

Habitat Suitability Modelling for Protected Corals in New Zealand Waters

Draft methodology report

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Executive summary

Many protected coral species occur as bycatch in commercial fisheries in the New Zealand region. To determine the overlap between commercial fishing and corals, it is first necessary to determine and predict the spatial extent of corals. This project will expand on previous protected coral habitat suitability modelling studies by utilising updated modelling techniques, incorporating additional coral presence records from recent commercial and research sampling surveys, and by using regional environmental predictor layers for the current and future climate conditions based on NIWA's Earth System Model (ESM).

There has been substantial development of habitat suitability modelling techniques in recent years, with boosted regression trees, maximum entropy, random forests, and generalised additive models the most commonly used methods in New Zealand over the last eight years. The most recent and sophisticated models now account for spatial autocorrelation in the sampling data, estimate precision of the predicted distributions, combine multiple model types, and assess model performance. Each of these new developments will be incorporated into our models to maximise their utility and accuracy.

The total number of modelled taxa will be limited by the complex modelling procedure with higher priority given to the reef-forming scleractinian coral species, the gorgonian octocoral genera *Keratoisis* and *Lepidisis* (bamboo corals) combined, and to a key antipatharian coral genus (*Bathypathes*). Medium priority will be given to the gorgonian octocoral genera *Paragorgia* (bubblegum corals), *Primnoa* (primnoid seafans), and the precious coral genus *Corallium*; and to a common genus of stylasterid hydrocorals, *Errina*. Low priority will be given to a second genus of black corals (*Leiopathes*) and a second genus of hydrocorals (either *Lepidopora*, *Lepidotheca*, or *Stylaster*). This selection is based on the need to produce models that cover a range of the protected coral taxa for which there is also a relatively large number of records.

Environmental predictors will be derived primarily from outputs of the New Zealand Earth System Model, expected to be available by mid-2019, along with other predictors such as recently revised and updated sediment data layers, plus seafloor slope and seamount distribution.

Model coefficients will be used to produce two sets of prediction grids for each model type; one for present-day environmental conditions, and one for the predicted environmental conditions in 2120 AD.

The risk to corals from interaction with fishing gear will be assessed by visual matching of the predicted coral distributions with either the footprint of recent bottom trawling activities or with the aggregated fishing effort from the most recent published analysis.

1 Introduction

All deep-water corals in the Orders Antipatharia and Scleractinia, Gorgonian octocorals in the Order Alcyonacea, and Stylasterid hydrocorals in the Order Anthoathecata, are protected under the Wildlife Act (1953) and a later (2010) amendment. Many of these protected coral species occur as bycatch in commercial fisheries in the New Zealand region (e.g., Anderson et al. 2017).

In order to refine our understanding of the overlap between commercial fishing effort and corals, and to assess potential fishing impacts across their distribution, it is necessary to quantify and predict the spatial extent of corals in relation to these impacts. This project is designed to expand on the work undertaken by Anderson et al. (2014), by carrying out improved and refined habitat suitability modelling to predict species distributions using new data. These new data include; coral records collected by researchers and the Department of Conservation's (DOC) Conservation Services Programme (CSP) Observer programme during the past four years and identified by specialists (Tracey et al. 2017), coral records from shallow depths (less than 200 m), and regional environmental predictor layers for the current and future climate conditions based on the New Zealand Earth System Model (NZESM), and updated modelling methods.

Comparison of the predicted distributions of coral taxa with current fishing effort will be made using published trawl footprint data for the most recent fishing years (Baird & Mules in prep). Coral data from less than 200 m will be included in the models where available, and the predictions will cover the shallowest depths possible within the limits of the available environmental predictor layers.

Updating the predicted distribution maps for protected corals will enable improved definition of suitable current and future habitat, help to assess risk from commercial fishing, and inform the management of these fragile and long-lived fauna.

The specific objectives of this project are:

1. To carry out improved habitat suitability modelling for protected corals in the New Zealand region.
2. To help identify areas of risk from interactions with commercial fishing gear.

