Relationships between Cold-water Corals off Newfoundland and Labrador and their Environment

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Abstract

Cold-water corals inhabit deep-water environments in many parts of the world, but the factors governing their distribution remain unclear. Effective cold-water coral conservation strategies depend on knowledge of their distributions, their ecology, and the threats they face. The main objective of this study is to quantify relationships between corals occurrence/abundance and six environmental parameters to determine how these parameters may control the distribution of cold-water coral species in the Northwest Atlantic region. Data for six environmental parameters and two types of coral bycatch data were obtained. These datasets were processed to obtain regularly gridded data of each parameter which were subsequently sampled at each recorded coral location to build a sufficient database for analysis. The Geographically Weighted Regression (GWR) technique, along with correlation analysis, was used. This research approach is beneficial, as other similar studies have not accounted for local or spatial variation in the relationships between coral species and environmental parameters as using GWR allows this study to do. The strongest associations between environmental parameters and coral were used to determine which variables to use in the GWR analysis. Other strong associations between variables were used to determine where cases of collinearity may exist. When using the Fisheries Observer Program (FOP) coral data, it was found that the local regression performed significantly better than the global regression in explaining the variance in the dataset. Also, the range in current velocity was found to be significant in explaining some of the local variation without being significant on a global scale. Using the Scientific Survey (SS) coral data did not show much improvement in the local regression over the global regression as did the FOP data. As found in previous studies, slope, on a regional scale, was the most significant parameter, but locally, the most important factors governing distribution were range in velocity and mean bottom temperature. Interesting areas or 'hot spots' were also observed through the visual analysis of important residuals.

Background and Relevance

Corals have been studied in oceans around the world since the mid 19th century (Bellwood *et al*., 2004), but most knowledge of corals is based upon warm water reef building coral species (Roberts *et al*., 2006). Cold-water corals inhabit much deeper environments and are hence harder to observe and sample. As a consequence, they have been studied less and there is still little known about them (Buhl-Mortensen and Mortensen, 2005; Gass and Willison, 2005). Although the existence of cold-water corals has been recorded by fishermen since the late 19th century, it is only recently that there has been more systematic research done to better understand the factors governing their distributions (Leverette and Metaxas, 2005). There has been more interest and accessibility to information on these cold-water species due to activities like natural resource exploration into deeper waters in recent years (Roberts *et al.*, 2006), as well as technological advances (e.g. Remotely Operated Vehicles).

Cold-water coral research is currently being performed in several regions of the world and with diverse research goals. Regions of study include the Northwest Atlantic (Bryan and Metaxas, 2007; Edinger *et al.*, 2007a; Wareham and Edinger, 2007; Mortensen and Buhl-Mortensen, 2005; Buhl-Mortensen and Mortensen, 2005; Reed *et al.*, 2005; Leverette and Metaxas, 2005), the Northeast Atlantic (Bryan and Metaxas, 2007; Entoyer and Morgan, 2005; Leverette and Metaxas, 2005), and the Northeast Pacific (Roberts *et al.*, 2005).

One of the goals of this research is to quantify the relationship between corals and fish habitats (Edinger *et al.*, 2007b; Etnoyer and Morgan, 2005; Buhl-Mortensen and Mortensen, 2005), as corals are thought to be an important habitat for fish and hence should deserve some level of protection. Another goal of these researchers is to monitor the vulnerability of marine life around cold-water corals using sensors and ocean floor photography (Roberts *et al.*, 2006). The distribution of cold-water corals is also being studied, as little is known about it (Gass and Willison, 2005).

One largely unknown fact about cold-water corals in the North West Atlantic region is how they relate to their environment. This involves the determination of which relationships deepwater corals share with individual environmental parameters (e.g. water temperature and salinity, substrate, current velocity), and which of these parameters most significantly influence corals occurrence and abundance. Generalisations about corals habitats have been made but few studies have quantified the relationships coral have with their environment.

