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Quantifying relationships between video observations of cold-water coral cover and seafloor features in Rockall Trough, west of Ireland

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ABSTRACT: Cold-water coral distributions are only partially understood even in the most well-studied areas. This is partly due to the only recent development of appropriate technology, and partly to the high cost and time associated with coral mapping, particularly in deep water. One way to optimise mapping is to develop predictive habitat models as proxies for the actual distribution of corals. These models may provide objective criteria for the selection of prioritised coral mapping areas. In this study, we quantified the relationship between observed cold-water coral distribution and terrain attributes as an important step in developing predictive habitat models. We estimated deep-water coral percentage cover from remotely operated vehicle video and demonstrate how such data can be used to examine quantitative relations between coral cover and terrain parameters (slope, aspect, rugosity and bathymetric position index) derived from ship-borne multibeam swath acoustic data. We show that, at carbonate mound provinces within sites on the Irish margin, coral abundance is correlated with terrain that is strongly sloping and irregular to a varying degree, depending on spatial scale. It is likely that terrain variations influence the hydrodynamic setting, resulting in a varying food supply. A similar approach may be applicable for other fauna in a variety of benthic environments.

KEY WORDS: Habitat mapping · Terrain analysis · Remotely operated vehicle · Carbonate mounds

INTRODUCTION

The dominant reef-framework forming scleractinian coral species in the northeast Atlantic Ocean is *Lophelia pertusa* (Rogers 1999). The scleractinian *Madrepora oculata* has also been recorded, but to a lesser extent, and forms thickets and/or rubbled facies rather than coral framework (Frederiksen et al. 1992, Freiwald 2002). In contrast, *L. pertusa* occurs as bushy skeletal colonies with the neighbouring colonies commonly growing together so that, over a timescale of thousands of years, they form reef-like structures often referred to as coral banks, bioherms or reefs (Mortensen et al. 2001, Freiwald 2002). This coral framework provides an important habitat for invertebrates and fish. Whilst most records of *L. pertusa* are from the North Atlantic Ocean, its geographical distribution ranges from 55° S to 71° N across a wide bathymetrical range from 39 to 3380 m (Mortensen et al. 2001) and it most commonly occurs in water with a temperature range of 4 to 12°C. Earliest records of *L. pertusa* were reported by fishermen (Le Danois 1948, Wilson 1979a). Recently, high-resolution video imagery has proved to be a useful tool in understanding the distribution and abundance of cold-water corals and the diverse habitats they are associated with. As well as providing spectacular imagery of the corals and revealing aspects of their biology, underwater video data offer a rapid, non-destructive method of sampling and *in situ* characterisation at remote locations. Several studies have

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described the extent of coral habitat specifically on carbonate mound features (Olu-Le Roy et al. 2002, Foubert et al. 2005a, Grehan et al. 2005, Wheeler et al. 2005a), which are considered to be particularly important in relation to cold-water coral ecosystems (van Weering et al. 2003). The factors controlling cold-water coral distribution are only partially understood, but substrate type and hydrographic conditions influenced by seabed topography are considered to be important (Frederiksen et al. 1992, Mortensen et al. 2001, Reed et al. 2006). On the Atlantic Ocean continental margin off Ireland, video surveys have been concerned with the validation of seafloor features previously observed in acoustic data, relevant for understanding sedimentary processes at carbonate mounds (Foubert et al. 2005b, Huvenne et al. 2005, Wheeler et al. 2005b). Existing video observations have provided fundamental qualitative information on the extent of the cold-water coral habitat and suggested the corals' preference to occupy particular locations on the seabed. However, quantitative assessments of cold-water coral abundance from video data in deep water have only been attempted in a few studies (Mortensen et al. 1995, Mortensen & Buhl-Mortensen 2004a,b). Consequently, deep-water coral distributions, even in the most well-studied areas in the world, are only partially understood. It is therefore not surprising that little is known of the abundance of cold-water corals in our study area in the Rockall Trough, even though this deep-water channel to the west of Ireland has been the focus of several surveys investigating the cold-water coral ecosystem (Kenyon et al. 2003, Masson et al. 2003, van Weering et al. 2003). One way of overcoming the paucity of data on coral distribution is to develop predictive habitat models as proxies for the actual distribution.

The availability of swath acoustic technology for acquiring seabed bathymetry (e.g. de Moustier 1988) has prompted studies using digital terrain models (DTMs) to explore relationships between seafloor terrain and the distribution of benthic species (Van de Beuque et al. 1999, Kostylev et al. 2001, Kenny et al. 2003, Parnum et al. 2004). Benthic habitats are usually delineated using a combination of acoustic remote sensing, video data and benthic sampling information, and classified according to geological and geophysical features (Greene et al. 1999, Kostylev et al. 2001, Anderson et al. 2002, Kenny et al. 2003, Parnum et al. 2004, Jordan et al. 2005, Kostylev et al. 2005). This approach to mapping has achieved widespread recognition as a partial solution to understanding habitats in a range of water depths (Paull et al. 2000, Kostylev et al. 2001, Mortensen et al. 2001, Mortensen & Buhl-Mortensen 2004b).

The present study focuses on a method for quantifying the distribution and abundance of cold-water corals from video data, acquired with a remotely operated vehicle (ROV), and establishing their relationship with terrain attributes derived from ship-borne multibeam swath acoustic data. The specific research goals were to: (1) present a method for quantifying coral cover (in %) in video frames recorded with an ROV flown at varying altitudes above the seabed; (2) characterise cold-water coral habitat from underwater video data acquired at carbonate mounds in the Rockall Trough; and (3) quantify the relationship between coral cover and terrain parameters at different spatial scales as a first step towards developing predictive habitat models. Whilst we restricted ourselves to corals on carbonate mounds in the Rockall Trough (Fig. 1), we suggest that the approach may be adapted for other fauna in a variety of deep-sea benthic environments.

MATERIALS AND METHODS

Study areas. The Rockall Trough has been described in terms of its ocean water circulation (Holliday et al. 2000, New & Smythe-Wright 2001), deep sea biology (Wilson 1979b, Gordon 2003) and geomorphology (Kenyon et al. 2003, Masson et al. 2003, van Weering et al. 2003). The present study utilised data from ROV habitat mapping surveys conducted at 2 carbonate mound locations in the southeast Rockall Trough (13° 58.241′ W, 53° 46.472′ N, R1) and southwest Rockall Trough (15° 40.139′ W, 55° 32.521′ N, R2).

R1 study area: Carbonate mounds at R1 (Fig. 2a) occur in water depths ranging from 650 to 900 m aligned along a northeast–southwest trend at the upper slope; the tallest mounds are ~200 m higher than the seafloor with a base length of 1500 m (Kenyon et al. 2003, van Weering et al. 2003). Seismic reflection studies have identified current-scoured moats at the base of the mounds, with sediment tails in the direction of currents flowing upslope established on the lee side (van Weering et al. 2003). The seafloor between mounds is characterised by reworked coral debris and fragments with gravel and boulders, which are interpreted as evidence of the erosive nature of vigorous bottom currents (van Weering et al. 2003).