To ensure the analyses are conducted using methods that are acceptable to DOC's CSP, and to enable agreement to be reached on the selection of taxa to be modelled, the proposed methodology, and initial selection of taxa are presented in this report. To provide context for the proposed methods, a review of recent modelling techniques applied in deep-sea studies of the New Zealand region, is also provided below.

2 Review of habitat suitability modelling

Various techniques exist for predicting species distributions through the spatial estimation of habitat suitability, and there has been a substantial development of these in recent years, taking advantage of increased computing power, machine learning algorithms, availability of global and regional datasets of environmental variables, the ongoing sampling of the world's oceans, and accessible species record databases.

The most commonly used of the available habitat suitability modelling methods include:

- Generalised Linear Models (GLMs and GAMs) (McCullagh & Nelder 1989, Hastie & Tibshirani 1990)
- Maximum Entropy (Maxent) (Phillips et al. 2006)
- Random Forests (RF) (Breiman 2001)
- Boosted Regression Trees (BRT) (Elith et al. 2008)
- Genetic Algorithm for Rule-Set Production (GARP) (Stockwell 1999)
- Multivariate Adaptive Regression Splines (MARS) (Friedman 1991)
- Ecological Niche Factor Analysis (ENFA) (Hirzel et al. 2002)
- Artificial Neural Networks (ANNs)
- BIOCLIM (Nix 1986)

Although the approaches and underlying structures differ, each of these models essentially explores complex non-linear correlations between point-sampled species occurrence records (and usually absence or background records), and spatially continuous environmental variables. The models predict the likelihood of occurrence of a species, or group of species, across unsampled environmental space (Reiss et al. 2015, Vierod et al. 2014).

Some of the above habitat suitability modelling methods have been used in deep-sea studies in the New Zealand region. The following summary does not in any way represent a complete review of all previous research carried out on predicting distributions of benthic invertebrates (including protected corals) in New Zealand waters, but rather outlines the progression of habitat suitability modelling that has been applied in the region. We also briefly describe habitat suitability modelling methods in the context of various international research.

2.1 New Zealand

Most of the Habitat Suitability modelling (HSM) research on deep-sea benthic invertebrates in New Zealand has been carried out by NIWA modellers, often collaborating with scientists from overseas research institutions. The work has been funded primarily by government agencies such as DOC, the Ministry for Primary Industries (MPI), and the Ministry for Business, Innovation and Employment (MBIE).

Among the earliest of the HSM studies were those that focussed on the reef-forming branching scleractinian corals (Tracey et al. 2011), and other broad taxonomic coral groups based on their morphology (e.g., 'tree-like' forms such as various gorgonian octocorals and certain black corals (Baird et al. 2013)). These studies used the Boosted Regression Tree (BRT) method, and the predicted species distributions encompassed the entire New Zealand region (Figure 2-1).

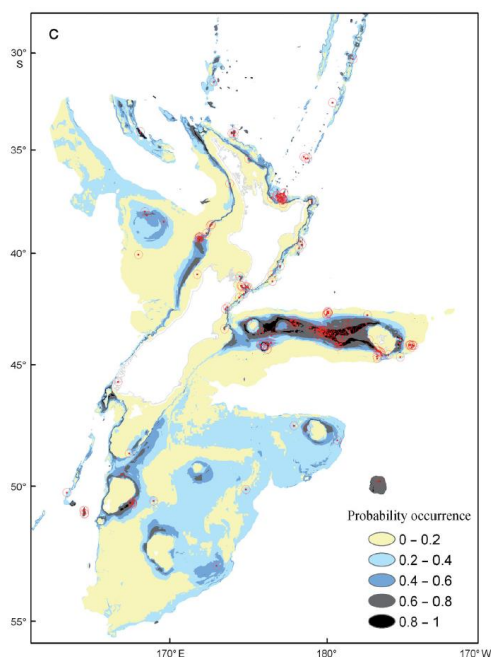


Figure 2-1: Predicted distribution of reef-forming scleractinian stony branching coral *Goniocorella dumosa*. From Tracey et al. (2011).