Recently, a study which involved the prediction of the most suitable habitat parameters of two coral families (*Paragorgiidae* and *Primnoidae*) was conducted by Bryan and Metaxas (2005, 2007) on the Atlantic and Pacific Continental Margins in North America, using empirical and written data from interviews with local fishermen. This study used the program Biomapper[1] to produce habitat suitability maps. Biomapper uses the ecological niche factor analysis (ENFA) statistical technique (Bryan and Metaxas, 2007; Leverette and Metaxas, 2005). This technique is similar to a principal component analysis (PCA) except that the resulting components have direct ecological meaning (Bryan and Metaxas, 2007; Leverette and Metaxas, 2005). The study found that, on either side of the continent, corals lived within specific ranges of each of the environmental parameters used in the study (Bryan and Metaxas, 2007; Leverette and Metaxas, 2005). Slope and chlorophyll *a* concentration were reported to be the common factors in all of the top ranking combinations for each study area, and they report that temperature and currents were also present in many top ranking combinations (Bryan and Metaxas, 2007; Leverette and Metaxas, 2005).

As Bryan and Metaxas use a non-spatial method to determine which environmental parameters are of greatest importance in controlling the distribution of cold-water corals, the question of local spatial variation was ignored. The study presented in this paper uses non-spatial correlations along with Geographically Weighted Regression

[1] Further information pertaining to Biomapper can be found at: http://www2.unil.ch/biomapper/

(GWR), which enables the spatial drift of the regression parameters to be identified by looking at the data on a local level (Brunsdon *et al.*, 2001).

Methods and Data

Data have been collected from various sources. They include geological data about surficial sediments from digital and paper atlases, biological and environmental data provided by the Department of Fisheries and Oceans (DFO) Canada (Newfoundland and Labrador region) and bathymetric data from the General Bathymetric Chart of the Oceans (GEBCO). Each of the environmental parameters have been transformed into gridded datasets, if not originally in this format. The spatial extent of each of these datasets varied and played an important role in determining which of the coral data could be analysed with the appropriate environmental parameters.

The scientific survey (SS) data were obtained from the Department of Fisheries and Oceans (DFO). These surveys, which took place between 2003 and 2005, were conducted as part of a multispecies stock assessment and were sampled using a random-stratified technique. The corals found during these surveys were collected and later identified and recorded at Memorial University of Newfoundland (Edinger *et al.*, 2007). Two SS datasets were acquired for the purpose of this project. The first dataset only records presence/absence of corals while the second one also includes corals' biomass.

Fisheries Observer Program (FOP) data were also obtained from the Department of Fisheries and Oceans Canada. The FOP data, collected from 2004 to 2006, contain presence/absence records of coral caught accidentally (by-catch) during commercial fishing activities. These data were recorded by observers placed aboard vessels for the purpose of monitoring fishing activities and collecting biological scientific data. To obtain a quantitative measure, the data collected in 2004 to 2005 were normalized. The presence/absence data were converted to percentage of coral occurrence per cell of fishing effort.

Pairwise Pearsons' and Spearman's correlations have been performed using SPSS v.15 statistical software to quantify the relationship existing between (1) the environmental parameters and the coral abundance or presence/absence for both available datasets (SS and FOP), (2) corals and other coral species /groups and (3) environmental parameters and other environmental parameters. The coral datasets analysed consisted of FOP presence/absence, FOP percentages, SS presence/absence and SS biomass. The environmental parameters analysed were salinity (minimum, mean, maximum and standard deviation), temperature (minimum, mean, maximum and standard deviation), bottom velocity (mean and range), bathymetry, slope and surficial geology. These analyses were performed to identify the environmental parameters most strongly associated with coral occurrence/abundance that could be used in further analyses.

Analyses were then performed using Geographically Weighted Regressions (GWR) to establish relationship between corals and their environmental parameters. This technique also determines whether there is a locally significant explanation of the variation in the datasets that is greater than the variation explained by a global multivariate regression. The parameters selected as independent variables in the analysis are mean bottom temperature, slope and the range in current velocity. For this project, a Gaussian model was the one showing a best fit with the data. An adaptive kernel was chosen. The optimal bandwidth, which defines how many data points should be included in each calculation, was found to be 15 by running several trial regressions. Due to the elongated distribution of the data, including more points would have increased significantly the region analysed locally. GWR produces several types of statistics. These help to assess whether or not the local regression model is of significant improvement upon the global regression model. There is also an output which is readily viewable in a GIS to examine individual results at each data point, such as residuals and predicted values.

