Refined habitat suitability modelling for protected coral species in the New Zealand EEZ

Presentation to DOC CSP TWG

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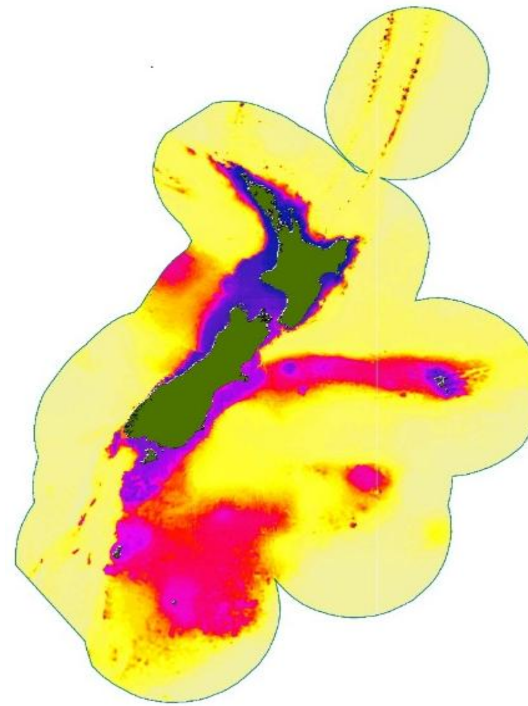


Objectives

1. Produce models of protected coral distribution refined using the most recent data.

2. Use refined predictive models to inform an assessment of their risk to commercial fishing gear. (focussed on the Chatham Rise)

Overview of analyses

- Boosted Regression Tree models of protected coral species distributions within the NZ EEZ were used to update the work of Baird et al. (2013) by examining corals in taxonomic rather than structural groups and incorporating new environmental variables.

- Coral groups modelled comprised four species of reef-building scleractinian (stony) corals, four genera of alcyonacean (gorgonian) corals, and four genera of antipatharian (black) corals.

- The new variables were seafloor saturation levels of aragonite and calcite; forms of calcium carbonate integral to the formation of the calcareous endoskeletons of cold-water corals.

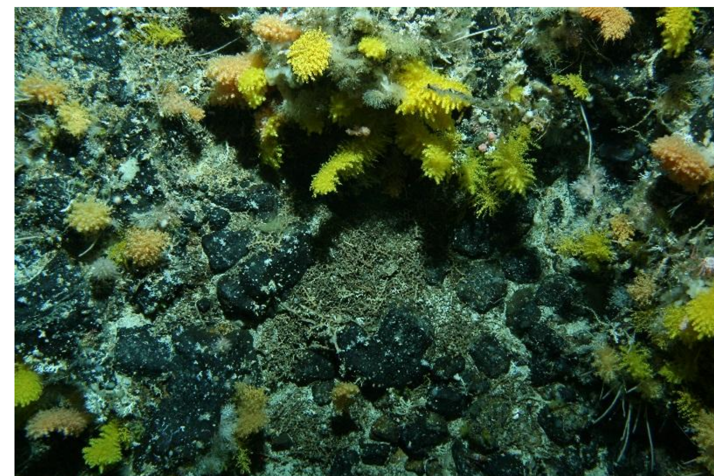
- The variables with the most influence across all of the models were dynamic topography and bottom temperature. Aragonite and calcite saturation levels had only moderate influence in most of the models

- Distribution patterns differed strongly between taxa, with models performing better for taxa modelled at a finer taxonomic resolution (eg Genus).

- The overlap of the EEZ-wide coral distribution with the trawl footprint was greatest for the bushy hard coral *Goniocorella dumosa*, and was also high on the Chatham Rise for most scleractinians and antipatharians. Substantial areas of refuge within the EEZ were predicted to exist for all taxa outside of the historic trawl footprint.

Coral taxa

- Selection of modelled taxa guided by the DoC Threatened Species List.
- **Scleractinians** – calcified skeletons (aragonite), form biogenic reefs
- **Alcyonaceans** (gorgonians) – also have calcified skeletons (mainly calcite), incl. bubblegum, primnoids, bamboo corals
- **Antipatharians** (black corals) – calcite skeletons



The threat status of all these corals are listed as nationally vulnerable, naturally uncommon, or data deficient (Freeman 2013)

Coral taxa

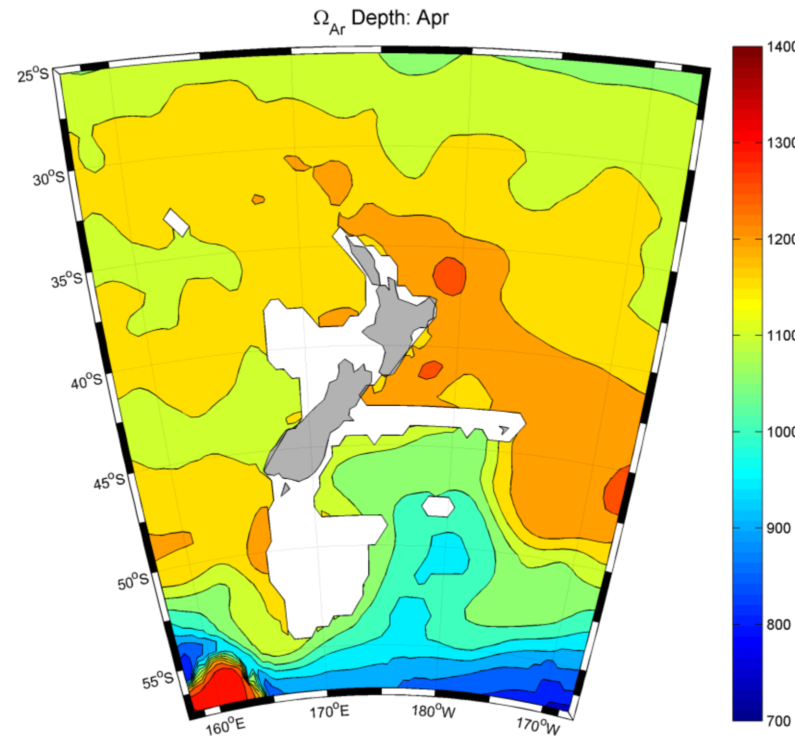
Order	Taxon	Description	Number of records
Scleractinia	Species combined: Enallopsammia rostrata Solenosmilia variabilis Goniocorella dumosa Madrepora oculata	Reef-like corals	779
	Enallopsammia rostrata	Reef-like coral	130
	Solenosmilia variabilis	Reef-like coral	311
	Goniocorella dumosa	Reef-like coral	212
	Madrepora oculata	Reef-like coral	126
Alcyonacea	Paragorgia spp.	Bubble-gum corals (tree-like)	98
	Primnoa spp.	Primnoid sea-fans (tree-like)	73
	Genera combined: Keratoisis spp. Lepidisis spp.	Bamboo corals (tree-like)	241
Antipatharia	All species	Black corals (tree-like)	711
	Bathypathes spp.	Black coral (tree-like)	75
	Dendrobathypathes spp.*	Black coral (tree-like)	8
	Dendropathes spp.*	Black coral (tree-like)	16
	Leiopathes spp.	Black coral (tree-like)	67
	Lillipathes spp.*	Black coral (tree-like)	3
	Parantipathes spp.	Black coral (tree-like)	56
	Triadopathes spp.	Black coral (tree-like)	27

Carbonate layers

NIWA developed algorithms to estimate carbonate parameters for the South Pacific (10N-60S) from commonly measured hydrographic parameters – temperature, salinity, & oxygen

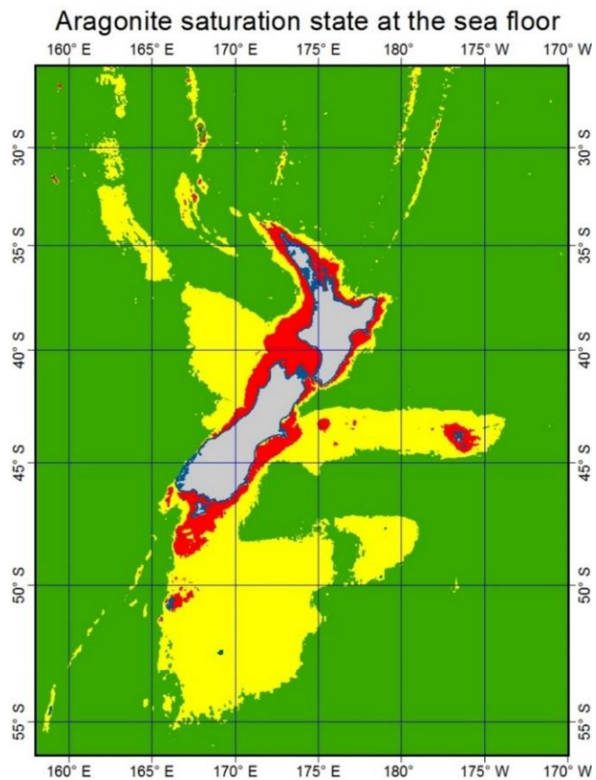
Reduction of carbonate ions with OA may limit the ability of corals to grow skeletons

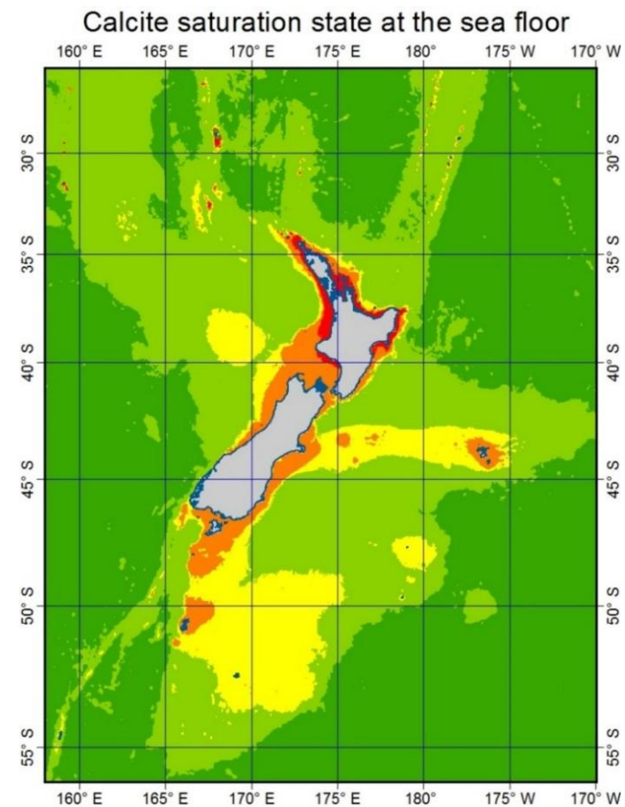
With a flow-on effect to other organisms that rely on the biogenic habitat provided by the corals