At around the same time that this coral modelling work was carried out, the BRT technique was also being used to predict distributions of benthic invertebrate species on the Chatham Rise and Challenger Plateau regions. In this study, 68 separate invertebrate taxa were modelled using presence absence data from two camera transect surveys carried out in 2007, and used global or regional scale environmental predictors (Compton et al. 2013) (Figure 2-2). This study then used the predicted distributions from the BRT models, along with two community-based methods, to identify and describe species assemblages within the study region.

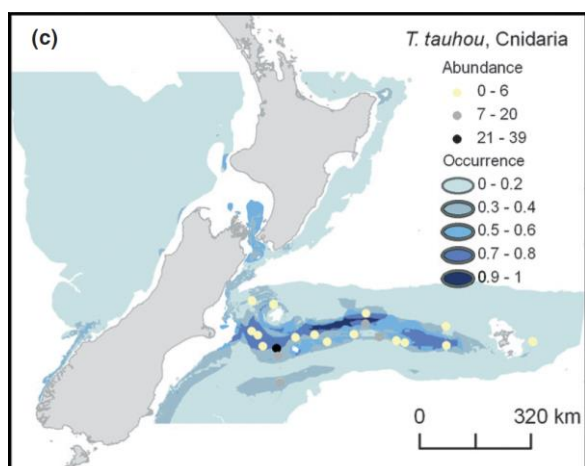


Figure 2-2: Predicted distribution of the alcyonacean *Taiaroa tauhou*. From Compton et al. (2013).

BRT was also used in two further studies for the DOC CSP, where the focus was on protected coral species within the New Zealand EEZ (Anderson et al. 2014, Anderson et al. 2015). A unique aspect of

these studies was the incorporation of future seafloor environmental conditions estimated from earth system models, to predict likely suitable coral habitat in 2100. The model covariates were based on model simulations from a global Coupled Model Intercomparison Project (CMIP) model (Taylor et al. 2012), specifically those simulations that were a best fit with observational data for the New Zealand region, and represented a “business-as-usual” future emissions scenario (Figure 2-3).

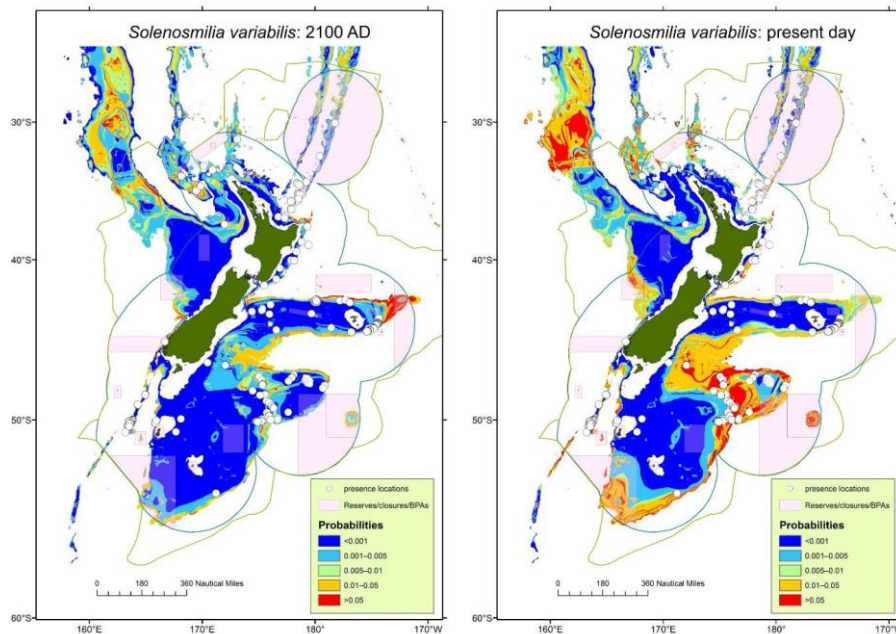


Figure 2-3: Predicted distribution of reef-forming scleractinian branching coral *Solenosmilia variabilis*. Left, present day; right, 2100 AD. From Anderson et al. (2015).