R2 study area: In the R2 area, the mounds are of variable shape and dimension and occur at the upper slope of the southwest Rockall Trough between 500 and 1200 m water depth (Fig. 2b). The mounds are topographically complex and separated from each other by valleys and gullies. Small mounds in the province with base diameters of 2 to 3 km occur as steep pinnacles rising up to 300 m above the seafloor. A number of mounds with a base diameter of ~15 km are aligned parallel to the bathymetric contours (van Weering et al. 2003). The seafloor between mounds is characterised

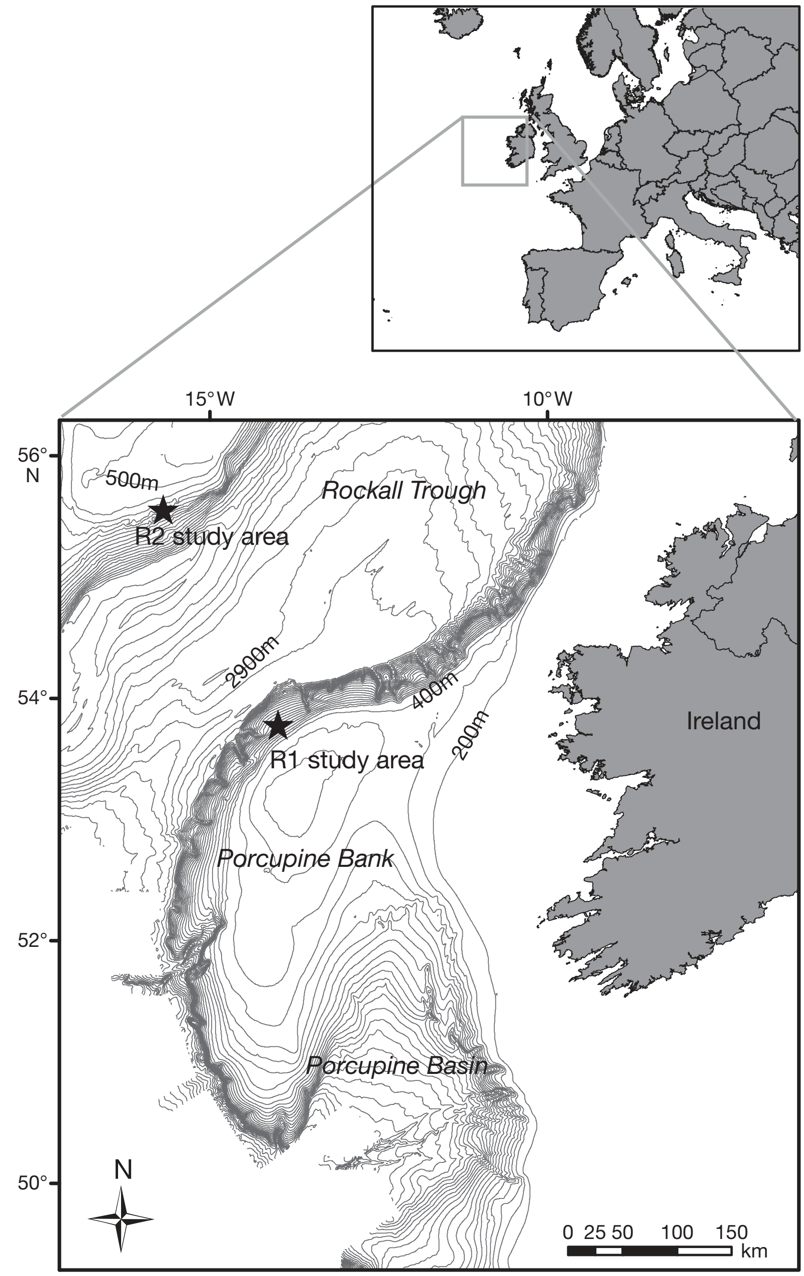


Fig. 1. Rockall Trough, northeast Atlantic Ocean. Study areas R1 and R2 are indicated by stars and were the focus of ROV multibeam and video surveys on board the RV 'L'Atalante' in 2001

by carbonate coarse grained debris and winnowed glacial sediments (van Weering et al. 2003).

Data acquisition and analysis. ***Multibeam swath acoustic data:*** The ship-borne multibeam bathymetric data used in this study were acquired by the Geological Survey of Ireland as part of the Irish National Seabed Survey (GOTECH 2002). Bathymetric data were processed using industry-standard software according to the SP44 Order 3 accuracy requirements of the International Hydrographic Organisation. The bathymetric data for the R1 and R2 study areas (Fig. 2) were georeferenced to the World Geodetic System 1984 ellipsoid, converted to coordinates (in metres) within Zone 28N of the Universal Transverse Mercator projection and data were gridded with a cell size of 30 m.

ROV-based video data: Two video surveys were conducted using IFREMER's ROV 'Victor 6000' within a depth range of ~600 to 900 m at each of the study sites (Olu-Le Roy et al. 2002). Video data were recorded with colour video cameras positioned in vertical and oblique views. A broadcast quality Panasonic AWE-650 SDI recorded the seabed vertically below the ROV, whilst a second camera recorded video from the oblique view. Video frames were captured at 5 s intervals, using the software ADÉLIE developed by IFREMER for underwater vehicle data post-processing, and stored as JPEG images for subsequent analysis. To ensure high quality imagery, the surveys were conducted at an altitude of ~3 m above the seafloor and a vehicle speed of 1.5 km h^{-1}.

Quantification of coral cover: The extent of cold-water coral distribution is usually defined in terms of % coral cover. The cover can be conveniently estimated using the point quadrat method, which relies on recording species presence at designated points in contact, either directly or as photographic counts, with the species. The present study estimated the % cover of the scleractinian cold-water coral *Lophelia pertusa* from video data acquired at the study areas. Due to strong benthic currents and variable local bathymetry, the ROV altitude varied between 1.5 and 5 m during video acquisition, thus affecting the field of view of video imagery. In order to derive % live coral cover, a standard window (quadrat) containing random points for the cover analysis was assigned to a video frame. This was calculated with information on the size of the camera detector, camera-to-target distance (related to ROV altitude) and focal length of the lens. The window (1.9 × 2.9 m) used in the present study was based on the calibration of an image acquired from the minimum altitude (1.5 m). The % coral cover was derived for a quadrat using Coral Point Count with Excel extensions (Kohler & Gill 2006), developed for studies of tropical corals.

