CSP TECHNICAL WORKING GROUP DOCUMENT

(*in lieu* of working group presentation)

Report on the methods used to describe the distribution of deep sea corals in relation to areas where they are at risk of interactions with commercial fishing gear

Project: 4527 RFP Development of Coral Distribution Modelling

Prepared for comment from: CSP Technical Working Group

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Overall Objective:

The objective is to describe the distribution of deep sea corals in relation to areas where they are at risk of interactions with commercial fishing gear.

The key deliverables are:

1. Data on coral distribution in an electronic format suitable for use in fisheries risk assessment.
2. A technical report or reports describing the methods used and mapping the distribution of protected corals in relation to commercial fishing effort.
3. Recommendations for any future research required to further improve the estimation of risk to protected corals from commercial fishing.

Specific objectives

1. Produce refined models of protected coral distribution using the most recent data to inform a risk assessment.
2. Use refined predictive models to inform an assessment of deep-sea coral risk to commercial fishing gear.

NIWA Research Plan

1. Summary

This report has been prepared for discussion with CSP, DOC and members of the CSP Technical Working Group prior to starting the work, to ensure that the methods applied will meet their overall requirements for understanding the ERA and its application to potential management. To meet the first specific objective and report the findings as stipulated in section 4 of this Schedule, we will use the groomed coral dataset used in Baird et al. (2013), and additional sources of environmental information, to model the distribution of the protected corals. The analytical method applied will be the boosted regression tree (BRT) model. All data will help inform a risk assessment using Productivity-Susceptibility-Analysis (PSA). We will provide recommendations for any future research required to further improve the estimation of risk to protected corals from commercial fishing.

2. Data to include in the model

Protected coral dataset: The dataset compiled and groomed for the analysis of coral distribution in New Zealand waters by Baird et al. (2013) will be utilised to re-run the models with the new environmental data. This dataset includes the verified (confirmed by experts and *cod* updated) observer coral dataset as well as all available observer coral data (non-verified) in combination with scientific research data collected from biodiversity and trawl surveys. These coral occurrence data provide a large dataset to model with the environmental data to predict the distribution of corals throughout the region.

The protected coral dataset is a subset of the full benthic stations dataset, which includes all research survey stations where all organisms were identified, including those with no corals. This dataset, which describes the sampling effort and provides absence data which can be used in predictive models, includes 62 144 records. This records in this dataset extend from about 30° S to 55° S and 162° E to 172° W within the New Zealand 200 n. mile EEZ.

The protected coral dataset comprises 7731 protected coral records and is bounded by similar limits to the full benthic dataset, though there are relatively few records from more southerly latitudes and from waters west of New Zealand.

The work by Baird et al (2013) produced predictive models at the minimum taxonomic level of Order, with each model combining presence data for multiple species. Individual species or genera within these groupings are likely to show distinct distributions, due to differing environmental requirements which are masked when groups of corals are analysed together at a higher taxonomic level. It was recommended by Baird et al. (2013) to attempt to build models at the species or genus level where there are sufficient data.

Selected coral species: Our selection of species or genera to be modelled in this project will be guided by the species listed in the DOC Threatened Species List (Freeman et al. 2010) and by the most recent DOC marine invertebrate expert panel list where the listings of threatened New Zealand marine invertebrates have been reviewed and modified. The distribution data available for these species/genera (see Sanchez 2005; Consalvey et al. 2006; Tracey et al. 2011a & b; Baird et al. 2013; Opresko & Tracey 2013), will be assessed for their suitability for modelling purposes to further refine the list of species/genera for which models will be made.

These species/genera are likely to belong to branching ‘reef-like’ and the ‘tree-like’ forms as these are the most vulnerable to trawling and have different habitats and most likely need separate treatment in a risk assessment. These are: genera of the branching stony coral forms (Order: Scleractinia) *Goniocorella dumosa*, *Solenosmilia variabilis*, *Enallopsammia rostrata*, *Madrepora oculata*; key octocorals genera / species (Order: Alcyonacea), specifically the gorgonian corals *Keratoisis* spp., *Lepidisis* spp., *Paragorgia* spp. and *Primnoa* sp; and black corals genera (Order Antipatharia) commonly found >200 m (Opresko & Tracey in prep.) *Bathypathes*, *Dendrobathypathes*, *Dendropathes*, *Leiopathes*, *Lillipathes*, *Parantipathes*, and *Triadopathes*.