Following United Nations General Assembly resolutions for member nations to form regional fisheries management organisations (RFMOs), such as the South Pacific Regional Fisheries Management Organisation (SPRFMO), and to facilitate the identification of vulnerable marine ecosystems (VMEs) in the High Seas, new habitat suitability models were developed and published first in 2015 (Rowden et al. 2015), and then in 2016 (Anderson et al. 2016a). Anderson et al. (2016a) predicted the distribution of reef-forming stony corals, as VME indicator taxa, across the South Pacific Ocean (including the NZ EEZ but excluding the EEZs of other countries). The models were constructed using global environmental variable datasets, species presence data collected from a variety of international agencies and databases (e.g., NIWA’s Invertebrate Collection Specify database *niwainvert*, and two model methods – BRT and Maxent (Anderson et al 2016a) (Figure 2-4). A dedicated camera survey carried out in 2014 (Clark et al. 2015), in a key deep-sea fishing region in the High Seas (the Louisville Seamount Chain (LSC)), was used to validate the model predictions. From this study serious inadequacies in the global environmental grids were revealed, stemming from large errors in estimated depths in remote regions where sampling density was low. The key outcomes from this research were to highlight the importance of model validation, the need to improve models, as well as the need for caution when making environmental management decisions based on HSM model outputs.

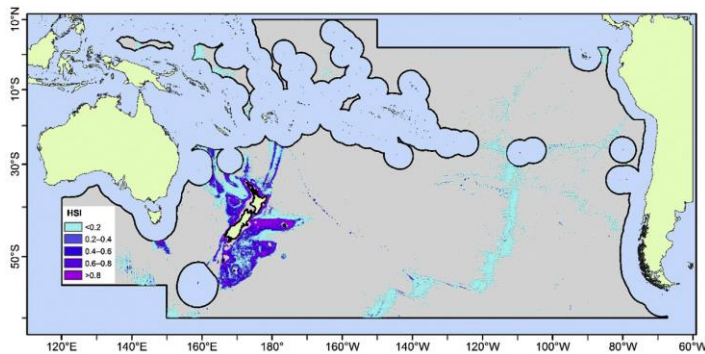


Figure 2-4: Predicted distribution of reef-forming scleractinian branching corals. From Anderson et al. (2016a).

The lessons learned from the poor predictive power of the wide-scale models led to a return of focus to regional HSM models. The next set of models produced by researchers were again limited to the New Zealand region (Anderson et al 2016b). In this instance, the models benefitted from utilising variables derived from, or upscaled to, a newly available 250 m resolution bathymetry. Concerns about inaccuracies in previous HSMs were partly addressed in these improved models by estimating model precision in each grid cell through resampling (bootstrapping) methods. Both BRT and Maxent techniques were again applied, but in this case, ensemble models were created by averaging the results of the two models, weighted by model performance statistics. As well as producing predictions for the reef-forming scleractinian coral species, models were produced for several other VME indicator taxa (black corals, stylasterid hydrocorals, sponges, sea pens, crinoids, and brisingid sea stars) (Anderson et al. 2016b) (Figure 2-5).

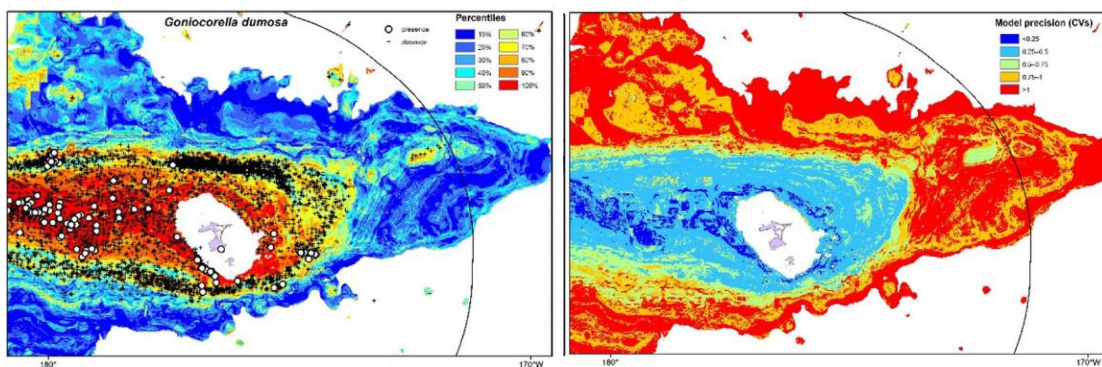


Figure 2-5: Predicted distribution of reef-forming scleractinian coral *Goniocorella dumosa* (close-up of eastern Chatham Rise). Left, habitat suitability; right, precision (coefficient of variation). From Anderson et al. (2016b).