Aragonite Saturation Horizon (ASH) - showing depth variation

Carbonate layers





Other environmental variables

A sediment layer being developed for MBIE VME contract was also to be included – but was not available in time

Variable	Description and data source	nits	Reference
Depth bathy	Depth at the seafloor interpolated from contours generated from various bathymetry sources, including multi-beam and single-beam echo sounders, satellite gravimetric inversion, and others. 250 m grid.		CANZ (2008)
Seamount smt	Seamount positions recorded in New Zealand region.		Rowden et al. (2008), Mackay (2007)
Slope slope	Sea-floor slope was derived from neighbourhood analysis of the bathymetry data.		CANZ (2008), Hadfield et al. (2002)
Dissolved organic matter cdom	Modified Case 2 inherent optical property algorithm applied to modified Case 2 atmospheric corrected SeaWiFS ocean colour remotely sensed data for the New Zealand region.	aDOM (443) m^{-1}	Pinkerton et al. (2006)
Dynamic topography dynoc	Mean of the 1993-1999 sea surface height above geoid, corrected for geophysical effects in the New Zealand region. This variable was produced by CLS Space Oceanography Division.		AVISO http://www.aviso.oceanobs.com
Bottom water temperature	Modelled seafloor temperature based on global climatologies.	C	CARS (2009) (www.cmar.csiro.au/cars)
Tidal current speed tidalcurr	Maximum depth-averaged tidal current velocity estimated by interpolating outputs from the New Zealand region tide model.	s^{-1}	Walters et al. (2001), Hadfield et al. (2002)
Sea surface temperature gradient sstgrad	Smoothed annual mean spatial gradient estimated from 96 months of remotely sensed SeaWIFS data.	C km^{-1}	Uddstrom & Oien (1999), Hadfield et al. (2002)
Surface water primary productivity vpgm	Vertically generalised productivity model based on net primary productivity estimated as a function of remotely sensed chlorophyll, irradiance, and photosynthetic efficiency estimated from remotely sensed sea-surface temperature.	g C m^{-2} d^{-1}	Behrenfield & Falkowski (1997)
Particulate organic carbon flux poc	Particulate organic carbon flux described as a function of the production of organic carbon in surface waters, scaled to depth below the sea surface.	g $C_{org.}$ m^{-2} d^{-1}	Lutz et al. (2007)
Aragonite saturation state arag	Saturation state of aragonite at the seafloor based on multiple linear regression algorithms developed from measured alkalinity and DIC compared with hydrographic data.	aragonite	Bostock et al., 2013, Tracey et al., 2013
Calcite saturation state calc	Saturation state of calcite at the seafloor based on multiple linear regression algorithms developed from measured alkalinity and DIC compared with hydrographic data.	calcite	Bostock et al., 2013, Tracey et al., 2013

Methods

- Described to DOC CSP Technical WG in Feb 2014
- Predictive modelling with Boosted Regression Trees
- Environmental variables as used in Baird et al 2013
- Coral dataset as used in Baird et al 2013 (comprises verified and un-verified observer records plus research survey data) – 7731 ETP coral records
- Species "absence" data provided by "Benthic Stations" dataset (research survey data plus selected observer records) – 62 144 records
- Model depth limited to 200—2000 m
- Model resolution set to 1 km^2
- Comparison of predicted distributions with 20-year fisheries footprint data
- PSA risk assessment

Methods - Boosted Regression Trees

- One of a crop of recent “machine learning” methods – uses presence/absence data
- Can use variables of different types (e.g. binary, categorical, continuous), without transformations, and easily handles outliers and missing data
- Uses an algorithm to learn the relationship between the response and its predictors
- Recursive binary splits used 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
- The final model is a linear combination of many trees – equivalent to a regression model where each term in the model is a simple tree
- Can fit interactions between variables
- Uses cross-validation within the model to determine the optimal number of trees

Methods - Boosted Regression Trees

- Model arguments controlling the fit – learning rate and number of trees were optimised manually
- Tree complexity – the degree of variable interactions was set to a moderate level (3)
- Presence and absence data strongly biased towards fishing grounds and other areas of scientific interest.
- Absences not "true" absences as sampling may encounter but not catch a coral, and the entire 1 km^2 cell is not sampled
- Random background data trialled but not used in models
- Presence records weighted by 1/n where n = the number of records in each 1km^2 cell
- Absence records given equal weight – at a value such that the sum of presence weights was equal to the sum of absence weights.

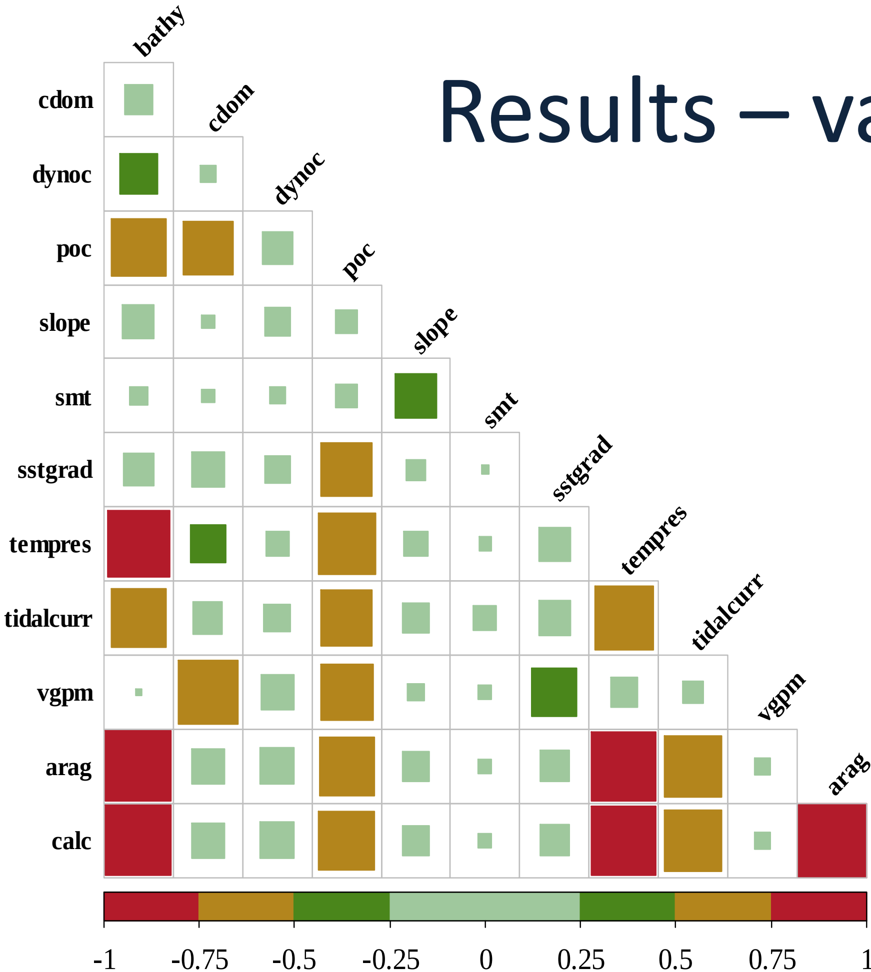
Previous models

- Tracey et al. (2011). BRT models for 5 reef-forming scleractinians. Depth and seamount were the primary predictor variables. Carbonate saturation data was not available.
- Baird et al. (2013) used the same coral dataset and env vars, but not carbonate saturation, and modelled in structural groups ("reef-like", "tree-like", "whip-like", "solitary/small"). Recommended that future models should focus on individual species or genera and include Carbonate saturation data when it becomes available.
- Recent global cold-water coral models have indicated the importance of carbonate concentration in distribution patterns (Davies & Guinotte 2011, Yesson et al. 2012)

Fisheries trawl footprint

- The 20-year (1989–90 to 2000–09) footprint as used in Baird et al. (2013)
- Determination of the overlap between habitat suitability plots and the trawl footprint requires selection of a probability cut-off
- Simply selecting 50% is not appropriate due to the inadequacy of the pseudo-absence data used in the models.
- Separate cut-offs for each taxon – based on the mean of the predicted probabilities across the entire modelled area. Generally is <50%, tends to ensure that presence locations are included
- Given the lack of certainty in the area of presence, overlaps were characterised into three broad groups:
  - Low (<25% overlap)
  - Medium (25-50% overlap)
  - High (>50% overlap)

Results – variable selection



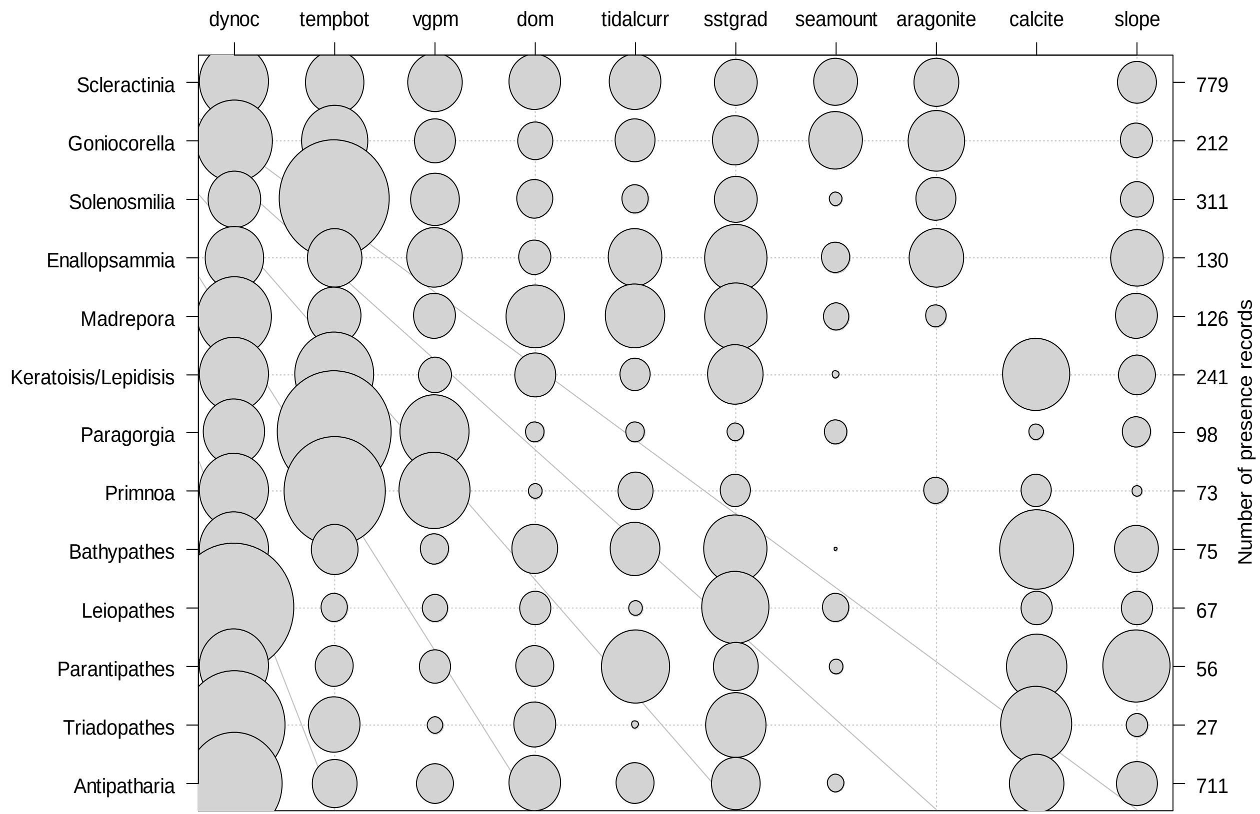
Correlations between variables (within EEZ and 200—2000 m model depth range)