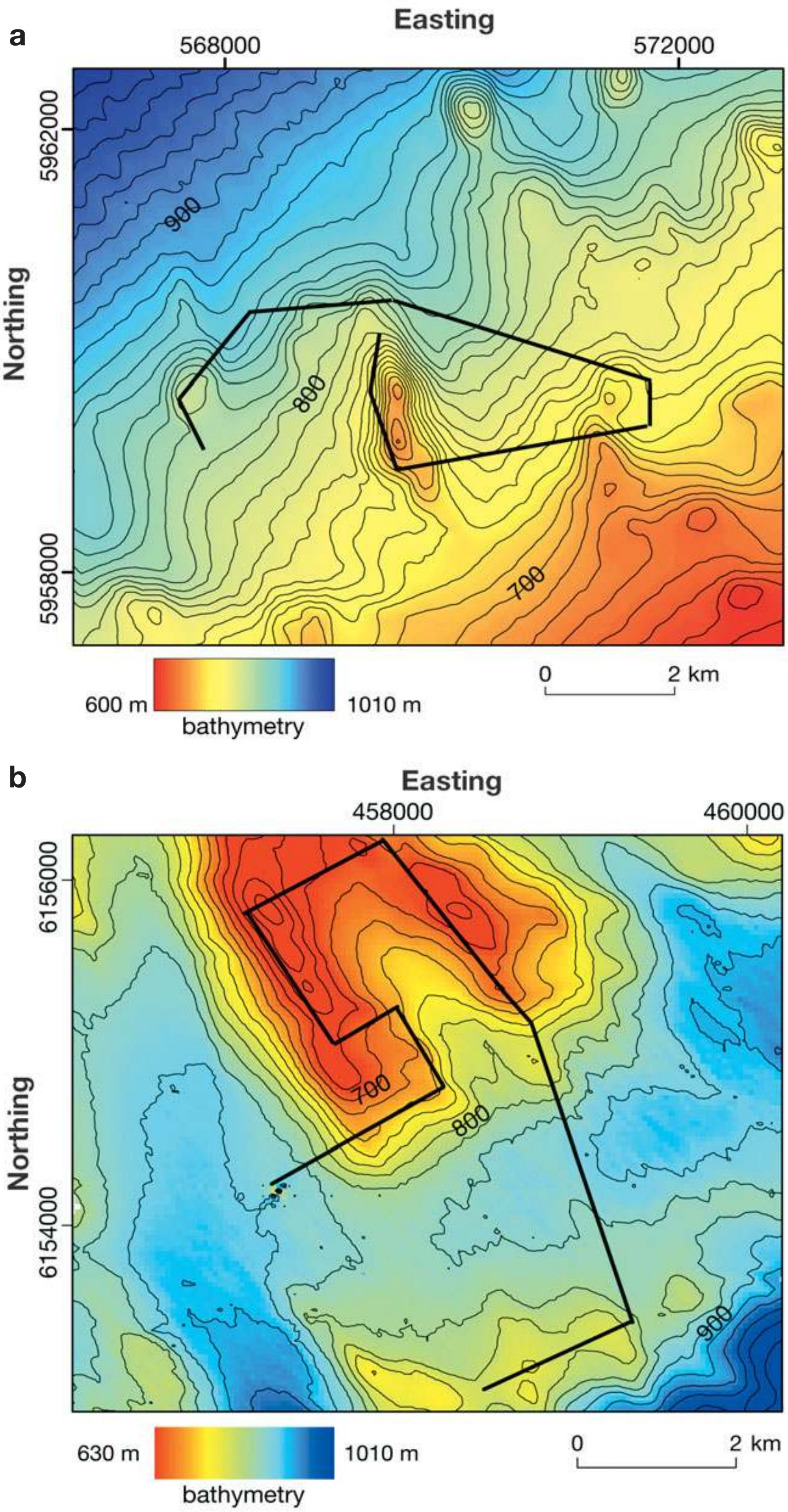


Fig. 2. Study areas R1 (a) and R2 (b) at carbonate mound locations in the Rockall Trough, west of Ireland. The black lines represent simplified versions of complicated navigation tracks that show the approximate locations of the ROV-based video data used in this study. Contour intervals (a) 10 m and (b) 20 m. UTM Zone 28N (WGS84)

We tested random point overlays of 36, 21, 16 and 9 points per quadrat on individual video frames. It was impractical to use more than 21 points given the size of the quadrat assigned because the high density of markers obscured the image so that coral identification was impaired. The percent cover estimates for 21, 16 and 9 points per quadrat were compared using an analysis based on Pearson's product–moment correlation (Zar 1999). This indicated little change in the accuracy of the percent cover estimate with data extracted at 21, 16 or 9 points per frame. The Pearson's product–moment correlations between percent cover estimates derived using 9 points and estimates derived using 16 or 21 points per frame were $r > 0.95$ with $p < 0.001$, suggesting that there was a <0.1% chance that the results arose from a random distribution. This is similar to the result of Stevens (2003). Therefore, to ensure efficiency in the analysis, percent cover data for the entire video data set were extracted at 9 points per quadrat on video frames sampled every 5 s (corresponding to a transect distance of ~1.3 m).

Terrain analysis and benthic habitat: Multiscale terrain analysis of the seabed is recognised as a valuable tool for delineating regions that provide a distinct habitat and thereby support a particular fauna. Wilson et al. (2007) provide a comprehensive summary of terrain parameters derived from multibeam acoustic data which may be used for deep sea benthic habitat mapping. In these surveys, the DTM resolution (cell size or area on the seabed represented by a single pixel in the DTM) is a function of the swath acoustic multibeam transmitter design, the physics of propagation of sound through the water column and the depth of water. Terrain parameters vary continuously over the seafloor (e.g. Herzfeld & Overbeck 1999, Albani et al. 2004), but the limited resolution of the bathymetric data means that they represent average values over an area of seafloor. The size of this area determines the scale of measurement and should be selected based on the scale relevant to the phenomena under study (Albani et al. 2004). In practice, benthic faunal composition often varies over distances smaller than the spatial resolution of ship-borne multibeam data and video observations also generally represent areas smaller than a DTM cell.

Video surveys have documented cold-water corals and other benthic fauna on fine-scale (~ 5 cm to 1 km) features such as sand ripples and dropstones as well as broad-scale terrain features (>1 km) such as carbonate mounds (De Mol et al. 2002, Kenyon et al. 2003, Wheeler et al. 2005a). The range of broad- and fine-scale terrain features influencing the distribution of cold-water corals requires that we use a multi-scale terrain analysis approach to investigate the relationships between coral abundance derived from ROV video data (typically at spatial scales of ~2 to 3 m) and seafloor terrain attributes derived from ship-borne acoustic data (corresponding to a minimum cell size of 30 m in this study). We employed ESRI's Spatial Analyst extension in ArcGIS to aid the computations in 2 analysis windows equal to a ground distance of 90 × 90 m or 270 × 270 m and centred at the same point.

'Slope' is defined by a plane tangent to a DTM surface at the centre of an analysis window. Slope is thought to influence animal distribution on the seafloor because it is linked to the local hydrodynamic regime with benthic currents sweeping upslope at seamount peaks, providing a source of food to sessile suspension feeders (Burrough & McDonnell 1998). Current velocities are typically strong along the slope as are internal tides (Genin et al. 1986, Huthnance 1986). White et al. (2005) reported how processes such as diurnal tides and Taylor column formation promote the retention of organic matter over banks in the Rockall Trough, promoting food availability to animals that occupy the lower flanks of the banks and carbonate mounds.

The 'aspect' or orientation of seabed terrain is the azimuthal direction of the steepest slope at the centre of the analysis window. Its influence on benthic community structure is also likely to be a consequence of local and regional hydrodynamics where benthic currents, steered by the seabed terrain, supply food, especially for suspension–feeding fauna (Gage & Tyler 1991). The relationship between aspect and coral cover can be most easily quantified by transforming aspect (Roberts 1986) into 2 variables, 'northness' and 'eastness', a technique employed in predictive modelling studies (Hirzel et al. 2002, Wilson et al. 2007). The transformation was performed using ArcMap's raster calculator, where northness (cosine of aspect) and eastness (sine of aspect) provide continuous measures of orientation in the range of –1 and +1. A northness value of +1 corresponds to a slope from shallow to deep water facing due north while an eastness value of –1 corresponds to a slope from shallow to deep water facing due west.

Terrain 'rugosity' or relief accounts for much of the observed variability governing the spatial distribution of benthic habitat because fauna are often associated with changes in geomorphological features (Brown et al. 2002, Edwards et al. 2003). Measures of rugosity have been derived to quantify species distribution and biodiversity in relation to features of the terrain (Brown et al. 2002, Edwards et al. 2003). Rugosity analyses presented here are based on Iampietro & Kvitek (2002), Jenness (2002), Kvitek et al. (2003), Iampietro et al. (2004) and Lundblad et al. (2006), implemented in ArcGIS within the Benthic Terrain Modeler (BTM) tool (Lundblad et al. 2006).