Examination of extensive image data from deep-sea habitats in New Zealand and overseas has shown that the distribution of sessile benthic invertebrates (such as corals) varies on a fine scale and is strongly related to both the variability in seafloor terrain and substrate type. Both these factors determine suitable attachment surfaces and exposure of the fauna to an adequate supply of food. Primarily utilising high resolution multibeam echo-sounder (MBES) based bathymetry, and precise species presence-absence data from the Louisville Seamount Chain camera survey, ‘high-resolution’ models were produced (Rowden et al. 2017). Models were produced for three VME indicator taxa (the reef-forming stony coral *Solenosmilia variabilis*, and the VME habitat indicators crinoids (Class Crinoidea), and brisingid sea stars (Order Brisingida). These models were produced at a resolution of

25 m, considerably finer than the 1 km resolution of the previous models, and seafloor terrain parameters (e.g., slope, roughness, aspect, curvature, hardness (backscatter)), were the primary model covariates used.

Three modelling techniques were used (BRT, GAM, and RF), and abundance was predicted as well as probability of presence. The models incorporated methods to deal with spatial auto-correlation in the presence-absence data (Rowden et al. 2017) (Figure 2-6).

While models based on the use of images and MBES-derived data are likely to be very reliable and accurate (e.g., Rengstorf et al. 2013), it is worth noting that because high-resolution models rely for their performance on continuous MBES data they are limited to areas that have such coverage. The area of the New Zealand region with continuous coverage of MBES data is increasing, but full coverage of the EEZ is likely to be many decades away.

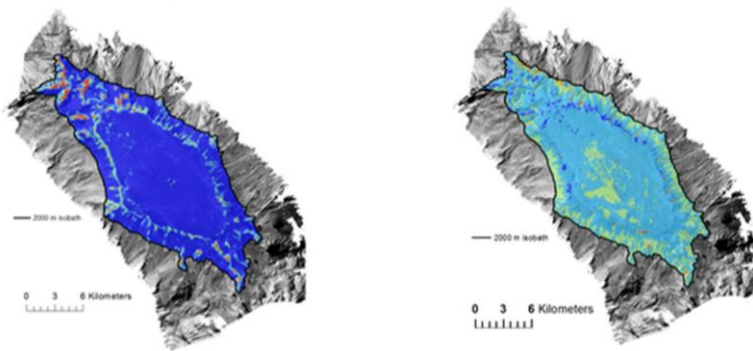


Figure 2-6: Predicted distribution of reef-forming scleractinian branching coral *Solenosmilia variabilis* on Forde Seamount, Louisville Seamount Chain. Left, abundance; right precision (coefficient of variation). From Rowden et al. (2017).

Until recently, the only application of HSM modelling to undergo any independent validation was that of Anderson et al. (2016a), as described above. Further validation research has now been conducted to test the accuracy of most of the above models. Validation of the models, where they included the Chatham Rise, was based on data from a series of camera surveys along the Rise between 2007 and 2017 (Anderson et al. submitted). Results of this work showed evidence of a general improvement in the reliability of models over time, with the best-performing models tending to be those developed for individual species rather than groups of species, and for frequently-recorded species rather than rare species. Poorer performance of models occurs when large groups of species are combined, most likely because the combined presence locations cover a broad ecological niche, thus blurring the association with environmental covariates. Models with a more restricted spatial extent tuned specifically to local environmental conditions also performed better than broader-scale models. Finally, models based on real absence records performed better than models that have relied on random background points (pseudo-absence data).