- Bathy excluded
- Poc excluded
- Calcite and aragonite strongly correlated

Model performance

- Measured using AUC (area under the Receiver Operating Characteristic (ROC) curve)
- A value of 0.5 indicates a model with no discriminatory power; 0.7 = “fair”, 0.8 = “acceptable”, 0.9 = “good”.
- The AUC values were > 0.9 in all models except for Scleractinia combined (0.68), *Paragorgia* spp. (0.88) and *Primnoa* spp. (0.89).

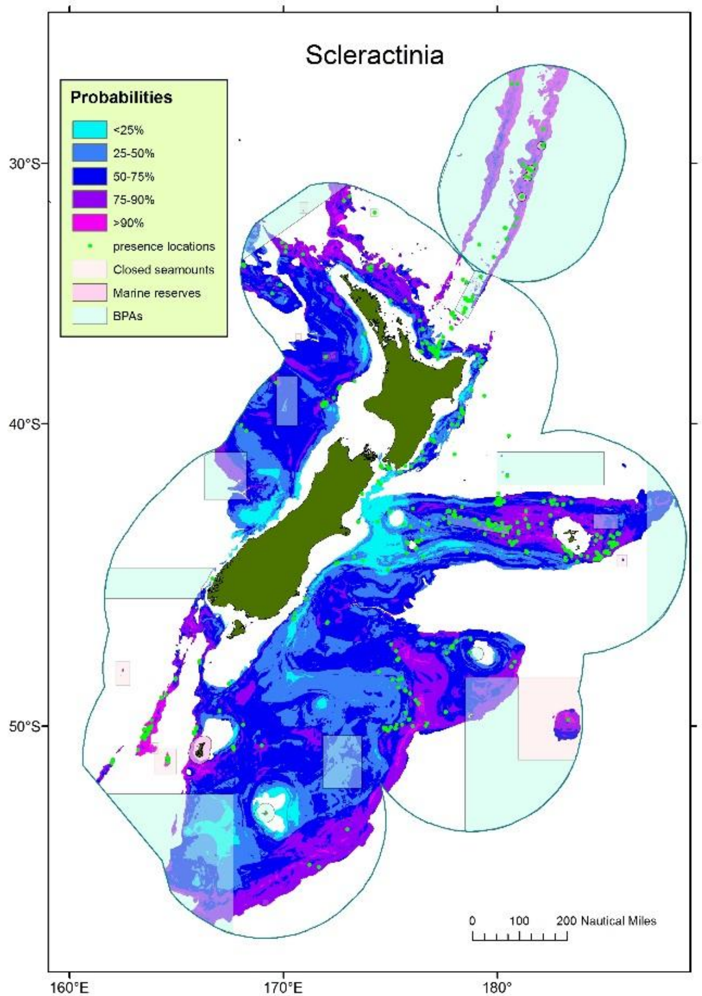
Model results

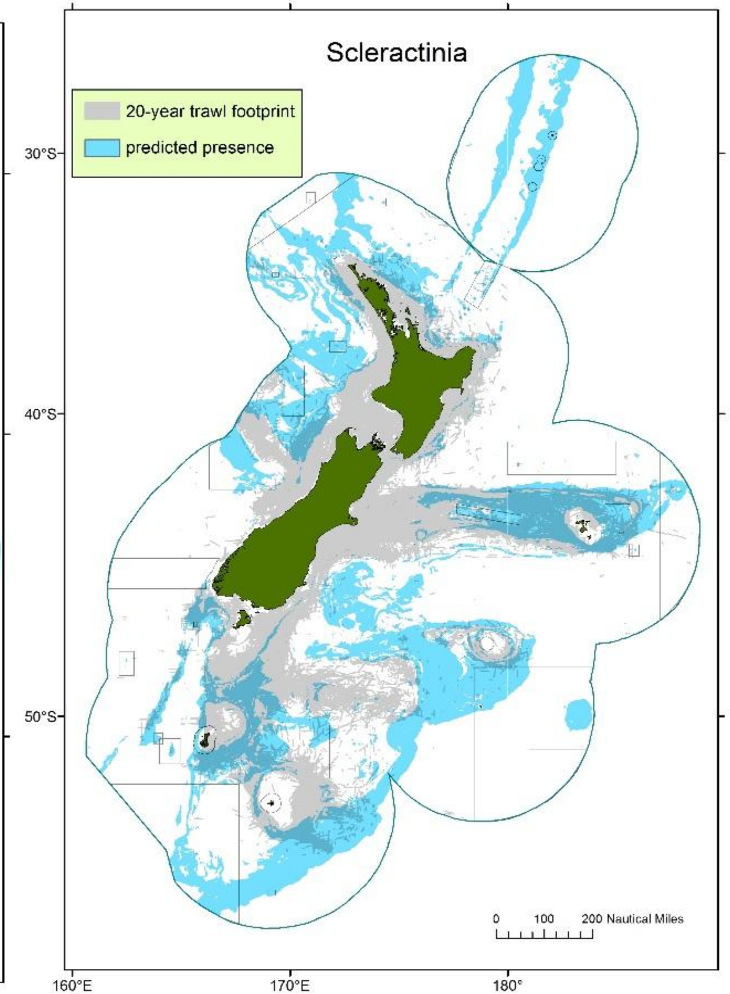


Main variables: Dynoc & Temp

Widespread distribution, similar to the predictions of Baird et al (2013)

Substantial overlap with trawl footprint, esp. Chat. Rise

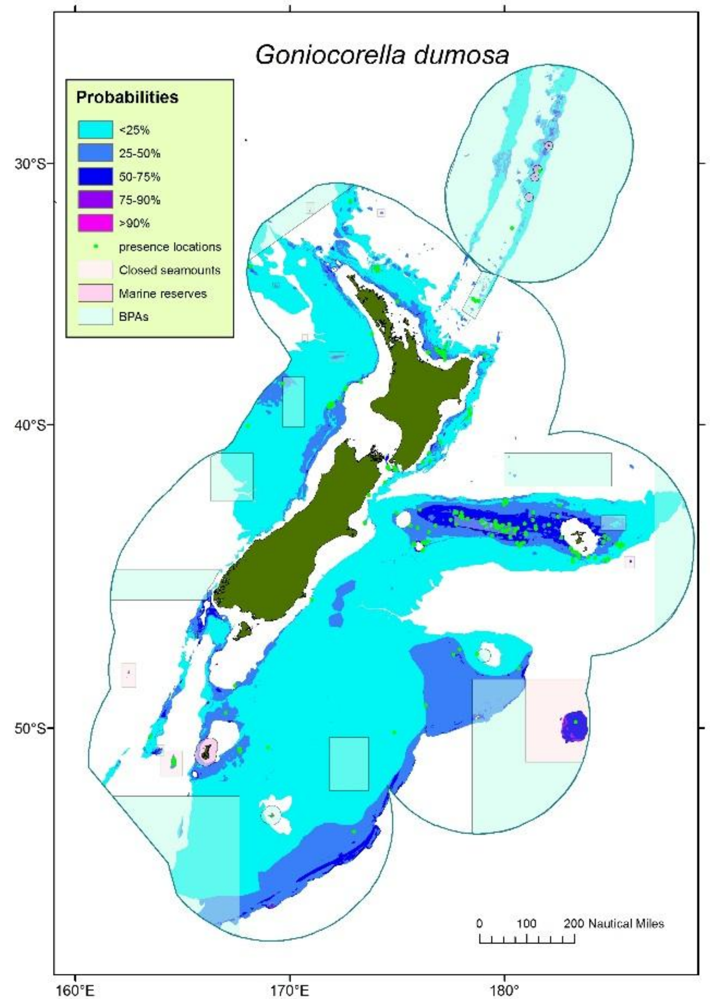


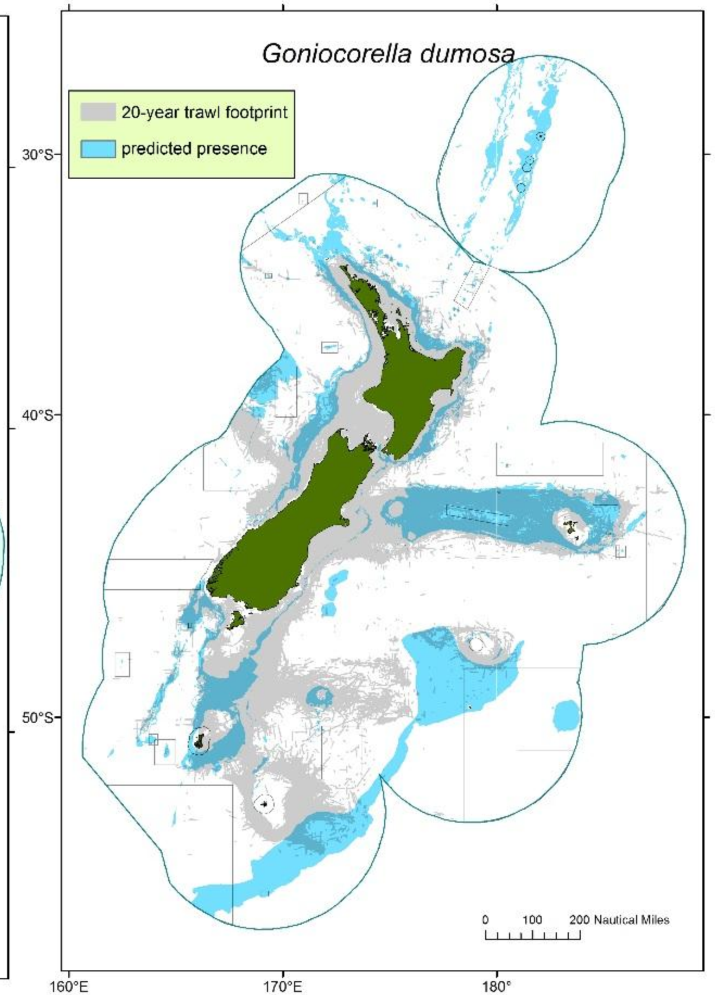


Main variables:
Dynoc & Temp

More restricted distribution, esp shallow parts of Chat Rise.