We will also re-run the models for the combined groups at the higher taxonomic level for Scleractinia, Antipatharia, as per Baird et al. 2013).

Fisheries data: For the reef-forming and tree-like coral groups we will overlay plots of habitat suitability with the trawl footprint layer as used in Baird et al. (2013), i.e., GIS layers of a 16-year (1989–90 to 2004–05) and 20-year (1989–90 to 2008–09) trawl footprint (Baird et al. 2011, Baird & Wood 2012)). The overlap between these layers will be assessed using cut-off thresholds from the habitat suitability modelling–for example 50% and 75%–both EEZ wide and in greater detail for the Chatham Rise. In addition, for the Chatham Rise only, we will overlay plots of habitat suitability with trawl location data by target species from the deepwater fisheries for orange roughy and oreos, obtained directly from MPI for this purpose. These data will include all available records of fishing to the end of the 2012–13 fishing year, and will indicate areas where trawling intensity is relatively high or relatively low.

New environmental layers: The choice of environmental variables is fundamental to habitat suitability modelling. Several global studies have found that the distribution of habitat-forming deep sea corals are strongly controlled by the carbonate concentration (Guinotte et al., 2006; Davies and Guinotte, 2011; Yesson et al., 2012). The data available for the study by Baird et al. (2013), did not include ocean carbonate chemistry data because it was not available for the New Zealand region at the time.

We will utilise additional sources of information that have recently been compiled and are relevant to the distribution of corals. Specifically we will use the aragonite saturation state at the sea floor (a proxy for the carbonate saturation state) that was developed as part of the MPI Project ZBD201041 (Bostock et al., 2013; Tracey et al. 2013). Re-runs will incorporate the aragonite saturation state data currently being compiled for the VME project (from 25^{o} S).

We will also investigate the suitability of NIWA sediment layer data for use in the analysis. However we wish to inform CSP Technical Working Group that the sediment data may only be available as a final ground-truthing of the models. Currently the sediment layer data are being prepared for the MBIE VMES133 Project (Ashley Rowden Programme Manager) and most likely will not be ready for this Project.

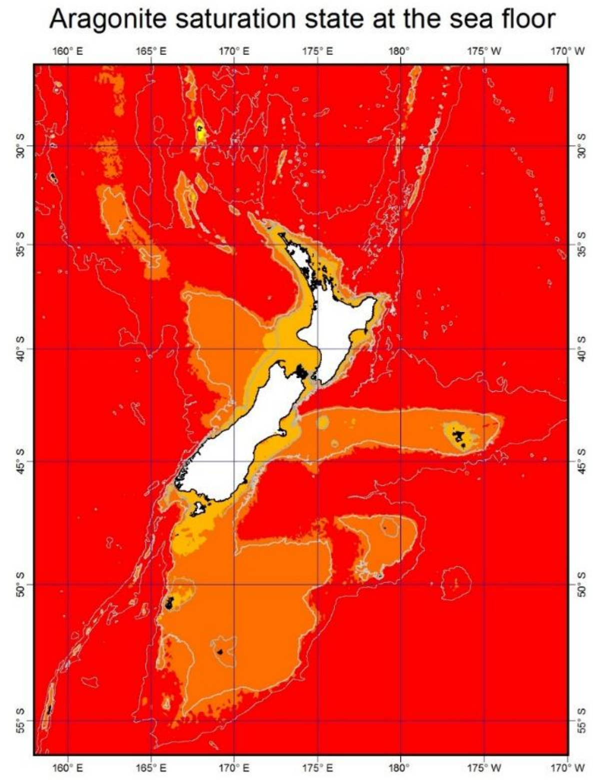

Figure 1: Map of the aragonite saturation state at the sea floor. Red colour represents undersaturated (Ωaragonite <1), orange (Ωaragonite=1-2) and yellow (Ωaragonite=2-3) are saturated.