The bathymetric position index (BPI) is a second order derivative of bathymetry and the marine equivalent of the topographic position index used in terrestrial landscape studies (Weiss 2001). The BPI provides an indication of whether any particular pixel in the seabed DTM forms part of a positive (e.g. crest) or negative feature (e.g. trough) of the surrounding terrain. Our calculations were performed in the ArcGIS raster calculator according to the methods described by Lundblad et al. (2006).

Statistical analysis. Linear regressions were employed to explore the correlation between the coral cover (dependent variable), and the terrain attribute (independent variable). Coral cover was averaged from all video frames sampled along transects within an analysis window nominally located at the centre of the video frame. This method of quantifying coral cover implies a definition of 'coral presence' in the analysis window when the area covered by all video frames contained at least 10% of frames with some coral cover. The terrain attribute was computed at the centre of the analysis windows containing 3 × 3 DTM cells. These windows were either 90 × 90 m, corresponding to the highest resolution (30 m DTM cells) available in the multibeam data, or 270 × 270 m to test correlations at a broader scale; the latter window was derived by first computing the arithmetic mean of the bathymetry in sub-windows consisting of 3 × 3 DTM cells (30 m resolution).

Following the analysis of the video data using Coral Point Count software, a transformation (Aitchison 1986) was applied to the % coral cover data, e, to produce a logarithmic % coral cover, $\acute{e}$. We used the transformation $\acute{e} = 0.5 \log_{10} (1 + e)$ because it converts percent data (in the range 0 to 99) to the range 0 to 1 and decreases the relative importance of high % coral cover values. The correlations between coral cover and each terrain parameter (slope, rugosity, northness, eastness and BPI) at each analysis scale (90 and 270 m) were quantified by the coefficient of determination, r^2 (0 = no correlation, 1 = perfect correlation).

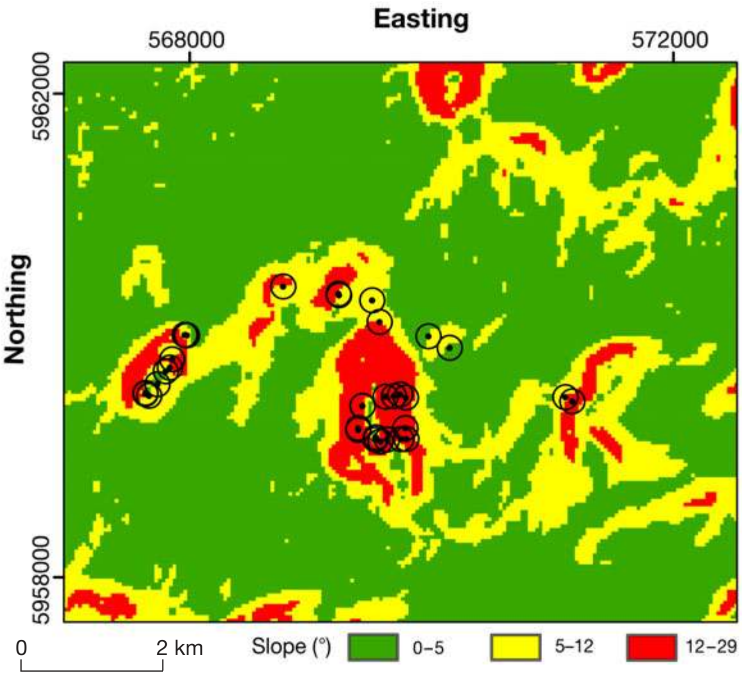


Fig. 3. Study area R1. Coral presence (circles) and slope, calculated at the 90 m analysis scale

RESULTS

Coral cover and terrain parameters

The locations of coral presence and the correlations between coral cover and terrain parameters calculated at the 90 m analysis scale for each study area are illustrated in Figs. 3 to 10. All map co-ordinates are referred to UTM Zone 28N.

For the R1 study area, the highest slope values (>12°) were recorded from the upper flanks and near the summit of carbonate mounds while intermediate slope values (5° to 12°) were associated with the mid- to lower mound flanks, and slope values <5° were characteristic of the seafloor at the inter-mound area. Coral cover tended to increase with increasing slope. A clear correlation between % coral cover and aspect at R1 is not discernible in Fig. 4, although the corals may have a slight preference for east-facing terrain. As shown in Fig. 5, the highest rugosity values (1.03 to 1.15) at the site were associated with the upper mound flanks and mound summits at the carbonate mounds. Lowest rugosity values (1 to 1.03) were associated with the flat inter-mound areas and lower mound flanks of the carbonate mounds. High % coral cover tended to be associated with higher rugosity values (i.e. >1.06). Finally, the highest positive BPI values at R1 were recorded from mound summits, while lower positive BPI values (~1 to 4) were associated with the mid- to lower flanks of the carbonate mounds (Fig. 6). A high % coral cover was associated with BPI values >2. Low coral cover occurred at locations with negative BPI values, suggesting that depressions in this area support but are not favourable for coral colonisation.

In the R2 study area, the highest % coral cover was associated with slopes of ~10° to 30° (Fig. 7). There was no discernible relationship between % coral cover and terrain orientation (northness and eastness) at R2 (Fig. 8). High rugosity values were associated with the mid- and upper-mound flanks of the carbonate mounds (Fig. 9). High % coral cover was associated with rugosity >1.25 and low % coral cover with rugosity <1.25, which is characteristic of the inter-mound areas. A few corals were found on dropstones in areas with rugosity <1.03. Fig. 10 illustrates that highest positive BPI values at R2 were recorded from mound summits while lower positive BPI values were associated with the mid- to lower flanks of the mounds. A high % coral cover was associated with BPI > 100; a significant minority of low % coral cover occurs in depressions with BPI < –14 (Fig. 10b).

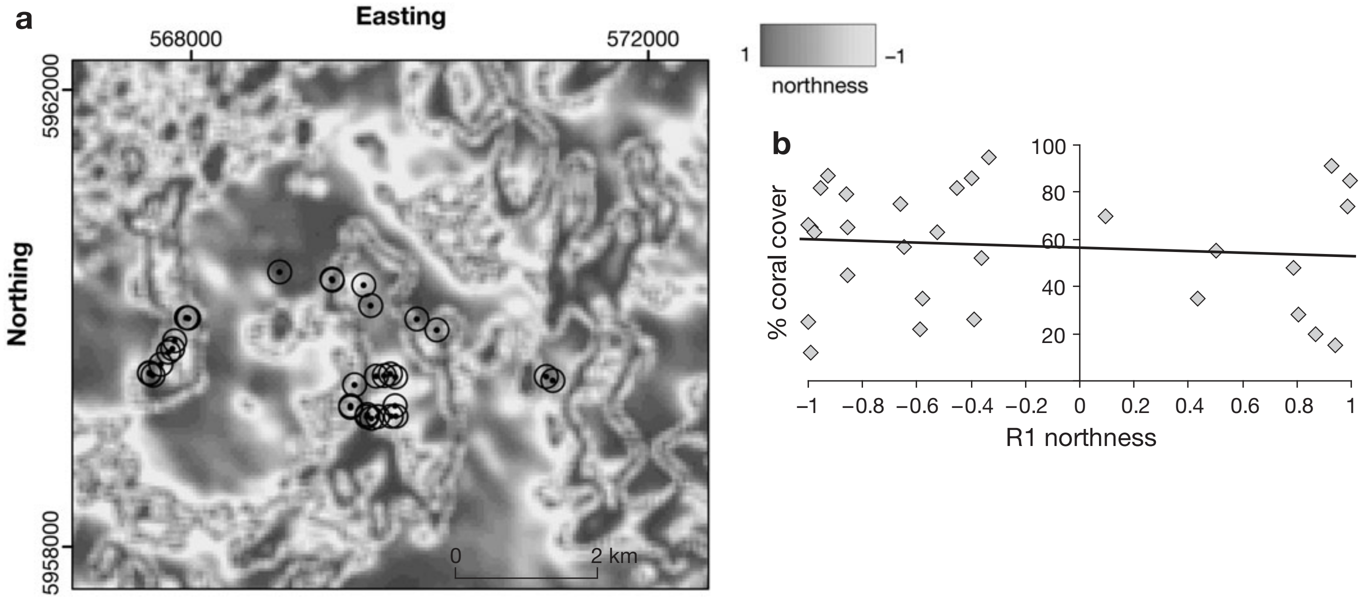
Correlation between coral cover and terrain parameters