Substantial, widespread overlap with trawl footprint

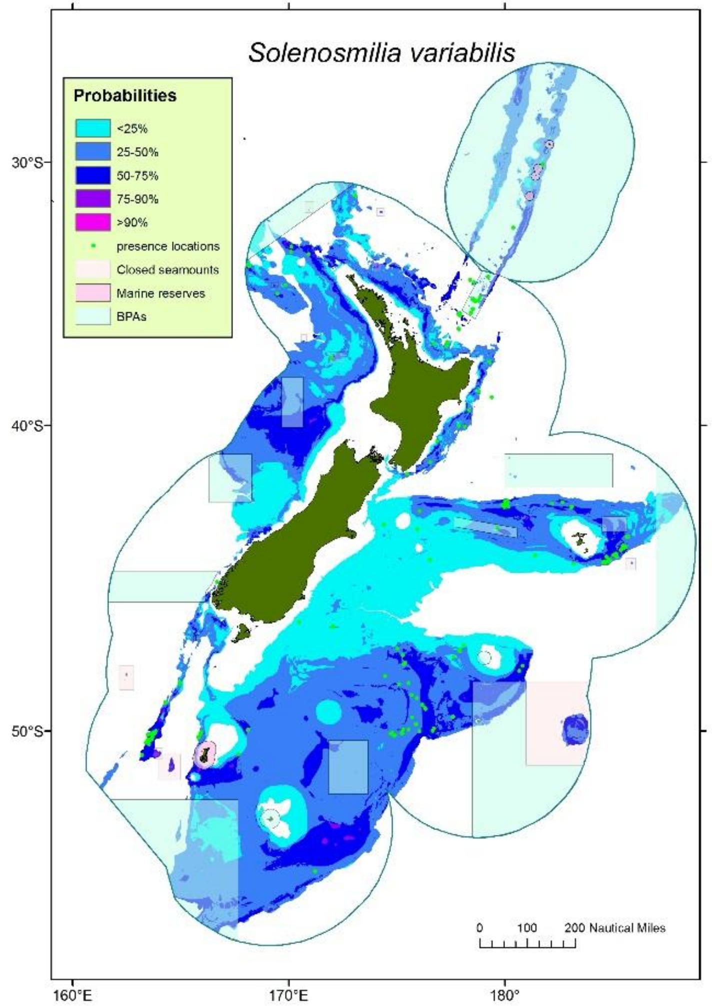


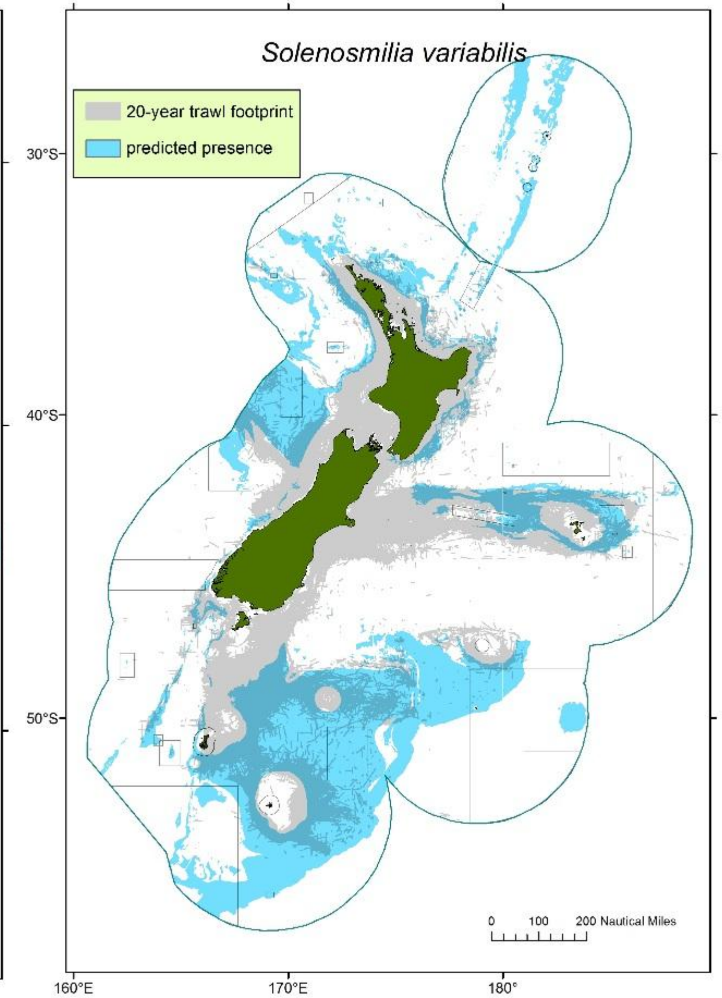


Main variables: Temp & Dynoc

Widespread but patchy distribution.

Substantial overlap with trawl footprint

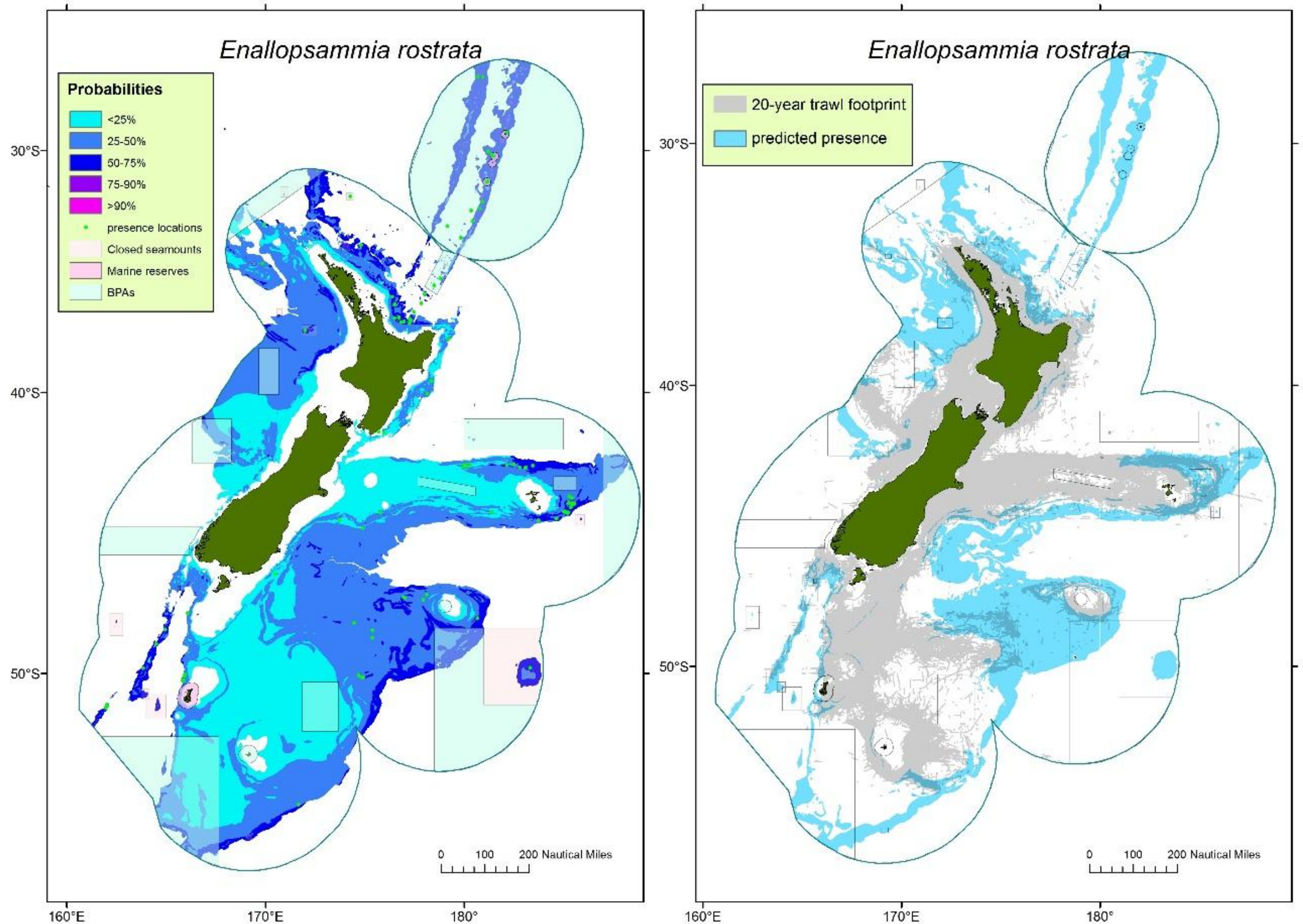




Main variables: SSTGrad & Dynoc

Widespread but patchy distribution.