Data for the carbonate saturation states will be used along with the environmental variables used in study carried out by Baird et al. (2013). That is, depth, seamount, slope, dissolved organic matter, dynamic topography, bottom water temperature, tidal current speed, sea surface temperature gradient, surface water primary productivity, and particulate organic carbon flux.

3. Habitat Suitability modelling

Predictive species distribution modelling is a rapidly advancing field and a number of methods have been developed in recent years. Boosted Regression Trees (BRT) are one of several machine-learning (ML) methods which use an algorithm to learn the relationship between the response and its predictors rather than relying on the more subjective approach used in statistical methods. Other commonly used species distribution models include Random Forest models, GLMs, and Maxent. We have chosen the BRT method for this project as it has performed well in previous models of New Zealand deepwater invertebrates and fish (e.g., Rowden et al. in press, Leathwick et al. 2006) where it has been shown to make use of absence data (where available) to enhance predictive performance outside of the areas of known distribution.

Description of BRT: The boosted regression tree (BRT) method, as used by Baird et al. (2013), will again be used to carry out the predictive distribution modelling. This approach uses recursive binary splits within a regression tree (decision 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). The final model is a linear combination of many trees (hundreds to thousands) –and is equivalent to a regression model where each term in the model is a simple tree. BRT is an attractive method as it easily accommodates predictor variables of different types (e.g. binary, categorical, continuous), transformations are unnecessary, and outliers have little influence on model results. BRT can use pseudo-absence data drawn from the positions of benthic sampling stations, but these tend to be biased in their distribution in relation to the presence data and predictor variables. An alternative is to use randomly selected background data locations from across the region, in order to fully characterise the environmental variables across the area being predicted to. Both options will be considered.

Application to date: BRT modelling on coral and VME datasets has been used for several recent studies. Tracey et al. (2011) modelled the distribution of five species of stony corals (Order Scleractinia) relative to 11 environmental variables using boosted regression trees. They identified depth and position relative to a seamount as consistently important factors and different environmental factors distinguished the deep-water species from the more shallow-occurring species. Baird et al. (2013) used BRT analysis to predict the likely distribution of coral groups throughout the New Zealand Exclusive Economic Zone (EEZ), according to a set of 10 environmental variables. The areas where the environmental conditions were most suited to the coral groups were generally in deeper waters where the seafloor had steep slopes. Most of the known coral distributions were within the areas predicted by the models to have suitable environment; however, some deep-water and steep relief areas where corals were known to exist were not identified by the predicted distribution. By grouping the corals by their taxonomic orders and by "functional" groups, "tree-like" e.g., bubblegum corals; "reef-like", e.g. the stony branching corals; "solitary small" e.g., the scleractinian cup corals; and "whip-like", e.g., bamboo coral Lepidisis spp. and black coral Stichopathes spp), some details and differences in habitat preferences between species were effectively lost.

The South Pacific Ocean region vulnerable marine ecosystems (VME) research project (Rowden et al. 2013), used BRT and Maxent models. The model variables were grouped into two environmental data sets: a 'regional' set of 11 environmental data layers that included variables for the New Zealand region and a 'global' set of 9 environmental data layers. The BRT and Maxent models predicted that large areas of the study region represented suitable habitat for VME indicator taxa including corals. The general inability of models to finely discriminate highly suitable habitat is in part a consequence of the coarse taxonomic levels used to classify VME indicator taxa. The data included coral groups: Alcyonacea (soft corals and gorgonian corals, both analysed separately), Antipatharia (black corals), Pennatulacea (sea pens), Scleractinia (stony corals), and Stylasteridae (hydro corals). The data available for the High Seas region were sparse and highlighted data gaps for this region.

4. The risk assessment method

Linked with the second objective to develop predictive models further to inform risk assessment, we propose to carry out a preliminary ecological risk assessment to describe the relative risk of certain deep-sea coral species (or grouping of species) to bottom trawling - i.e. which corals are most at risk from commercial fishing and may require different or increased levels of management input.