2.2 International habitat suitability modelling studies

There have been numerous HSM studies carried out for benthic invertebrates in other parts of the world's oceans in recent years, mirroring the increasing attention this field of research has attracted in New Zealand. According to a recent review (Robinson et al. 2017), the area receiving the most attention has been the temperate North Atlantic (e.g., Rengstorf et al. 2012, Rengstorf et al. 2013), followed by temperate Australasia (e.g., Pitcher et al. 2012 for Australia, and see above for New Zealand), and temperate Pacific (e.g., Guinotte & Davies 2014, Rooper et al. 2014); there have also been several global-scale studies (e.g. Davies & Guinotte 2011, Yesson et al. 2012, Yesson et al. 2017). Maxent has been the most common habitat suitability method used in these studies but other methods, in particular GAM and RF, have also been used frequently. There is little in terms of general approach in studies conducted elsewhere that has not already been adopted, or initiated, by the New Zealand-based studies.

3 Proposed methodology

3.1 Assembly of coral presence and absence data

A database containing records of benthic invertebrate samples from the South Pacific region is regularly updated by NIWA staff for use in various marine biodiversity research projects, including HSM studies. The database includes taxa which are considered VME indicator taxa (e.g., various coral groups and sponges) and taxa that are considered indicators of VME habitat (i.e., that are associated with VMEs; crinoids and brisingid starfish) (Parker et al. 2009). As such the database records include all protected New Zealand coral species.

Coral presence data used in the various previous analyses of protected coral species distributions have now been augmented by several years of additional records. The data have come from fisheries observer sample collections, research surveys, and from records from overseas museums and research institutes. These revised and updated datasets of coral records will be used in this new study. In addition, and as agreed with DOC, we will include coral presence data from shallow waters (less than 200 m) which will enable the prediction of coral distributions to the shallowest depths possible within the limits of the environmental predictor layers. Coral records are recorded at different taxonomic levels in the database. The focus of the current study will be to produce models at the genus and species level.

The coral occurrence dataset is a subset of a larger database of position records comprising all research survey stations at which all organisms in the sample were identified, including stations with no corals. This dataset, comprising over 60 000 records within the New Zealand EEZ, was used to provide the absence location data for earlier HSM models, and will be used again in this study, expanded as necessary to include data points from stations shallower than 200 m.

3.2 Selection of taxa to model

The set of taxa modelled in the two previous related studies (Anderson et al 2014, Anderson et al. 2015) provide a starting point for taxa selection in the current study. The selection of these taxa was initially guided by the coral species listed in the DOC Threatened Species List (Freeman et al. 2010) and

a recent DOC marine invertebrate expert panel list (Freeman et al. 2013) (Table 3-1). Further details of selection criteria and rationale for species groupings can be found in Anderson et al. (2014).

Despite indications from model validation studies that indicate models of groups of taxa produce less reliable models, this issue needs to be balanced against the lack of resources available to the current project to produce models for large numbers of individual species, and the limited number of individual species with sufficient presence data to produce reliable models. The available presence data will be assessed prior to the final selection of taxa to model, considering any additions of records of protected coral species collected since the most recent database update. Ideally models will be run for individual species or genera.

It is likely that the limited resources available to the current project will restrict the number of taxa that can be modelled. That is, the total number of taxa modelled is likely to be less than the thirteen taxa achieved in the previous study, given the greater complexity of the analyses to be used in the current study. These complexities – combining multiple independent models, calculating cross-validated model performance statistics, resampling for precision estimation, accounting for spatial auto-correlation – now represent NIWA’s current accepted strategy for producing habitat suitability maps for VME indicator taxa in the New Zealand and wider Pacific region (e.g., Anderson et al. 2016b, Rowden et al. 2017, Georgian et al. 2019). To ignore any of these aspects of the modelling approach would be to take a ‘step backwards’ in the development of the use of HSM models and should be avoided if possible. Therefore, we have assigned a priority ranking to each candidate taxon (Table 3-1). Models will be produced for all six taxa with a priority of 1, with further models produced for taxa with priority 2 and 3 if time and resources permit within the project budget.

Table 3-1: Protected coral taxa to be modelled, a brief description, the number of recorded observations available for the Anderson et al. (2015) study, and a priority rank. –, not modelled previously.