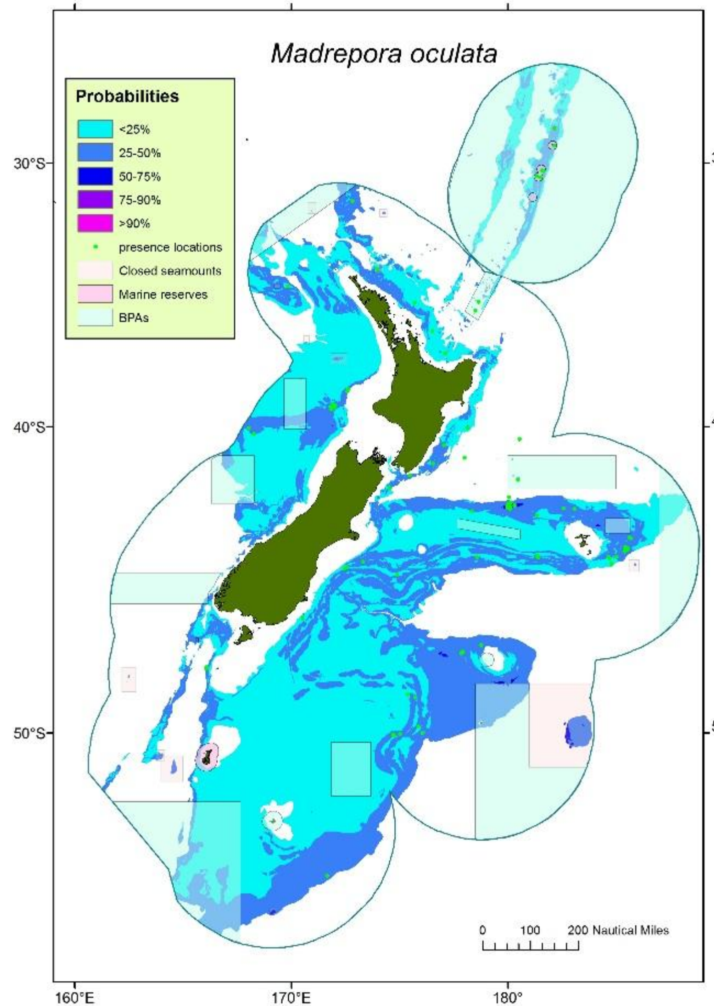
Low to moderate overlap with trawl footprint – refuges in deeper water around Chatham Rise

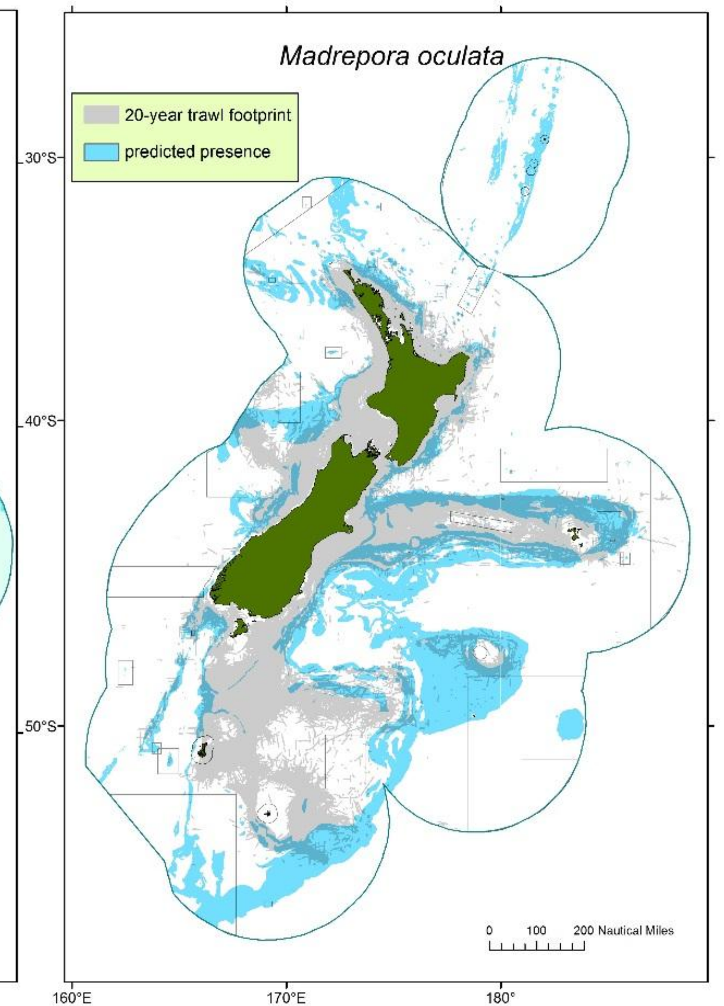


Main variables: Dynoc & SSTGrad

Restricted distribution, fringes of Chat Rise and sub-Antarctic.

Moderate to high overlap with trawl footprint – refuges in deeper water

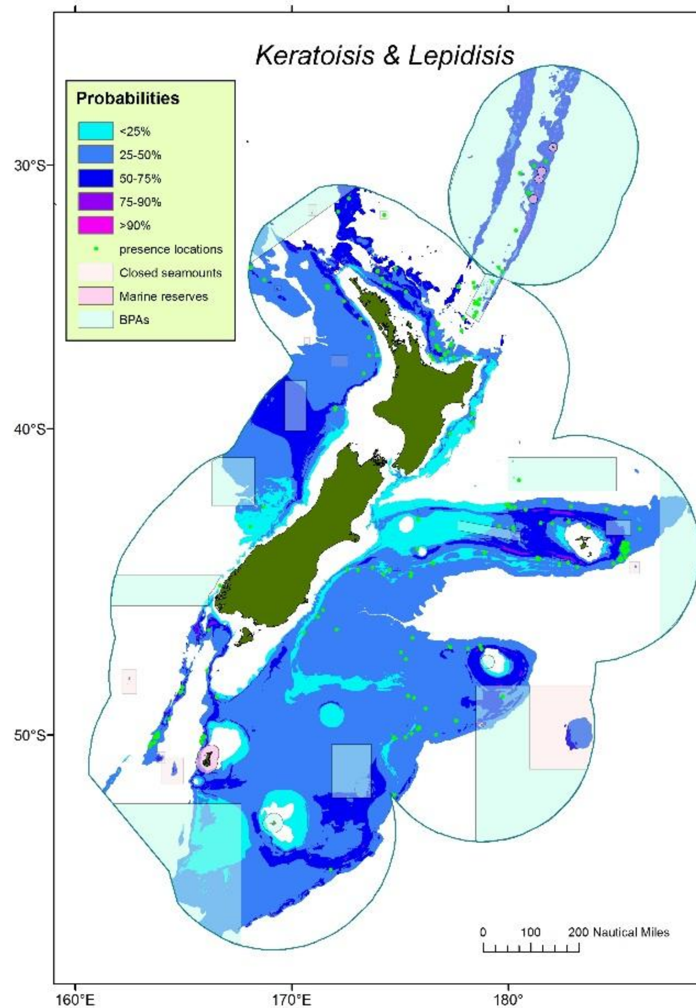


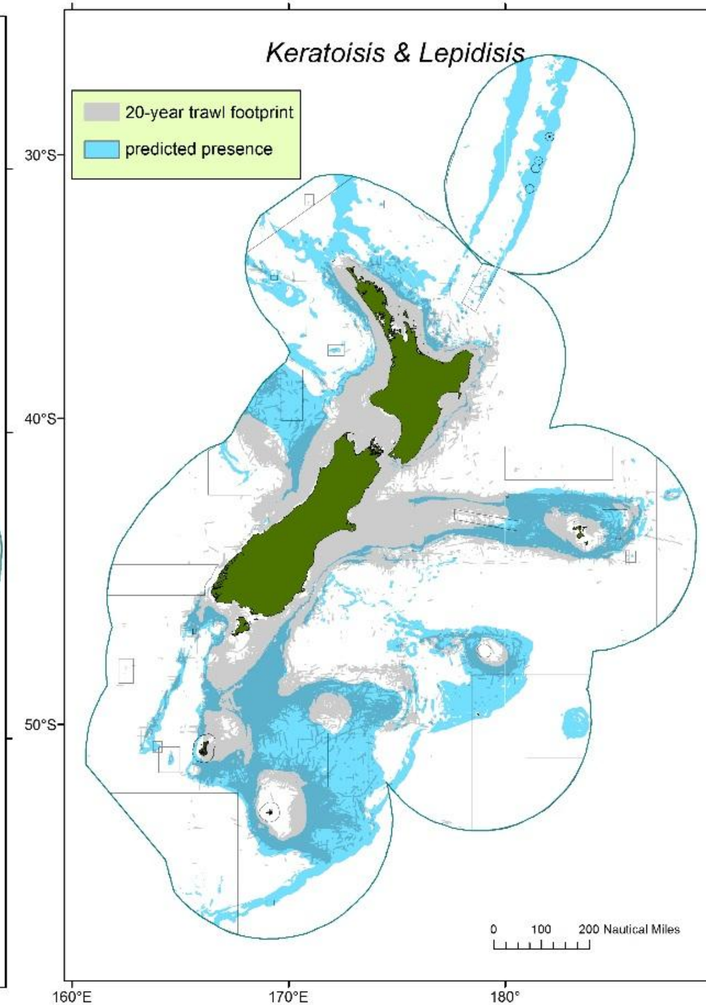


Main variables: Temp & Dynoc

Widespread, esp in eastern Chat Rise, parts of the sub-Antarctic and northern features.