Taking risk assessment one step further: Risk assessment is a developing concept within the New Zealand fisheries management approach. These have been applied in a number of New Zealand situations including deep-water fisheries, Antarctic benthos, South Pacific High Seas fisheries, seabird bycatch, and a variety of marine habitats, including seamount (see brief review in Baird et al. 2013). However, to date, these assessments have not been carried out specifically for protected species of deep-sea coral, and hence in this project we propose carrying out a preliminary risk assessment to assess the feasibility of applying formal risk assessment methodology more widely to evaluate the risk from commercial fishing operations.

Method to carry out a risk assessment using Productivity-Susceptibility-Analysis (PSA): A commonly-used type of framework in Australia, which is also being considered for wider application to New Zealand fisheries (Clark et al. submitted), is the Ecological Risk Assessment for the Effects of Fishing (ERAEF, Hobday et al. 2011). This approach evaluates risk to benthic habitats, ecological communities, and threatened-endangered-protected species. We propose to use the level 2 “Productivity-Susceptibility Analysis” (PSA) method to assess the risk to protected coral species from the orange roughy trawl fishery. This will be a pilot assessment in order to evaluate the suitability of the method, as well as the adequacy of available data on coral distribution and vulnerability to bottom trawling.

The PSA approach is based on the assumption that the risk to an ecological component will depend on two characteristics of the component units: (1) the extent of the impact due to the fishing activity, which will be determined by the susceptibility of the unit to the fishing activities (Susceptibility) and (2) the productivity of the unit (Productivity), which will determine the rate at which the unit can recover after potential depletion or damage by the fishery. It is presented as a PSA plot (Figure 2).

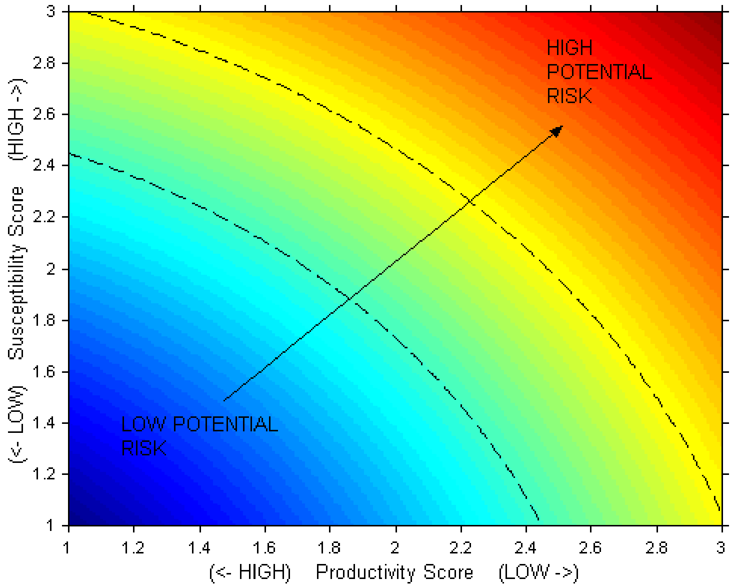

Figure 2. The Productivity-Susceptibility plot, which displays risk to the ecological unit. The contour lines divide regions of equal risk and group units of similar risk levels (from Hobday et al. 2007).

The x-axis includes attributes that influence the productivity of a unit, or its ability to recover after impact from fishing. The y-axis includes attributes that influence the susceptibility of the unit to impacts from fishing. The combination of susceptibility and productivity determines the relative risk to a unit, i.e. units with high susceptibility and low productivity are at highest risk, while units with low susceptibility and high productivity are at lowest risk.

In the context of deep-sea corals the objective of a risk assessment is to describe the relative risk of each coral species (or grouping of species) -i.e. which corals are most at risk from fishing and hence may require management input.