Order	Taxon	Description	Number of records	Priority
Scleractinia	<i>Enallopsammia rostrata</i>	Reef-forming coral	130	1
	<i>Solenosmilia variabilis</i>	Reef-forming coral	311	1
	<i>Goniocorella dumosa</i>	Reef-forming coral	212	1
	<i>Madrepora oculata</i>	Reef-forming coral	126	1
Alcyonacea	<i>Paragorgia arborea</i> (or spp.)	Bubblegum coral (tree-like)	98	2
	<i>Primnoa</i> spp.	Primnoid sea-fans (tree-like)	73	2
	<i>Corallium</i> spp	Precious coral	–	2
	Genera combined: <i>Keratoisis</i> spp. <i>Lepidisis</i> spp.	Bamboo corals (tree-like)	241	1
Antipatharia	<i>Bathypathes</i> spp.	Black coral (tree-like)	75	1
	<i>Leiopathes</i> spp.	Black coral (tree-like)	67	3
Anthoathecata	<i>Errina</i> spp.	Hydrocorals (small, hard)	–	2
	<i>Lepidopora</i> or <i>Lepidotheca</i> or <i>Stylaster</i> (spp.)		–	3

3.3 Environmental predictors

A wide range of environmental parameters that can potentially have an impact on seafloor-dwelling invertebrates are available as outputs from ESM models, representing both current condition and predicted conditions at some time in the future (e.g., 2120).

A New Zealand Earth System Model (NZESM) is currently under development which, when complete, will incorporate component models of ocean biogeochemistry and other aspects of biology and chemistry to provide a highly complex model of the climate system. This NZESM is specifically tuned to the New Zealand region of the Pacific and Southern Oceans and is capable of producing projections for up to 200 years into the future (Williams et al. 2016).

The full set of potential environmental data layers available from the NZESM is not yet determined, but should include, at a minimum, all of those used in the previous analysis (Anderson et al. 2015).

In addition to these temporally variable parameters from the NZESM, other environmental parameters that vary only spatially (rather than temporally) will be considered for inclusion in the models. These include such variables as depth, slope, roughness, substrate type, and seamount; spatial grids of these parameters are readily available from published research and databases. Updated data layers of seafloor substrate type for the New Zealand region have recently been produced (Bostock et al 2018a, 2018b). The availability of these new sediment data layers (those of sand, gravel, and mud) for use in the habitat suitability models is important because substrate is likely to have a substantial influence on the distribution of corals. Nonetheless, it is worth noting here that these data layers are gridded at 1 km, a spatial scale that is typically much larger than the scale at which substrate type influences sessile fauna such as corals.

The final set of environmental predictors will be selected from a larger set of candidate variables using either correlation analyses or by selecting a complementary set of predictors known from previous work and from ecological studies to be important drivers of habitat suitability for corals. A potential list of variables is shown in Table 3-2.

Table 3-2: Potential set of environmental data layers to be used in the models. From Anderson et al. 2015.

Variable	Description	Units	Reference
Seamount	Seamount positions in the New Zealand region	–	Rowden et al. (2008), Mackay (2007)
Slope	Seafloor slope derived from bathymetry	°	CANZ (2008), Hadfield et al. (2002)
Dissolved Inorganic Carbon	Seafloor DIC concentration	mol/m ³	NZESM
Sea surface height	Sea surface height above geoid	m	NZESM
Bottom temperature	In-situ bottom temperature	Degrees C	NZESM
Aragonite concentration	Seafloor aragonite concentration	mol/m ³	NZESM
Calcite concentration	Seafloor calcite concentration	mol/m ³	NZESM
Nitrate concentration	Seafloor dissolved nitrate concentration	mol/m ³	NZESM
Phosphate concentration	Seafloor dissolved phosphate concentration	mol/m ³	NZESM
Oxygen concentration	Seafloor dissolved oxygen concentration	mol/m ³	NZESM
Chlorophyll concentration	Seafloor total chlorophyll mass concentration	kg/m ³	NZESM
Salinity	Seafloor salinity	g/kg	NZESM
Sediment	Percent mud or gravel	%	Bostock et al. 2018ab

3.4 Habitat suitability models and approach

We propose to produce ensemble models comprising the weighted, averaged output from a minimum of two separate modelling techniques, selected from BRT, RF, Maxent, and GAM. Model performance, as measured by the area under the receiver operating characteristic curve (AUC) statistic using

withheld sets of test data, will be used to weight the separate components of the ensemble models. Bootstrap resampling techniques will be utilised to produce maps of model precision, to complement the habitat suitability maps.