Moderate to high overlap with trawl footprint – refuges in deeper water

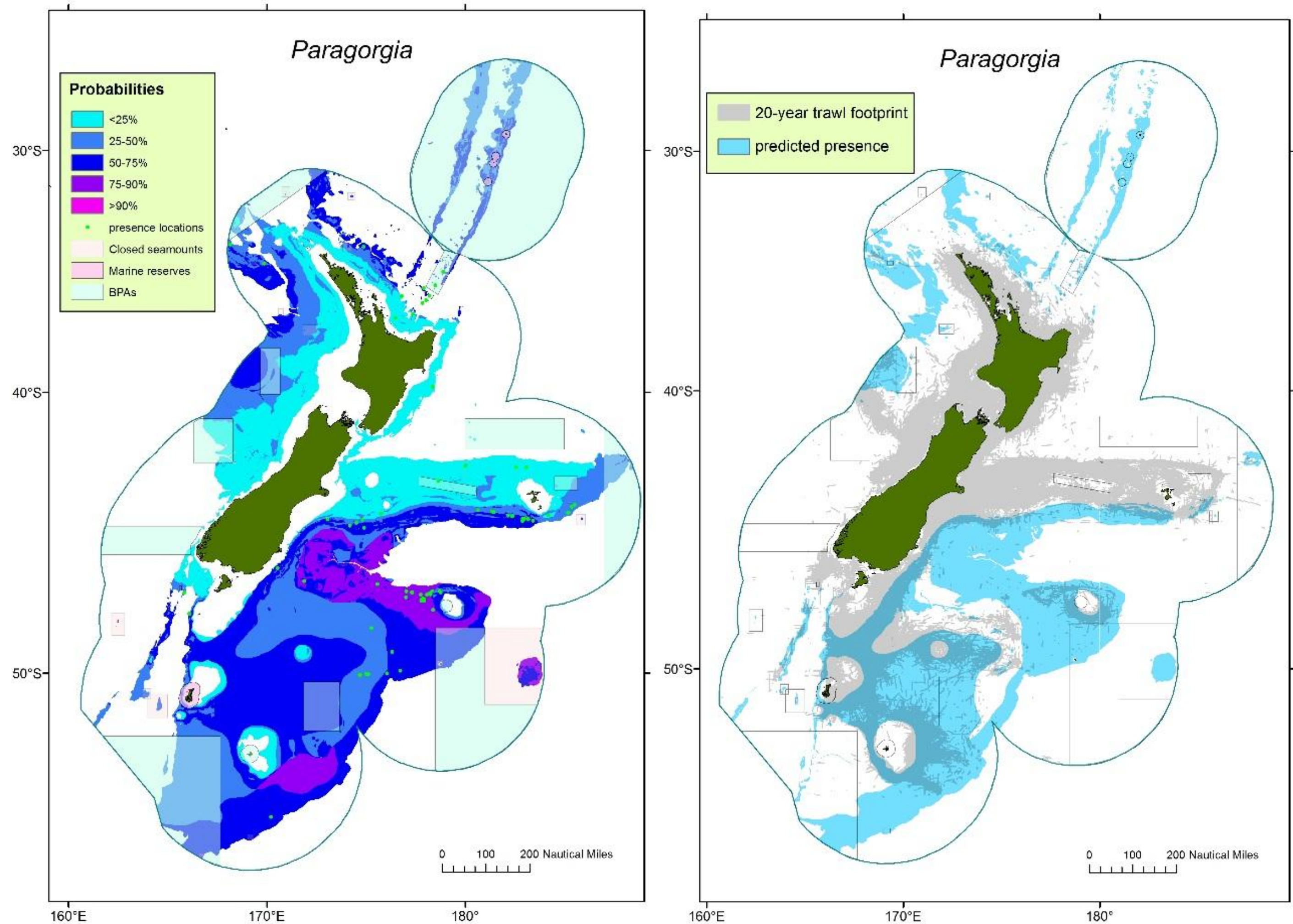




Main variables: Temp & VGPM

Highest probabilities around sub-Antarctic, esp Bounties region.

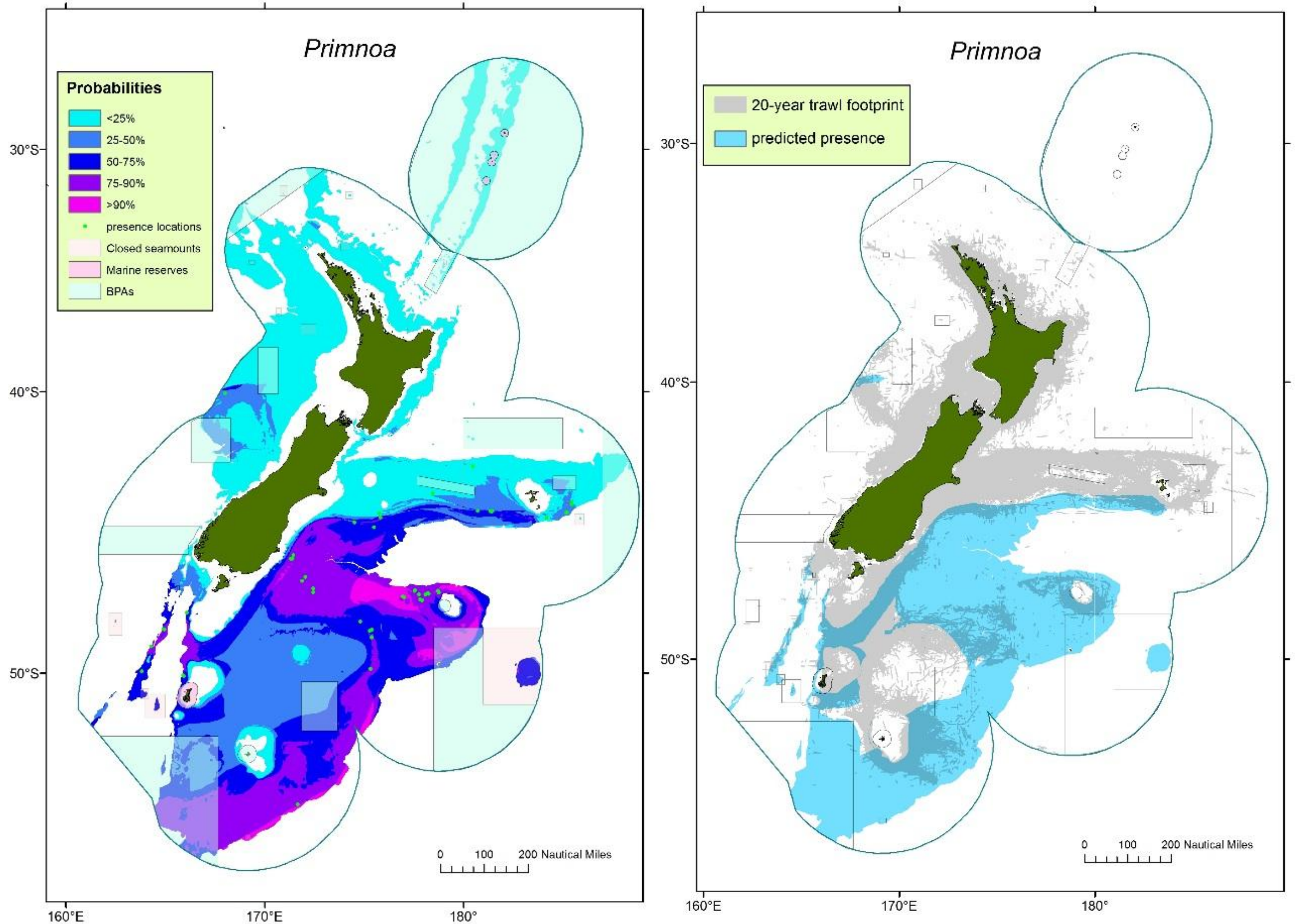
Moderate overlap with trawl footprint – but low on Chat Rise



Main variables: Temp & VGPM

Similar distribution to *Paragorgia* but low probabilities in north and most of Chat Rise.

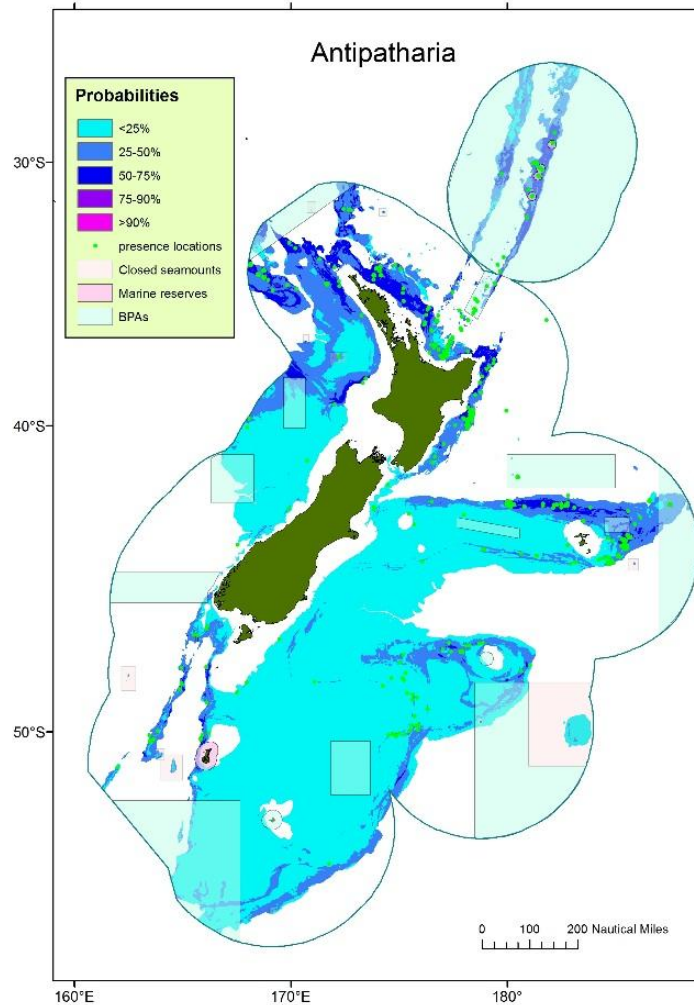
Low overlap with trawl footprint – moderate on Chat Rise

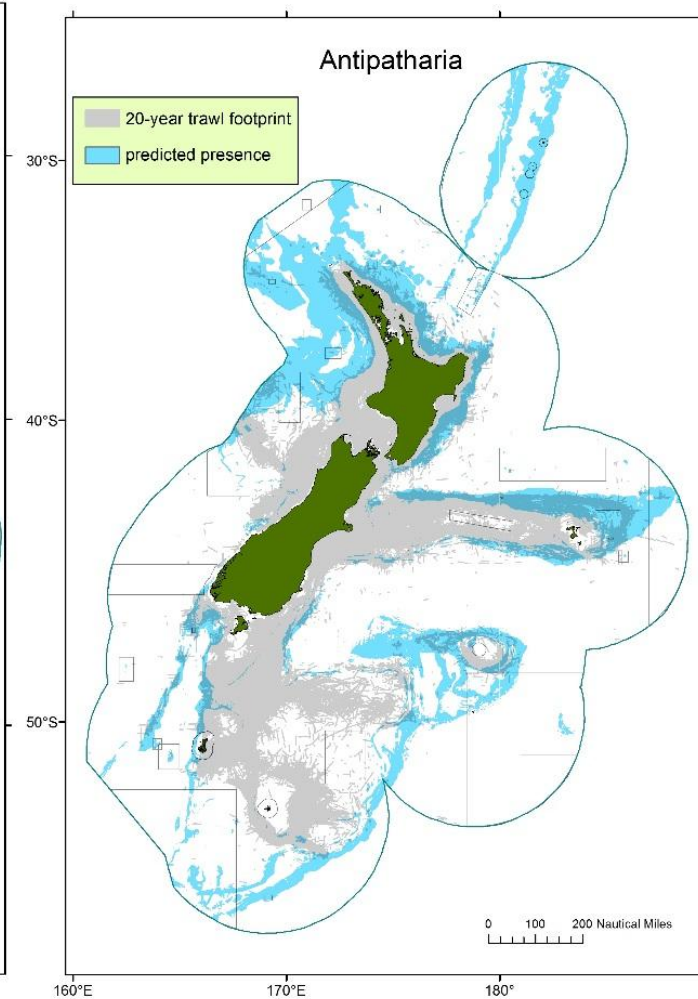


Main variables: Dynoc & calcite

Low probabilities in most areas, higher in NE Chat Rise and northern features.

