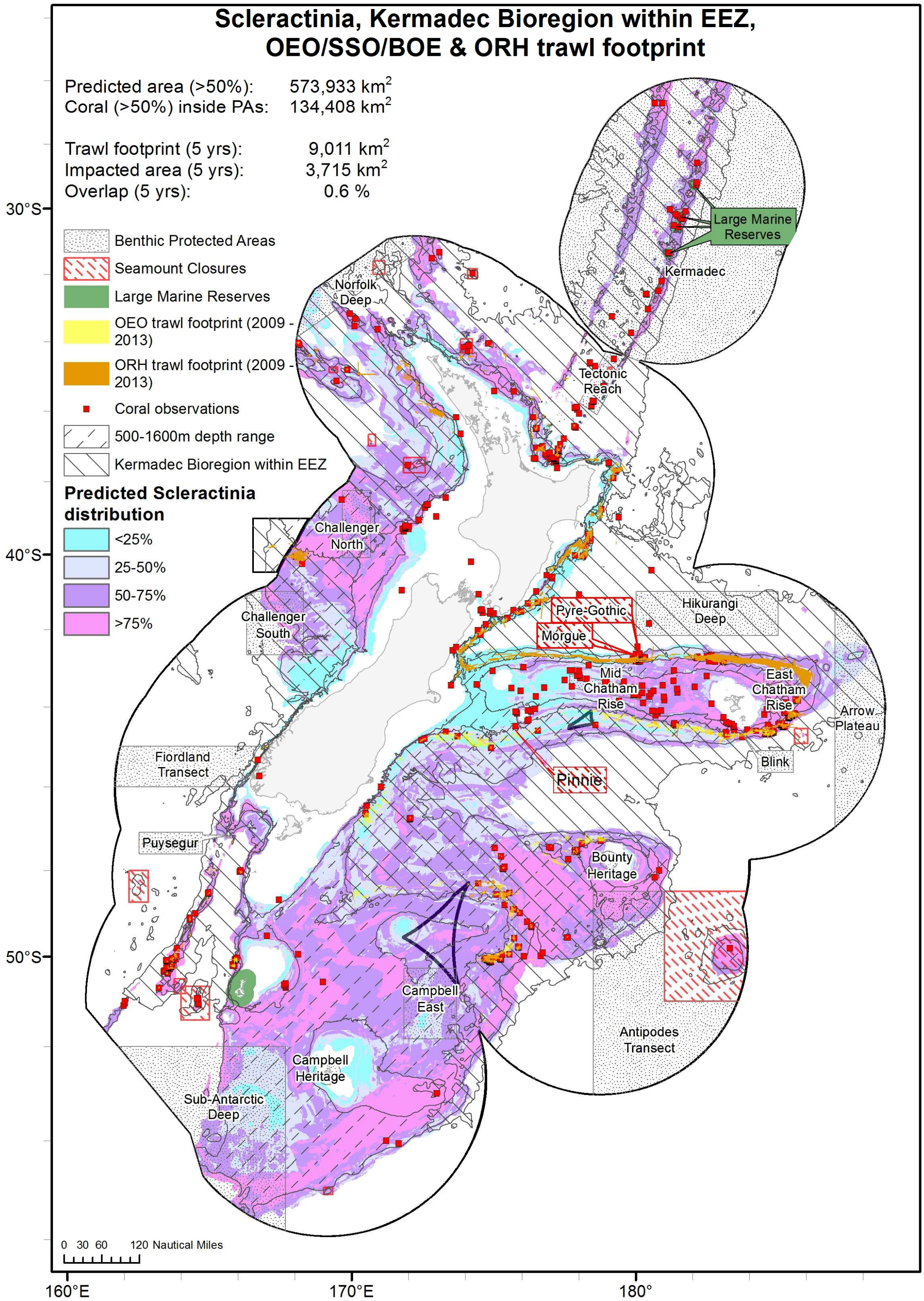

Figure E1. **SIA - CBR Scleractinian stony branching corals *(Goniocorella dumosa*, *Solenosmilia variabilis*, *Enallopsammia rostrata*, *Madrepora oculata*) combined.**