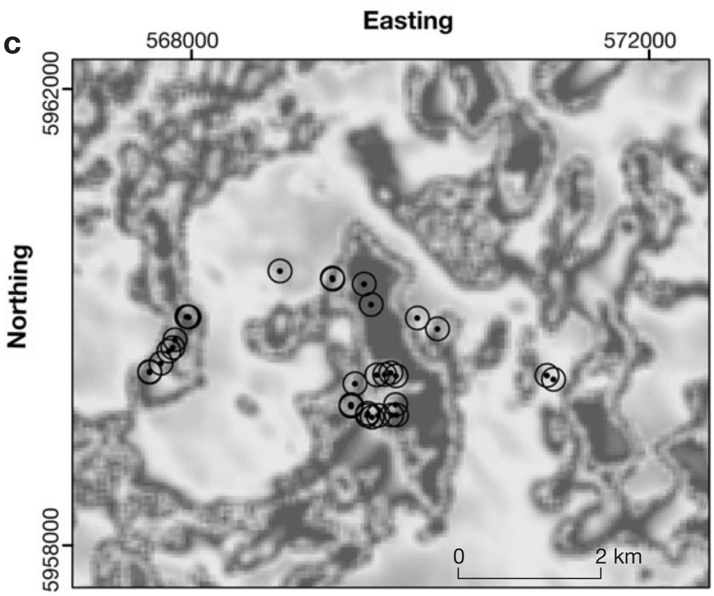
The significance of the correlations of % coral cover with all terrain attributes at the R1 and R2 study areas was $p < 0.001$. The correlations were variable (Table 1). For example, at the 90 m analysis scale the correlation between coral cover and slope was $r^2 = 0.72$ for R1 and $r^2 = 0.30$ for R2, whereas at the 270 m scale there is a stronger correlation ($r^2 = 0.94$ for R1, $r^2 = 0.80$ for R2) for both areas (Fig. 11).

DISCUSSION

Quantification of coral abundance from ROV video

The method presented here offers a rapid and efficient approach to quantifying coral abundance from ROV video data that can be easily compared with other studies (Grehan et al. 2005). It is essential to have vertically downward-looking cameras to facilitate estimates of coral abundance. The method may be also applied to perform cover estimates of other non-motile benthic species, e.g. sponges, in a variety of benthic environments.





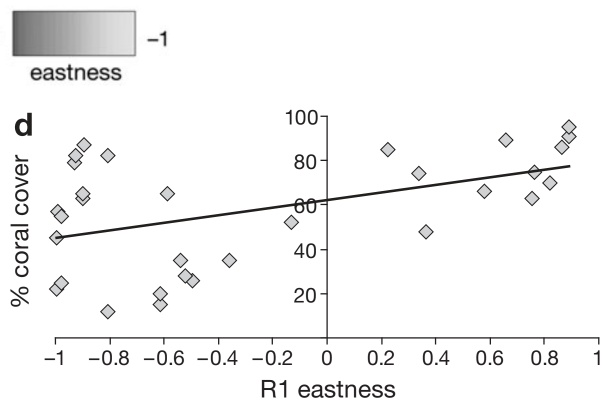
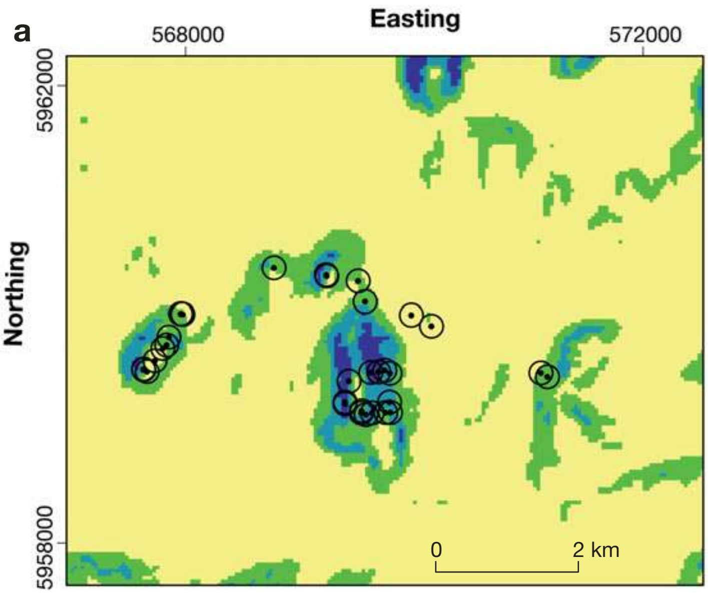


Fig. 4. Study area R1. Coral presence (circles) and aspect: (a) northness and (c) eastness, calculated at the 90 m analysis scale. Scatter plots for (b) northness and (d) eastness show the relationship between % coral cover and aspect

Table 1. Correlations between % coral cover and terrain attributes. r^2: coefficient of determination for the log-linear regression. σ: standard error in % coral cover estimated from the regression. All correlations are highly significant ($p < 0.001$). BPI: bathymetric position index

Analysis	Scale	90 m					270 m				
		Slope	Rugosity	Northness	Eastness	BPI	Slope	Rugosity	Northness	Eastness	BPI
R1	r^2	0.72	0.80	0.50	0.40	0.68	0.94	0.90	0.56	0.52	0.90
	σ	24	20	26	23	20	14	13	19	15	12
R2	r^2	0.30	0.55	0.22	0.27	0.72	0.80	0.85	0.38	0.40	0.88
	σ	28	19	28	29	14	15	15	20	18	10



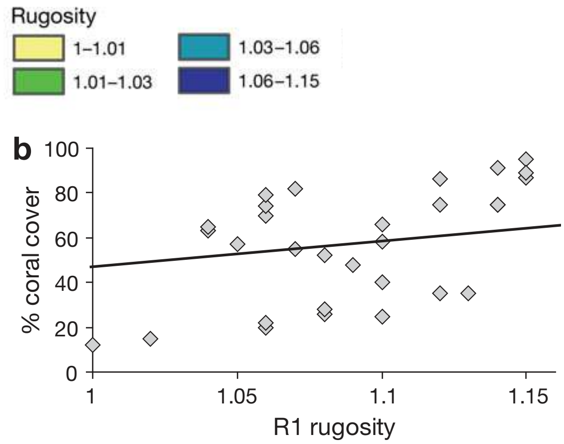
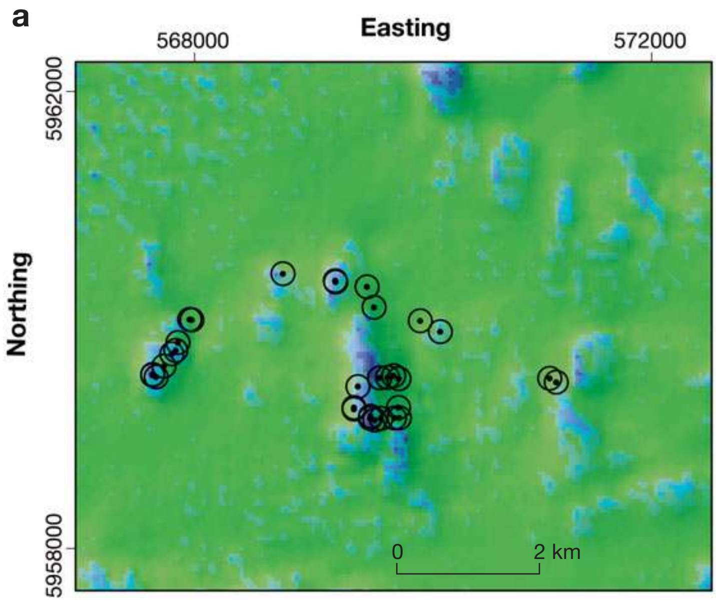