Low overlap with trawl footprint overall – but high on Chat Rise

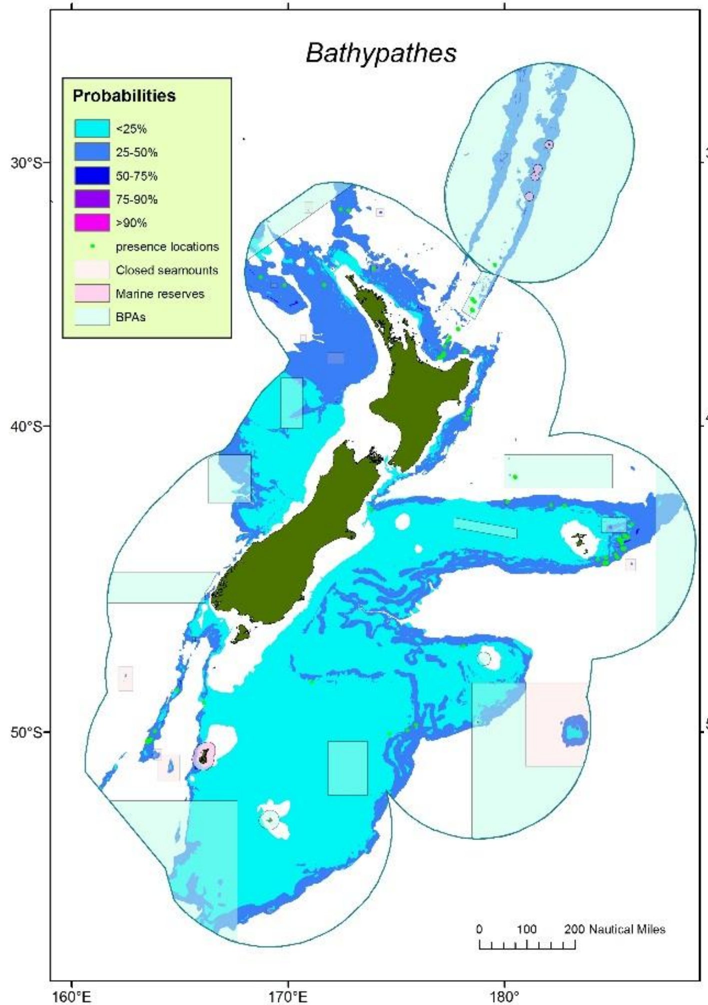


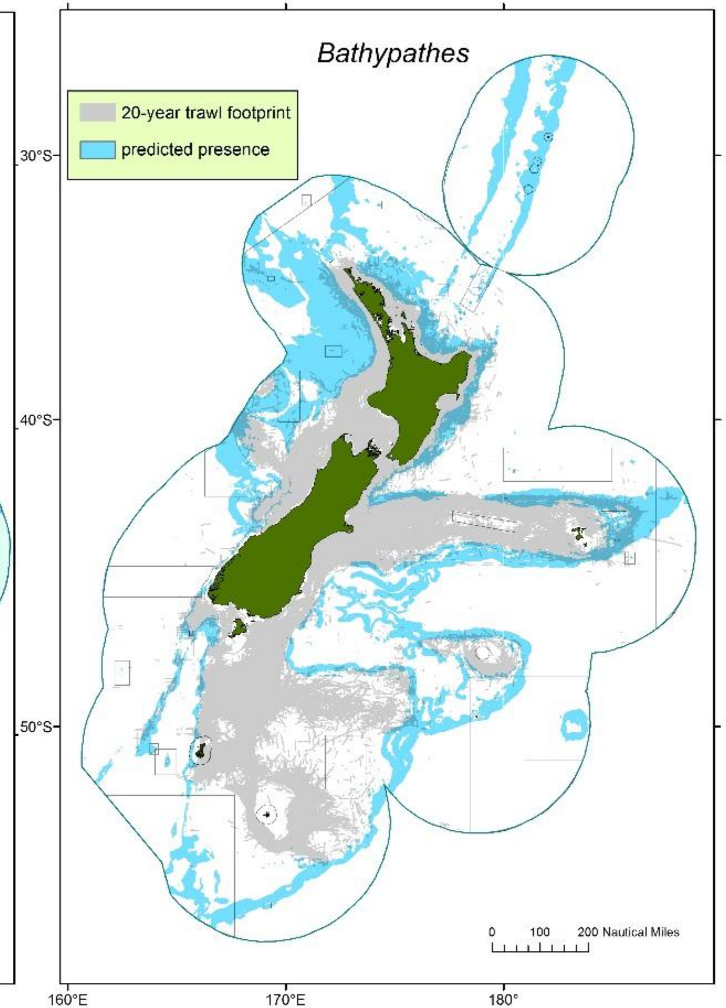


Main variables: Calcite & Dynoc

Similar distribution to Antipatharia.

Low overlap with trawl footprint – but moderate on Chat Rise

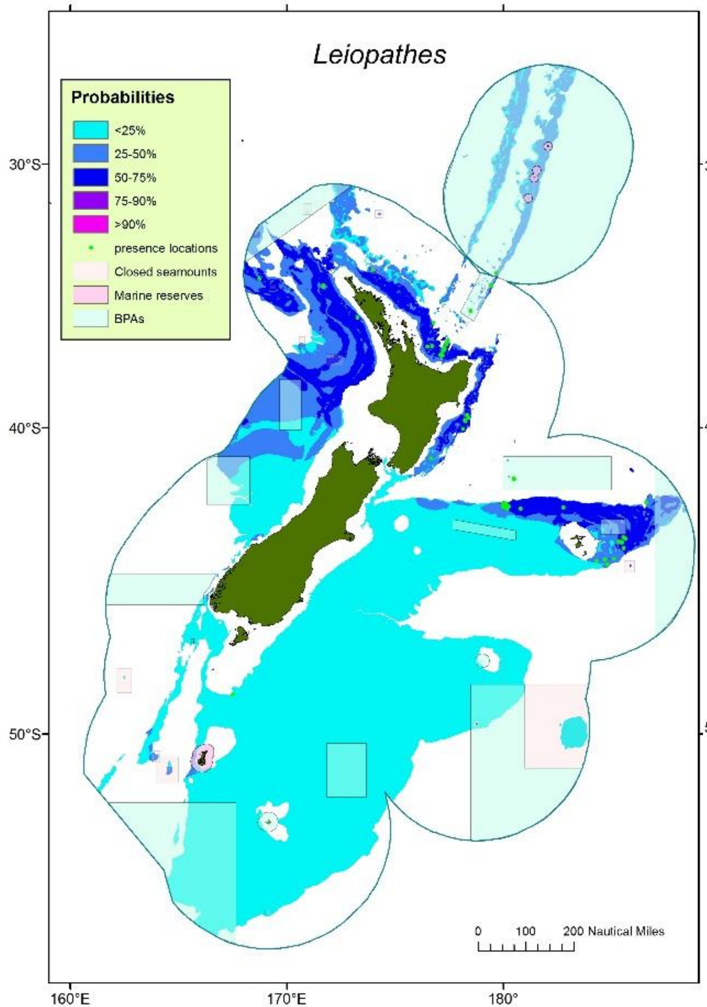


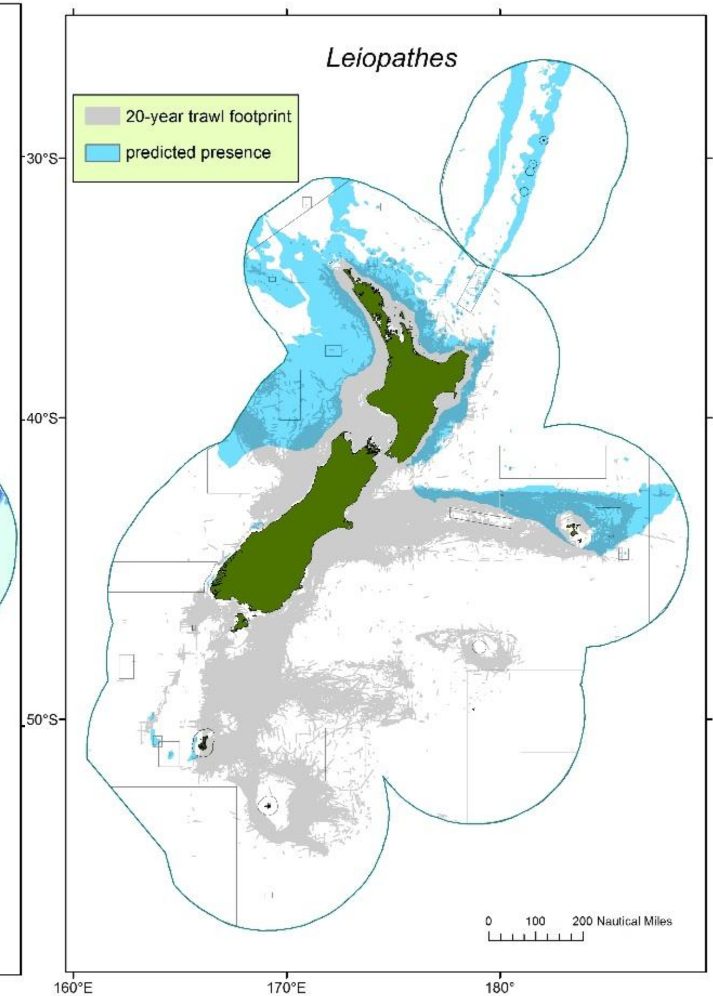


Main variables: Dynoc & SSTGrad

Distribution restricted mainly to northern areas plus NE Chat Rise.