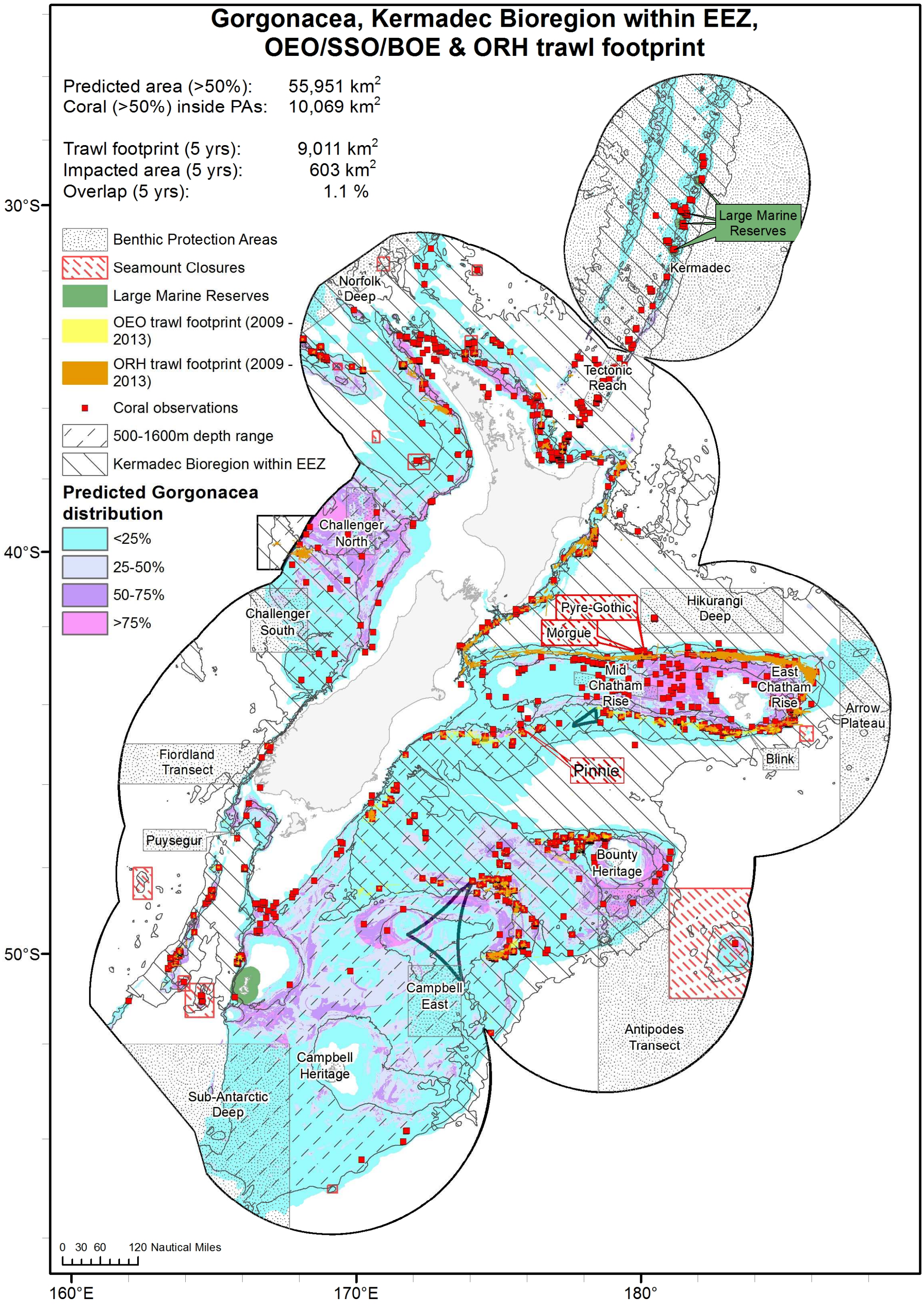

Figure E2. GOC Gorgonacea (all records, selected genera include the Precious coral Corallidae (*Corallium* and *Hemicorallium)* and selected Primnoids and Plexaurids (sea fans)