Fig. 5. Study area R1. (a) Coral presence (circles) and rugosity, calculated at the 90 m analysis scale. (b) Relationship between % coral cover and rugosity



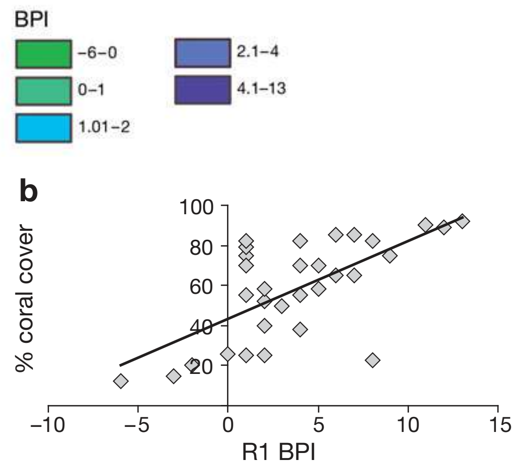


Fig. 6. Study area R1. (a) Coral presence (circles) and bathymetric position index (BPI), calculated at the 90 m analysis scale. (b) Relationship between % coral cover and BPI

Relationships between terrain and cold-water coral cover

We demonstrated quantitative relationships between the abundance of cold-water corals and seabed terrain parameters using ship-borne multibeam acoustic data and ROV video imagery. The data illustrated in Figs. 3 to 10 indicate that (1) the higher coral abundances observed at the R2 study area compared with the R1 study area reflect the higher values of BPI, rugosity and slope at R2; (2) high coral abundances tend to be associated with rough bathymetric highs near mound summits; and (3) some corals are found in bathymetrically rough depressions. Table 1 shows that coral abundance (1) is better correlated with BPI, rugosity, slope and aspect at an analysis scale of 270 m than it is at a scale of 90 m; and (2) increases as BPI, rugosity or slope increases.

There are limitations to our analysis. First, we restricted our computations of terrain parameters to 2 spatial scales (90 and 270 m), which may not capture broader-scale terrain features (e.g. continental margin slope) affecting cold-water coral distribution. The correlation between coral cover and aspect is weak at the

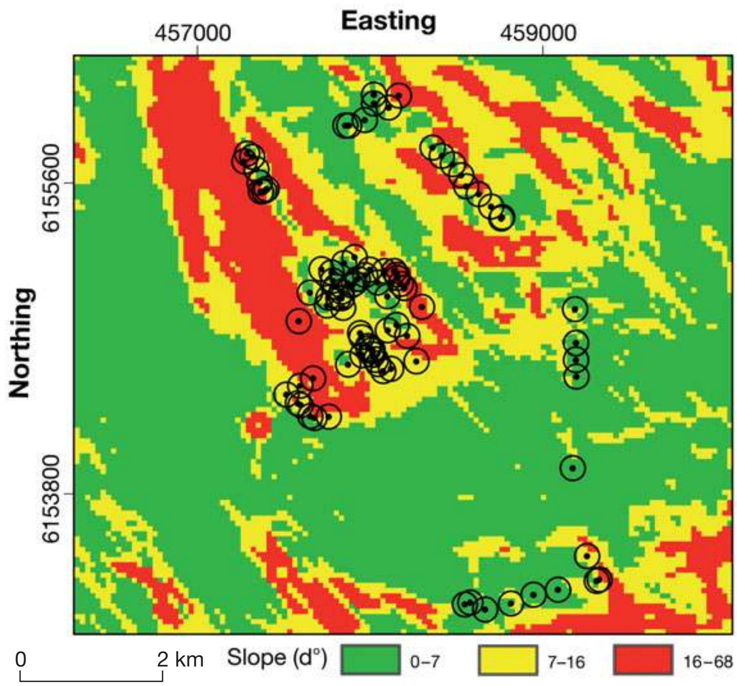


Fig. 7. Study area R2. Coral presence (circles) and slope, calculated at the 90 m analysis scale

90 m analysis scale but higher at the 270 m scale, suggesting the possibility of stronger correlations between coral cover and aspect at even broader scales. Second, we recognise that other key environmental variables operating at broader spatial scales are likely to play a role in structuring coral distribution at our study sites. These include the availability of food, e.g. in the form of plankton falling from the photic zone of the water column (Greene et al. 1999), suitable substrate for planula settlement (Kiriakoulakis et al. 2004), and sediment–animal relationships and water mass characteristics such as the biogeochemical regime, oceanic temperature and current strength (Rogers 1999). Third, the resolution (30 m DTM cell size) of the ship-borne swath bathymetry data for water depths >500 m is not suitable for the computation of terrain parameters at a scale relevant for the classification of macro- and microhabitats (1 to 10 m) (sensu Greene et al. 1999). This limitation in bathymetric resolution in the deep sea can only be addressed by flying swath acoustic instruments closer to the seabed with the aid of ROVs or autonomous underwater vehicles (Grehan et al. 2005).

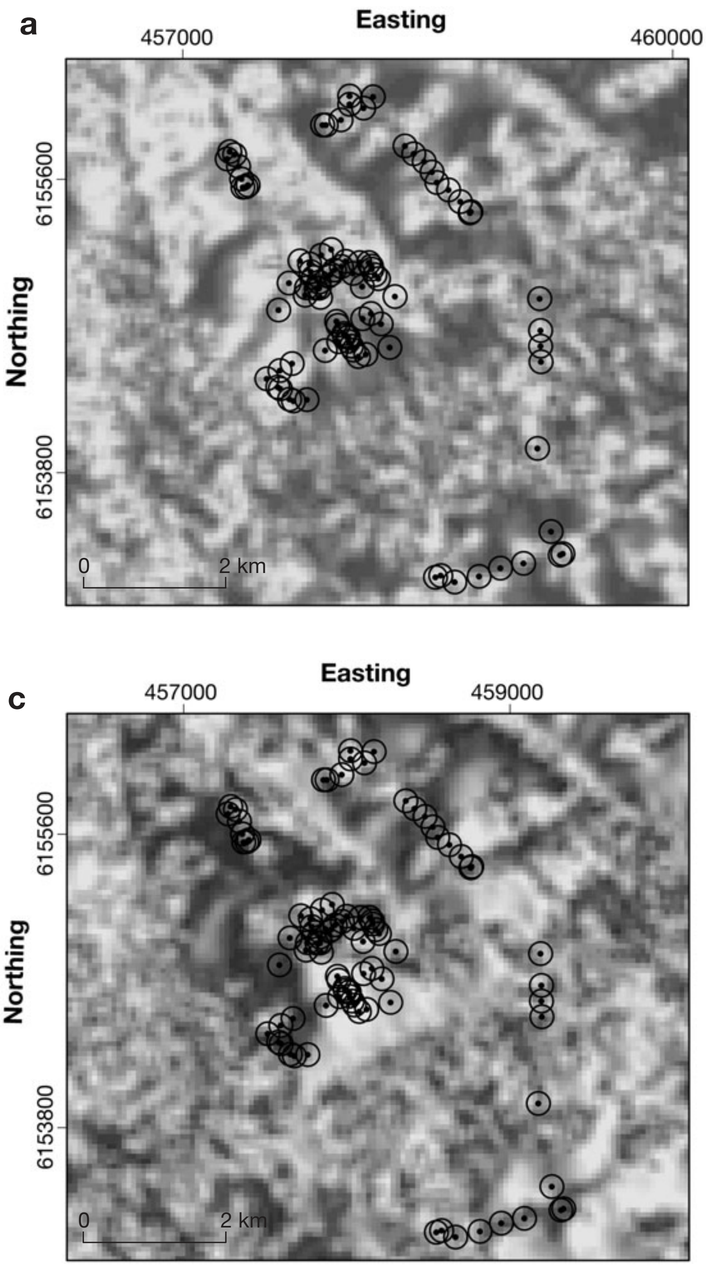
Despite the differences in terrain at our 2 geographically distinct study sites, our results indicate that coral cover is influenced by the same terrain parameters. This suggests that the approach could provide the basis for predicting the distribution of cold-water corals in other areas.