Results

The pair-wise correlation analyses between environmental parameters and corals identified bathymetry as the most significant environmental parameter overall, followed by temperature and salinity. The five coral groups all had significant associations between each other for one or more of the datasets analysed. Since almost all these associations were positive, it suggests that certain types of environment are more suitable for corals in general and where any coral is found, other species are likely to be found as well. The analysis performed in GWR showed that the technique may be suitable for predicting occurrences of corals but not coral biomass. The Monte Carlo simulation in GWR identified slope as the variable which explains the most variability in the data at a global scale. This result generally indicates that corals mostly occur on the continental shelf edge and the upper continental slope, which may indicate a relationship with local surficial geology as both parameters are related. Mean bottom temperature and the range of current velocity were the parameters controlling most of the variability at a local scale, whereas slope was not as important. As corals are found mainly on the continental shelf in the Northwest Atlantic, slope is likely to be the parameter which changes the most over a large study area. Therefore, when looking at the study area as a whole (i.e. on a global scale), the parameter which would seem to account for the most variability in the locations of coral would be slope.

The standardised residuals from the GWR model identified interesting outliers in two specific areas, the southwest Grand Banks and north of the Grand Banks (near Tobin's Point). These two areas have been identified as coral hotspots in the Northwest Atlantic region (Edinger *et al.*, 2007a, Wareham and Edinger, 2007). They are areas which are known to have greater coral occurrences and diversity. This may make them more susceptible to being positive outliers, which was found as an interesting result.

In areas where there are significant positive standardised residuals in the analysis of the FOP percentages, data may indicate that the model is slightly underestimating coral occurrence. The locations of significant negative standardised residuals indicate that there was a considerably greater number of corals estimated than observed. One possibility is that some estimates are in waters too shallow to have corals, even if the other parameters (i.e. temperature and velocity) are optimal for corals. Another possible explanation of these negative residuals is that there should be a higher occurrence of corals at these points, but due to prior extensive bottom trawling of these areas corals were depleted in abundance prior to the data collection. It has been concluded in studies, such as Gass and Willison (2005), that areas where bottom trawling has occurred on a regular basis have seen depletions in the amount of corals observed in those areas. Also, studies on the amount of by-catch of coral in commercial fishing activities have found that significant amounts of corals are disturbed by these activities (Krieger, 2001; Anderson *et al.*, 2003; Edinger *et al.*, 2007a). The amount of fishing effort documented in the FOP data used in this study can be seen in Edinger *et al.* (2007a) as maps of total fishing effort.

Conclusions

Few studies attempted to understand cold-water coral habitats using quantitative approaches. This study contributed by using pair-wise correlations and Geographically Weighted Regression (GWR) techniques to take into consideration spatial variation into the analysis. This study suggests that local spatial variability in environmental parameters seems to play a role in determining coral habitats while findings on the global scale coincide with previous studies.

When the data are analysed spatially on a local scale, slope is found to drop out as an important parameter. Range in bottom velocity and mean bottom temperature are important in explaining variation on a local scale, whereas previous works identified slope to be important parameter controlling corals' distribution (Metaxas & Bryan 2007). Interesting areas were identified through the analysis of standardised residuals. These areas coincided with previously identified coral hot spots in the study area region.

Although this study brings interesting results, several limitations should be raised. First, the analyses were performed using data spanning only two years in the FOP percentages dataset (2004 and 2005) and up to three years in the other datasets analysed. Unfortunately these are the only years available as corals have only recently been sampled. Also, due to the different spatial extents of the various datasets, the number of samples that could be used for statistics was limited. This resulted in a low number of samples used for calculation of the local statistics and results should hence be interpreted with caution. Finally, the FOP data are biased by fishing effort (Edinger *et al.*, 2007a; Wareham and Edinger, 2007) as their sampling is not random but is higher where commercial fishing is denser. It would be interesting to renew such a study in a number of years when the sampling of corals will allow a higher number of samples and increase the geographic coverage.

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