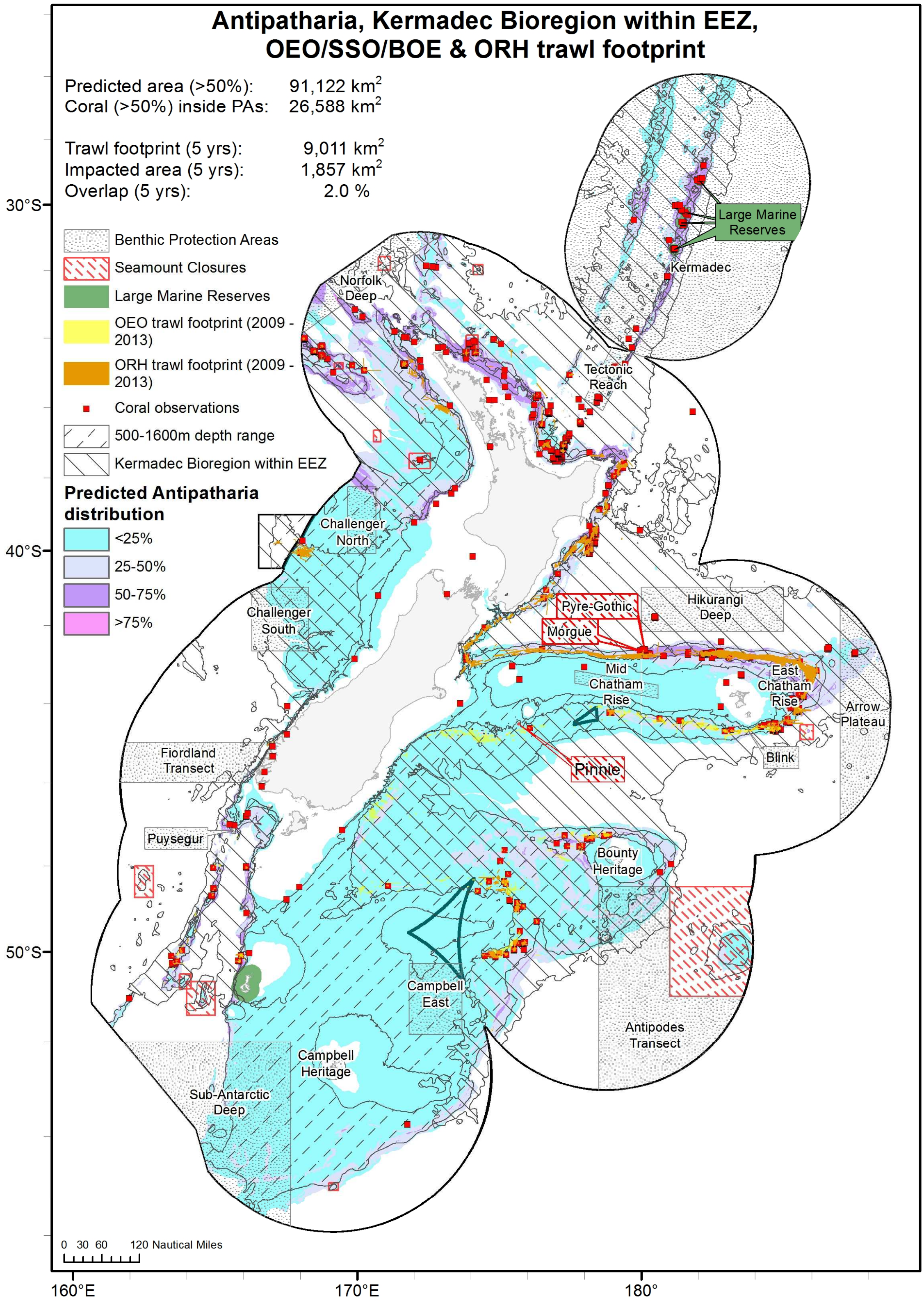

Figure E3. COB Antipatharia (Order level, all records)