We will consider four main aspects as part of the PSA:

1) Availability
2) Encounterability
3) Selectivity
4) Productivity

These will be evaluated under the criteria for the “Habitat” component of the ERAEF, rather than the “Threatened, Endangered, or Protected” component. The reason for this is that many fisheries ERAs are focussed more towards fish, seabird, or mammal interactions, and use different assessment parameters from those appropriate for sessile corals on the seafloor. The latter are more similar to benthic habitat than benthic fish species, and the extensive work carried out on marine mammals or seabirds utilising PBR methods (e.g., Richards & Abraham 2013) are not applicable. We note that there are currently discussions within MPI and NIWA about developing this concept to habitats and communities, but the approach is not yet clear on how to do this.

We propose to use the “level 2.5” methodology developed by Clark et al. (2011) for evaluating the risk of bottom trawling on the benthic habitat of seamounts. In order to keep the analysis relatively simple, we will apply the method to the Chatham Rise, and the deepwater fisheries for orange roughy and oreos.

The attributes and criteria that are likely to be used in the assessment are summarised below (based on Clark et al. 2011), although note that ths is a subset of the full list of Habitat attributes, a number of which are not applicable in this application of the method. The aspects, and especially the ranking criteria, may change as we work through the method specifically for corals.

Availability: Availability considers overlap of fishing effort with a species distribution.

	Aspect Attribute (s)	Concept and Rationale	Ranks 1 (low risk)	 2 (medium)	 3 (high risk)
	Availability				
A1	Spatial overlap (geographical and depth range)	Spatial overlap of fishery with habitat defined. This coral species is at fishable depth.	No	Partial overlap	Yes
A2	Level of current protection	A variety of spatial closures already operate.	Yes, protected	Interim protection	No protection
A3	Distance to port	Ease and economy of access to fishing grounds makes closer areas of fished habitat more attractive.	Distant	Moderate	Close

The principal attribute to be considered is A1, the spatial overlap between the fishery and modelled coral distribution.

Encounterability: Encounterability considers the likelihood that a species will encounter fishing gear that is deployed within the geographic range of that species (based on adult habitat and depth range) (see Table 2 for details).

	Aspect Attribute (s)	Concept and Rationale	Ranks 1 (low risk)	 2 (medium)	 3 (high risk)
	Encounterability				
E1	Depth zone	The coral habitat is fishable, but depth varies	Deep (1200-1500 m)	Shallow (500-800 m)	Intermediate (800-1200 m)
E2	Geographical area	Encounters driven by expectation of finding target fish species with latitudinal correlation with preferred coral distribution	>50°S	<35, 45-50°S	35-45°S
E3	Ruggedness	Relief, rugosity, hardness and seabed slope where the corals occur influence accessibility to bottom trawling	Predominantly high relief (>1.0 m), rugged surface structure (crevices, overhangs, boulders); > 30° slope.	Predominantly low relief (<1.0 m), rough surface structure (rubble, small boulders); <30° slope.	No relief to impede trawling, smooth simple surface structure; < 30° slope.

All three attributes will be included. For the Encounterability attribute, we will overlay the trawl footprint layer used in Baird et al. (2013). The overlap can be assessed using cut-off thresholds of probability of presence from the habitat suitability modelling, e.g., at 50% and 75%.

Selectivity: Selectivity considers the potential of the fishing gear to capture or retain species.

	Aspect	Concept and Rationale	Rank		
	Attribute (s)		1 (low risk)	2 (medium)	3 (high risk)
	Selectivity				
S1	Removability/ mortality of morphotypes	Erect, large, rugose, inflexible, delicate form are preferentially removed or damaged; mortality assumed.	Low, robust or small (<5 cm), smooth or flexible types. Numerical qualifiers to be decided.	Erect or medium sized (5-30 cm), moderately rugose /inflexible, OR moderately robust Numerical qualifiers to be decided	Tall, delicate or large (> 30 cm high), rugose or inflexible. Numerical qualifiers to be decided
S2	Reduction of faunal diversity	Potentially higher loss of diversity where diversity/species richness is relatively high associated with the coral habitat/speciers form.	Diversity low. Numerical qualifiers to be decided	Diversity medium. Numerical qualifiers to be decided	Diversity high. Numerical qualifiers to be decided
S3	Special ecological value	Individual species or coral group habitat has special role as habitat for community or species (e.g., spawning feature; endemic species, rare species)	No (based on sampling)	Uncertain	Yes (identified by sampling)
S4	Biogenic habitat area	How much of each habitat is present. Larger areal extent means a more significant habitat for maintaining biodiversity and community function.	Rare (<1%) within the area (area definition here applies to the Chatham Rise)	Moderately common (1-10%) within the area	Common (> 10%) within the area.