Implications for cold-water coral habitat

The distribution of cold-water corals on carbonate mounds is correlated with terrain parameters because (1) the carbonate mounds are topographically complex highs (Kenyon et al. 2003, Masson et al. 2003, Van Rooj et al. 2003, van Weering et al. 2003); and (2) the terrain steers benthic currents that act as proxies for the supply of food and sediment distribution. Slope is a proxy for higher velocity currents at mounds and hence the supply of food to suspension-feeding organisms (Frederiksen et al. 1992, Dorschel et al. 2005). This is corroborated by our analyses at R1 and R2, where high abundance of coral cover is associated with high slopes, particularly at the 270 m scale.

Coral occurrences are also strongly associated with bathymetric highs corresponding to large positive BPI and rugosity values, both significant factors in describing habitat complexity and its effect on the spatial distribution and density of epifaunal organisms (Brock et al. 2004). Local benthic currents, enhanced by the presence of pinnacles and scarps at the R2 study area, are likely to provide conditions suitable for prolific coral growth, for example through a stable supply of nutrients to the corals. Our analysis also indicates that some corals occur in rough bathymetric depressions (e.g. channels). This has also been reported for pockmark-dwelling *Lophelia* spp. reefs off central Norway by Hovland et al. (2005) and by the Norwegian seabed mapping programme MAREANO (www.mareano.no) in deep parts of a trench off Norway. Our video data corroborate previous results that show low coral abundances on ice-rafted debris such as dropstones and boulders over flat (at the resolution available from the ship-borne multibeam data) terrain.

Aspect provides information on the exposure of seabed terrain to local and regional currents and may be important in shaping benthic habitats, especially for suspension-feeding fauna (Gage & Tyler 1991). In this study, aspect calculated using windows of 90 × 90 m is weakly correlated with % coral cover at R1 and R2, but the correlation improves at the broader scale (270 × 270 m), with % coral cover showing a preference to occupy south-facing terrain. It is likely that aspect integrates the effect of differences in current velocity (and hence food supply) over scales of 100s of meters to kilometers, suggesting that a minimum scale length for currents of ~100s of metres is necessary to supply food particles to support coral growth.



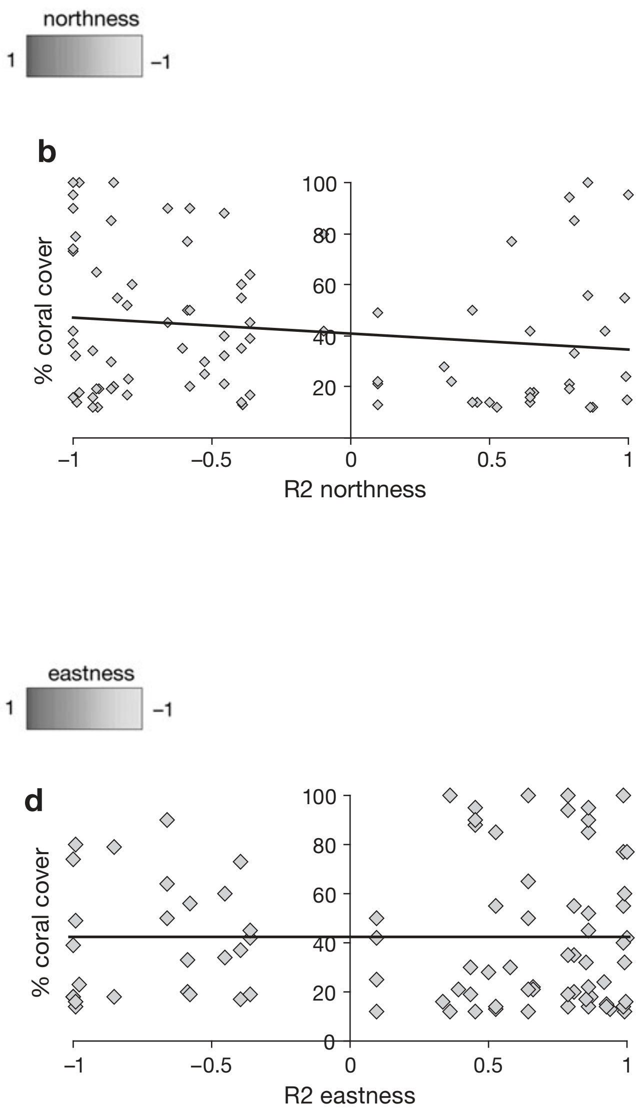
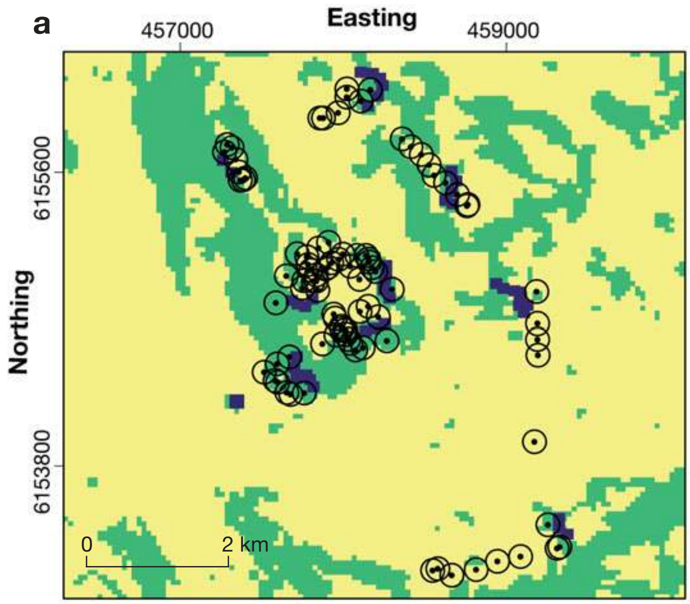


Fig. 8. Study area R2. Coral presence (circles) and aspect: (a) northness and (c) eastness, calculated at the 90 m analysis scale. Scatter plots for (b) northness and (d) eastness show the relationship between % coral cover and aspect

CONCLUSIONS

This study successfully used the software Coral Point Count to estimate % cover of deep-sea corals from ROV-acquired video data. It provided the basis for demonstrating a quantitative link between coral distribution and terrain parameters that were generated from the analysis of ship-borne multibeam bathymetry data. Our results highlight the correlations between coral abundance and some of the terrain parameters (rugosity, BPI and slope) that can be readily derived from high-resolution bathymetric data. The relationships between % coral cover and terrain parameters are scale-dependent, implying that future analyses must focus on identifying the most biologically relevant scales. The relationships are useful for optimizing mapping strategies and developing habitat suitability (predictive) models, but further work is required to understand the role of other environmental factors, particularly fine- and broad-scale hydrodynamics, in controlling cold-water coral distribution. Such data will contribute to providing a full ecological niche analysis of cold-water coral habitat.