Moderate overlap with trawl footprint – high on Chat Rise

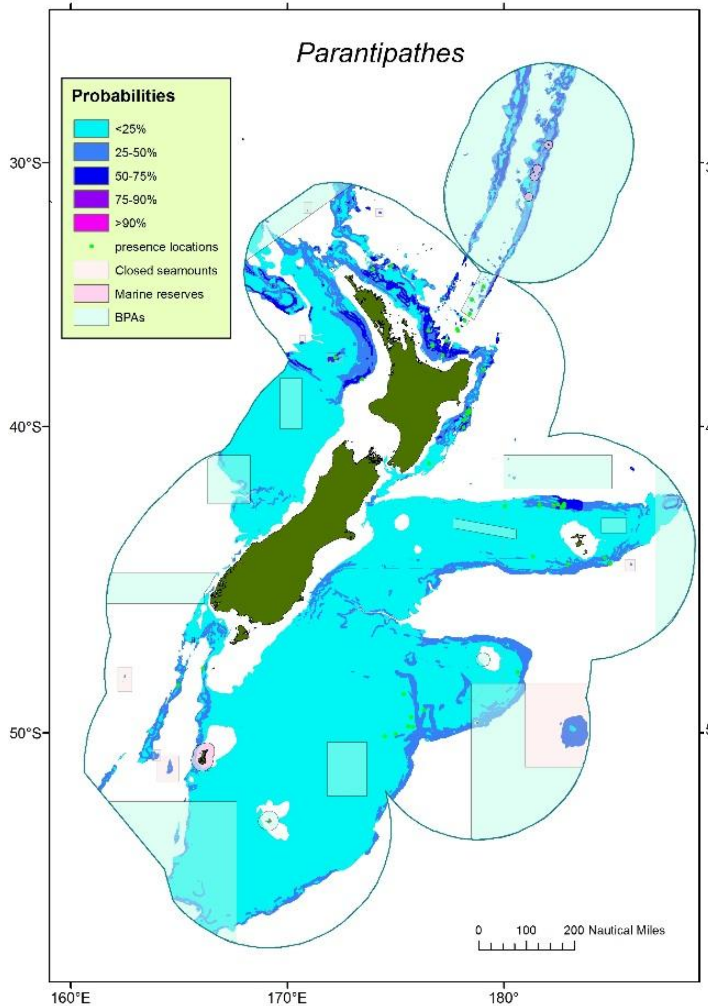


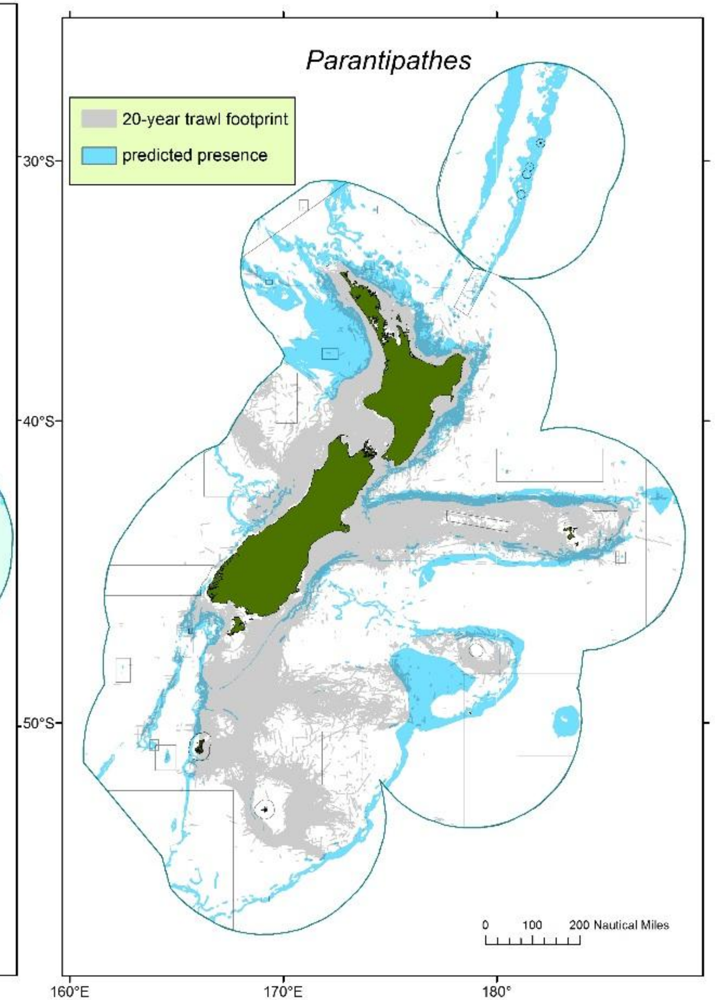


Main variables: Dynoc & Tidalcurrent

Similar distribution to Antipatharia but lower probabilities esp. Chat Rise.

Moderate overlap with trawl footprint – high on Chat Rise

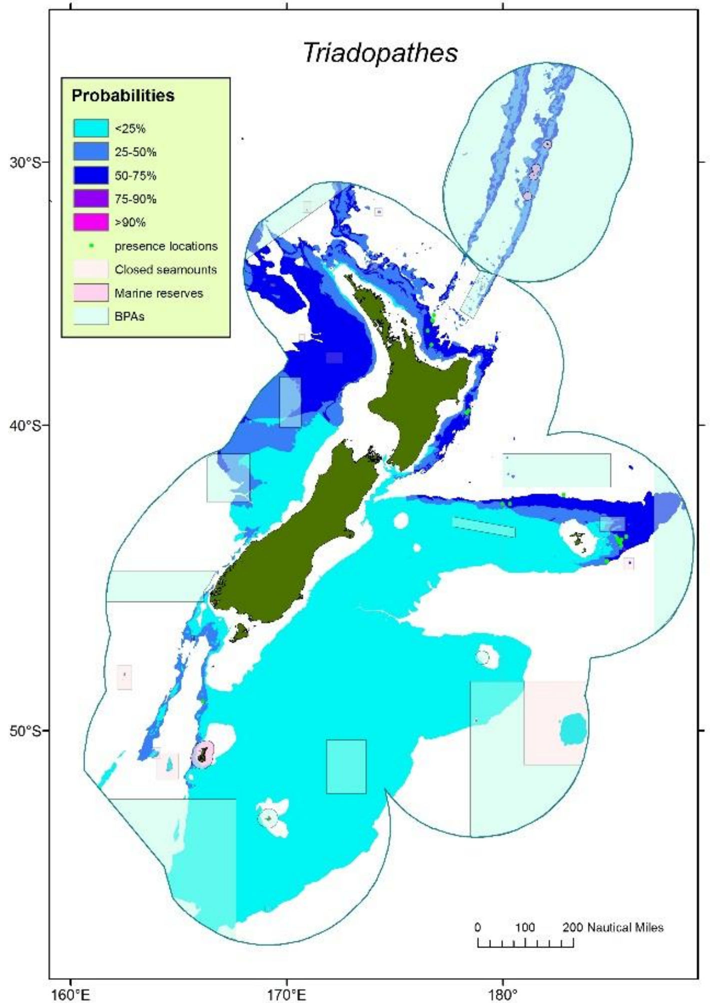


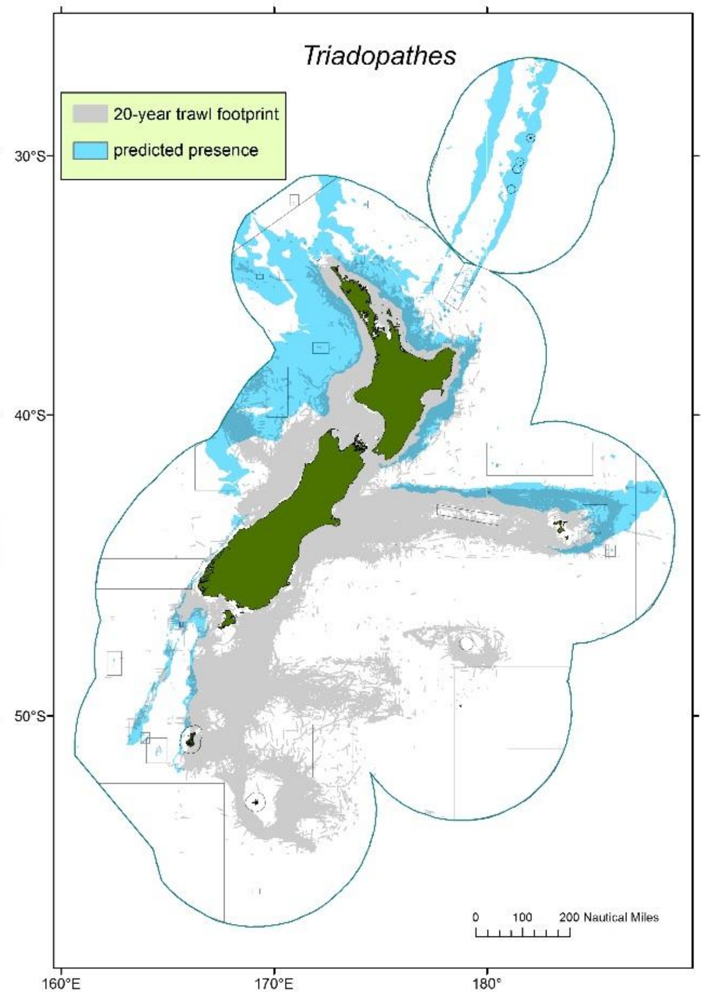


Main variables: Dynoc & Calcite

Very similar distribution to *Leiopathes*.

Moderate overlap with trawl footprint – high on Chat Rise





Summary

- New models created with focus on fine taxonomic groups as far as possible. AUC values indicated models performed better in these groups compared to combined groups (e.g. scleractinia) and structural groups.
- New variables (aragonite and calcite saturation levels) had a modest influence in the models. Perhaps because most presence records were from areas where saturation was >1
- Suitable habitat predicted to exist for all coral groups outside of recent bottom trawl grounds, but significant overlaps shown in some regions.
- Models will improve with higher resolution of environmental data layers
- Improved bathymetry data can be used to refine other layers where this is a critical input to their models.
- Fine-scale bathymetry (metres) can be used to produce terrain variables (rugosity, BPI, slope, etc)
- Multibeam backscatter data can be used to infer sediment properties (hardness).
- Modelling of future pH, O_2, temperature, ASH/CSH states can be used to predict future coral distributions and therefore identify important areas for protection now.