Productivity: Productivity determines how rapidly a unit can recover from depletion or impact due to fishing.

	Aspect Attribute (s)	Concept and Rationale	Ranks 1 (low risk)	 2 (medium)	 3 (high risk)
	Productivity				
P1	Regeneration of fauna	Accumulation/ recovery of coral habitat to a mature successional state. Based on intrinsic growth and reproductive rates that are variable in different temperatures, nutrients, productivity.	< Decadal	> Decadal	>100 years
P2	Natural disturbance	Level of natural disturbance affects intrinsic ability to recover.	High (e.g.,volcanism, tidal flow environments)	Intermediate	No natural disturbance
P3	Naturalness	The historical level of trawl impact determines present status of benthic habitat (this is determined quantitatively by the number of trawls	High trawling effort (effort thresholds to be determined)	Medium effort	Low effort
P4	Proximity	Proximity is used as a surrogate for the connectedness of coral habitats in the context of species recruitment to trawled areas or patches of coral habitat.	close (<25 km)	(25-100 km)	isolated (>100 km)
P5	Export production to seafloor	Organic material from surface is beneficial to benthic community, especially filter feeders such as corals, and is unequally distributed.	High	Medium	Low

Each coral species or grouping of coral types will be scored against the criteria for each aspect. The average scores are then calculated for each attribute. An example is shown below (hypothetical only).

	Availability	Encounterability				Selectivity					Productivity				
Coral species	A1	E1	E2	E3	av	S1	S2	S3	S4	av	P1	P2	P3	P4	av
Species A	3	2	3	3	3	1	1	3	1	2	3	3	1	1	2
Species B	3	3	3	2	3	1	2	3	1	2	3	3	1	1	2
Species C	3	3	3	3	3	2	2	1	2	2	3	3	1	1	2
Species D	3	3	3	2	3	3	2	1	3	2	3	3	3	1	3
Species E	3	3	3	2	3	3	2	1	3	2	3	3	3	1	3
Species F	3	3	3	2	3	3	2	1	3	2	3	3	3	1	3
Species G	1	1	3	2	2	2	1	1	2	2	2	2	3	2	2
Species H etc	1	1	3	1	2	1	1	3	1	2	1	1	3	3	2

The values from the assessment will then be input to the ERAEF spreadsheet, and an overall risk level calculated (this is a combination of additive and multiplicative functions within susceptibility and productivity attributes). An example is shown below (hypothetical only).

Coral species	Productivity score (Average)	Susceptibility score (Multiplicative)	Overall Risk Value	Overall Risk Ranking
Species A	2.00	1.89	2.75	Medium
Species B	2.00	2.04	2.85	Medium
Species C	2.00	2.17	2.95	Medium
Species D	2.50	2.33	3.42	High
Species E	2.50	2.33	3.42	High
Species F	2.25	2.33	3.24	High
Species G	2.25	1.22	2.56	Low
Species H etc	2.00	1.19	2.32	Low

The risk index is then graphed as a PSA plot, as shown earlier in the methodology description (Figure 2). This results in a RELATIVE risk ranking. It is not an absolute measure of risk, as some of the criteria are comparative rather than based on definitive thresholds. However, the assessment is semi-quantitative, and will provide both an indication of whether such an approach is practical given the available information on corals, and whether this type of result will be useful to inform fisheries and environmental management.

Most of the assessment work will be done by NIWA staff, and does not require an expert-group workshop that is the approach under level 1 type assessments. However, a meeting of either the Technical Working Group, or a smaller meeting of relevant people, will be held to discuss the initial data, selections, and ranking before the assessment is finalised.

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