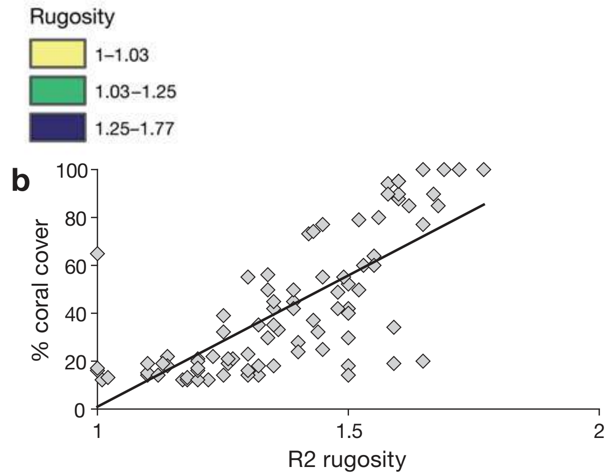
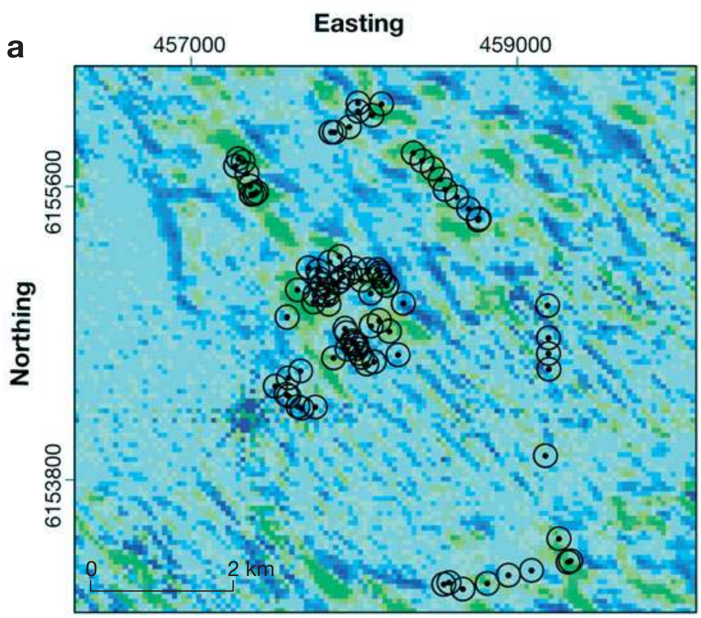


Fig. 9. (a) Study area R2. Coral presence (circles) and rugosity, calculated at the 90 m analysis scale. (b) Relationship between % coral cover and rugosity



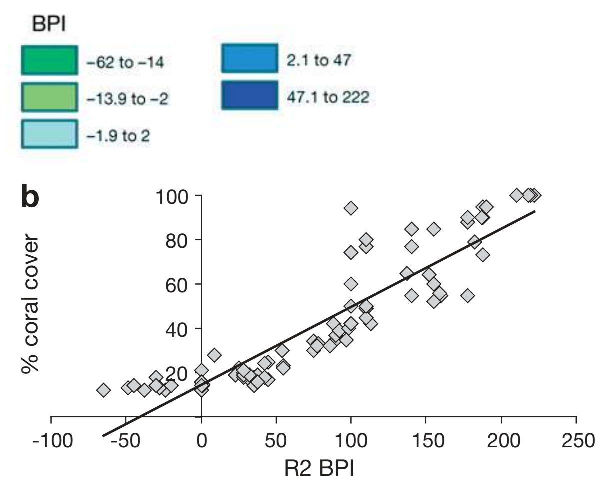


Fig. 10. (a) Study area R2. Coral presence (circles) and bathymetric position index (BPI), calculated at the 90 m analysis scale. (b) Relationship between % coral cover and BPI

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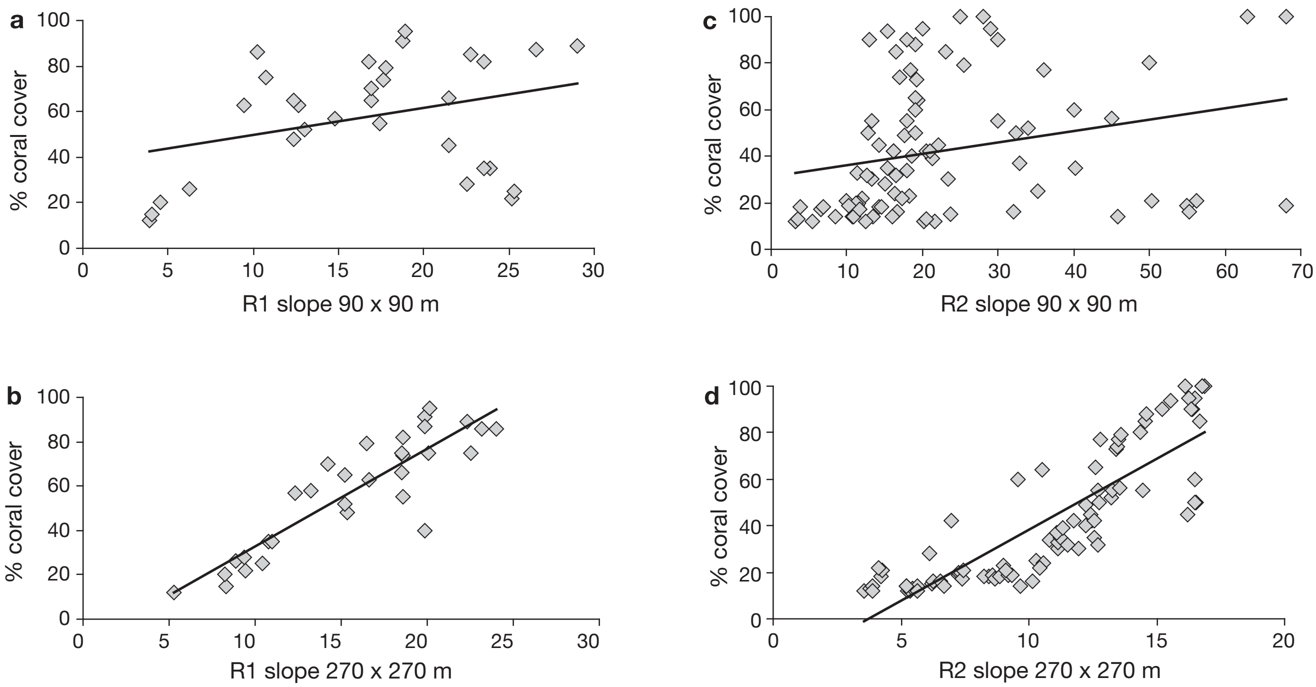

Fig. 11. Correlations between coral cover and slope calculated at the 90 and 270 m analysis scales for (a,b) R1 and (c,d) R2 study areas

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