The depth range for the models will be from 0 m (or as close to this as possible given the limitations of the environmental layers) to a maximum of 3000 m, a depth beyond which little sampling has been undertaken and few corals have been observed.

The procedure for creating each model will be as follows:

- Finalise selection of presence and absence data, including error checking and exclusion of any duplicate records.
- Finalise selection of environmental variables. This will be based on either the known ecophysiological requirements of corals, or an analysis of correlations between variables coupled with assessment of trial models with candidate variables (as in e.g., Georgian et al. 2019). A base set of predictors will be chosen for use in each model, modified by specific biological requirements of some taxa. The NZESM-derived predictors will represent average environmental conditions for a reference period which approximately matches that of the collection of biological input data (e.g. 1990 to 2010).
- Models run for each taxon, iteratively as necessary, to derive a residual autocorrelation variable (RAC) to account for spatial autocorrelation in the input data.
- Model precision determined from multiple re-runs using resampled input data.
- Model performance, measured as AUC, determined from cross-validation partitioning of the input data into training/testing sets.
- Final models produced for each method using the full set of presence-absence data.
- Model coefficients used to produce two sets of prediction grids for each model type; one for present-day environmental conditions and one for the predicted environmental conditions in 2120 AD.
- Ensemble models produced by averaging the predictions from the contributing models, weighted by the cross-validated AUC value, and possibly also by the inverse of the estimated uncertainty in each cell.

The resulting data grids of habitat suitability for each modelled taxon will be presented as colour-coded maps for each time period, alongside a map of model uncertainty.

3.5 Identification of the overlap between protected coral species and commercial bottom trawling

The footprint of reported commercial trawling activity in the New Zealand region is provided in regularly updated analyses of the catch-effort data submitted by all commercial fishing vessels registered in New Zealand (Baird et al. 2011; Black et al. 2013; Black & Tilney 2013; Baird & Wood 2018; Baird & Mules in press). These analyses provide estimates of both the footprint and the total

aggregated fishing impact across a 5 km by 5 km grid encompassing the entire New Zealand EEZ. The most recent analysis provides grids based on recent fishing activity (2008–2017) (Baird & Mules in prep) and is therefore the most relevant for comparison with coral distributions. Comparisons will be limited to the depth (200–1600 m) and geographical (EEZ) range covered by the footprint analysis. Comparisons will be made visually, by matching predicted coral distributions with either the footprint or the aggregated effort, supported by specific overlap statistics (e.g., the fraction of cells with predicted high habitat suitability (90% quantile) overlapping with cells with high footprint area (> 20 km²).

4 Abbreviations used

Abbreviation	Meaning
ANN	Artificial Neural Networks
AUC	Area Under the receiver operating characteristic Curve
BRT	Boosted Regression Tree
CMIP	Coupled Model Intercomparison Project
CSP	Conservation Services Programme (DOC)
DOC	Department of Conservation
EEZ	Exclusive Economic Zone
ENFA	Ecological Niche Factor Analysis
ESM	Earth System Model
GAM	Generalized Additive Model
GARP	Genetic Algorithm for Rule-Set Production
GLM	Generalised Linear Model
HSM	Habitat Suitability Model
LSC	Louisville Seamount Chain
MARS	Multivariate Adaptive Regression Splines
Maxent	Maximum Entropy
MBES	Multibeam Echo Sounder
MPI	Ministry for Primary Industries
NIWA	National Institute of Water and Atmospheric Research
NZESM	New Zealand Earth System Model
RAC	Residual Autocorrelation Variable
RF	Random Forest
VME	Vulnerable Marine Ecosystem

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