Habitat Suitability Modelling for Protected Corals in New Zealand Waters (POP2018-01)

Draft methodology report

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Objectives

• To carry out improved habitat suitability modelling for protected corals in the New Zealand region

• To help identify areas of risk from interactions with commercial fishing gear

Solenosmilia variabilis reef-like habitat forming scleractinian coral
Rationale

- Protected corals frequently occur as bycatch in NZ commercial fisheries (mainly bottom trawl)
- To determine the extent of the overlap between fishing and protected coral habitat, first we must determine the spatial extent of each
- Habitat Suitability Models – used to explore the relationship between point-sampled species occurrence records and sets of spatially continuous environmental variables
- We build on previous studies, incorporating new records, new regional environmental predictor layers from the NZ Earth System Model, and updated modelling approaches
- Resulting grids of predicted coral distributions (present and future) can then be used to more precisely define the risk to corals from fishing (and climate change); and inform resource management planning

*Keratoisis bamboo coral*
Habitat suitability modelling

Species occurrence records and maps of environmental variables

Map of probability of suitable habitat

Statistical model (including internal validation)
Environmental predictors

New Zealand Earth System Model (NZESM)

- Currently under development by NIWA
- Incorporates component models of ocean biogeochemistry and other aspects of biology and chemistry to provide a highly complex model of the climate system
- This ESM is specifically tuned to the New Zealand region of the Pacific and Southern Oceans
- Capable of producing projections for up to 200 years into the future (Williams et al. 2016).
### Environmental predictors

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Units</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seamount</td>
<td>Seamount positions in the New Zealand region</td>
<td>–</td>
<td>Rowden et al. (2008), Mackay (2007)</td>
</tr>
<tr>
<td>Slope</td>
<td>Seafloor slope derived from bathymetry</td>
<td>*</td>
<td>CANZ (2008), Hadfield et al. (2002)</td>
</tr>
<tr>
<td>Dissolved Inorganic Carbon</td>
<td>Seafloor DIC concentration</td>
<td>mol/m3</td>
<td>NZESM</td>
</tr>
<tr>
<td>Sea surface height</td>
<td>Sea surface height above geoid</td>
<td>m</td>
<td>NZESM</td>
</tr>
<tr>
<td>Bottom temperature</td>
<td>In-situ bottom temperature</td>
<td>Degrees C</td>
<td>NZESM</td>
</tr>
<tr>
<td>Aragonite concentration</td>
<td>Seafloor aragonite concentration</td>
<td>mol/m3</td>
<td>NZESM</td>
</tr>
<tr>
<td>Calcite concentration</td>
<td>Seafloor calcite concentration</td>
<td>mol/m3</td>
<td>NZESM</td>
</tr>
<tr>
<td>Nitrate concentration</td>
<td>Seafloor dissolved nitrate concentration</td>
<td>mol/m3</td>
<td>NZESM</td>
</tr>
<tr>
<td>Phosphate concentration</td>
<td>Seafloor dissolved phosphate concentration</td>
<td>mol/m3</td>
<td>NZESM</td>
</tr>
<tr>
<td>Oxygen concentration</td>
<td>Seafloor dissolved oxygen concentration</td>
<td>mol/m3</td>
<td>NZESM</td>
</tr>
<tr>
<td>Chlorophyll concentration</td>
<td>Seafloor total chlorophyll mass concentration</td>
<td>kg/m3</td>
<td>NZESM</td>
</tr>
<tr>
<td>Salinity</td>
<td>Seafloor salinity</td>
<td>g/kg</td>
<td>NZESM</td>
</tr>
<tr>
<td>Sediment</td>
<td>Percent mud or gravel</td>
<td>%</td>
<td>Bostock et al. 2018ab</td>
</tr>
</tbody>
</table>
Review of habitat suitability modelling

Commonly used methods

- Generalised Linear Models (GLMs and GAMs) (McCullagh & Nelder 1989, Hastie & Tibshirani 1990)
- Maximum Entropy (Maxent) (Phillips et al. 2006)
- Random Forests (RF) (Brieman 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)
New Zealand examples – deep-sea corals

*Goniocorella dumosa*
Tracey et al. (2011)

- BRT
- MBIE, MPI, NIWA

G. dumosa
New Zealand examples – deep-sea corals

*Taiaora tauhou*
Compton et al. (2013)

- BRT
- MPI, DOC, LINZ, NIWA

*T. tauhou*
Endemic solitary soft coral
New Zealand examples – deep-sea corals

Reef-forming scleractinians
Anderson et al. (2016a)

- BRT & MaxEnt
- SPRFMO region
- MBIE, MCI, NIWA
New Zealand examples – deep-sea corals

*Goniocorella dumosa*
Anderson et al. (2016b)

- BRT & MaxEnt (ensemble)
- Precision estimated
- NZ region
- MBIE, MCI, NIWA
New Zealand examples – deep-sea corals

*Solenosmilia variabilis*
Rowden et al. (2017)

- BRT & GAM & RF (ensemble)
- High resolution (25m²)
- Precision estimated
- Louisville Seamount Chain
- MBIE, MCI, NIWA
New Zealand examples – deep-sea corals

*Solenostomia variabilis*
Anderson et al. (2015)

- BRT
- Predicting present AND future distributions
- DOC, NIWA
Proposed methodology

Lessons learned from previous work

Recent model validation analyses indicated a general improvement in model reliability over time. The best-performing models were those:

- Developed for individual species rather than groups of species
- For frequently-recorded species rather than rare species
- With a more restricted spatial extent tuned specifically to local environmental conditions
- Based on real absence records rather than random background points (pseudo-absence data).
Proposed methodology

Coral presence/absence records

• Several years of additional records now available, from Observers, research surveys, and overseas institutes
• Records from shallower than 200 m will now be included
• The focus will be on producing models at the genus or species level
• Absence data will be based on research survey stations where the particular taxon was not caught
Proposed methodology

Selection of taxa to model

• Although models for grouped taxa may be less reliable, this needs to be balanced against limited resources to produce models for many individual species, and also the limited number of individual species with sufficient presence data

• Therefore if agreed, some models will be at the genus level and others the species level

• Models will be more complex than previous, limiting the total number possible
Proposed methodology

Prioritisation of taxa to model

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

Data

• Finalise selection of presence and absence data
• Finalise selection of environmental variables. A base set of predictors will be chosen for use in all models, modified by specific biological requirements of some taxa.

Models (for each method; BRT, RF)

• Run separate models by taxon, iteratively as necessary, to derive a residual autocorrelation variable (RAC) to account for spatial autocorrelation
• Estimate precision (bootstrapping)
• Assess model performance, as a cross-validated AUC value based on subsets of training/test data
• Produce final model using the full set of input data.
• Use model coefficients to produce two sets of prediction grids; present-day and 2120 AD
• Produce ensemble models by averaging predictions from contributing models, weighted by AUC and uncertainty
• Produce colour-coded maps of habitat suitability and model uncertainty for each modelled taxon and time period
Overlap between protected corals and bottom trawling

Current trawl footprint data obtained from published analysis (Baird & Mules in press)

- 5 km x 5km gridded data
- Provides both footprint (2D) and aggregated fishing effort (3D)
- Covers entire New Zealand EEZ
- Depth limited to 200–1600 m

- Visual matching of coral distributions with footprint/aggregated effort
- Overlap statistics calculated
  - E.g. fraction of cells with high habitat suitability (90% quantile) with high footprint area (>20 km²)
Acknowledgements

Thanks are extended to CSP, DOC for funding this Project POP2018-01)(NIWA Project Code DOC19301)