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Seabed image acquisition and survey design for cold water coral mound characterisation

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ABSTRACT

Cold-water coral (CWC) habitats are commonly regarded as hotspots of biodiversity in the deep-sea. However, a standardised approach to monitoring the effects of climate change, anthropogenic impact and natural variability through video-surveying on these habitats is poorly-established. This study is the first attempt at standardising a cost-effective video-survey design specific to small CWC mounds in order to accurately determine the proportion of facies across their surface. The Piddington Mound of the Moira Mounds, Porcupine Seabight, offshore Ireland has been entirely imaged by downward-facing video in 2011 and 2015. The 2011 video data is navigated into a full-mound, georeferenced video mosaic. A quadrat-based manual classification of this video mosaic at 0.25 m^2 resolution shows the exact proportion of facies abundance across the mound surface. The minimum number of random downward-facing images from the mound are determined to accurately characterise mound surface facies proportions. This minimum sample size is used to test the effectiveness of various common survey designs for ROV-video-based habitat investigations. Single-pass video lines are not representative of the mound surface whilst gridded survey designs yield best results, similar to 100% mound coverage. The minimum sample size and manual classification are applied to the 2015 video data to show a 19% mound surface facies change over 4 years at 0.25 m^2 resolution. The proportion of live coral facies show little change while coral rubble facies show most change. This highlights an inconsistency between temporally-separated data sets and implies that in 20 years, the mound surface may almost entirely change.

1. Introduction

Cold-water corals (CWC) are sessile, filter-feeding organisms found in many parts of the world's oceans, being common and well-studied in the NE Atlantic (Freiwald 2002; Roberts et al. 2003; Roberts et al. 2006; Wheeler et al. 2007). Also referred to as "deep-water" corals, their distribution actually covers a large depth range being found from 39 m to 2000 m water depth (Freiwald et al. 2004; Roberts et al. 2006). As their name suggests, they typically exist in cooler waters from 4 °C to 13 °C (Freiwald 2002) with the exception of *Oculina* spp., and within a salinity range of 31.7‰ – 38.8‰ (Davies et al. 2008). *Lophelia pertusa* is the most well-studied framework-forming CWC and is reliant on currents for food supply (Orejas et al. 2016; Purser et al. 2010 and references therein) and can form 3D carbonate structures that benefit from its ability to baffle currents and thereby enhance sedimentation (Wheeler, Kozachenko, et al., 2005; Wheeler et al. 2008). The complex hydrodynamic relationship between the CWC framework, food supply, currents and sedimentation often results in the generation of positive bathymetric features on the seabed called CWC mounds (De Mol et al. 2007; Dorschel 2003; Squires 1964; Wilson 1979). Wilson (1979) and Squires (1964) describe the early-stage development of cold-water coral mounds using evidence from rock outcrop, museum specimens and submersible dives. Through successive and continuous periods of CWC mound development in the same location, they can generate bathymetric features up to 350 m from base to summit (Henriet et al. 2014 and references therein). Evidence from a number of studies show that the continued development of these coral mounds is largely controlled by environmental conditions (Dullo et al. 2008; Raddatz et al. 2014; Rüggeberg et al. 2007), sediment supply (De Mol et al. 2007; Wheeler, Kozachenko, et al., 2005) and biological processes (Wienberg et al. 2008). Furthermore, a number of mound-development models linked to glacial-interglacial cycles have been presented (Douarin et al. 2014; Eisele et al. 2008; Roberts et al. 2009; Wheeler and Stadnitskaia 2011).

Advances in marine survey technologies and techniques have fostered novel research opportunities to help better understand the marine environment, particularly in cold-water coral habitats (e.g. Freiwald

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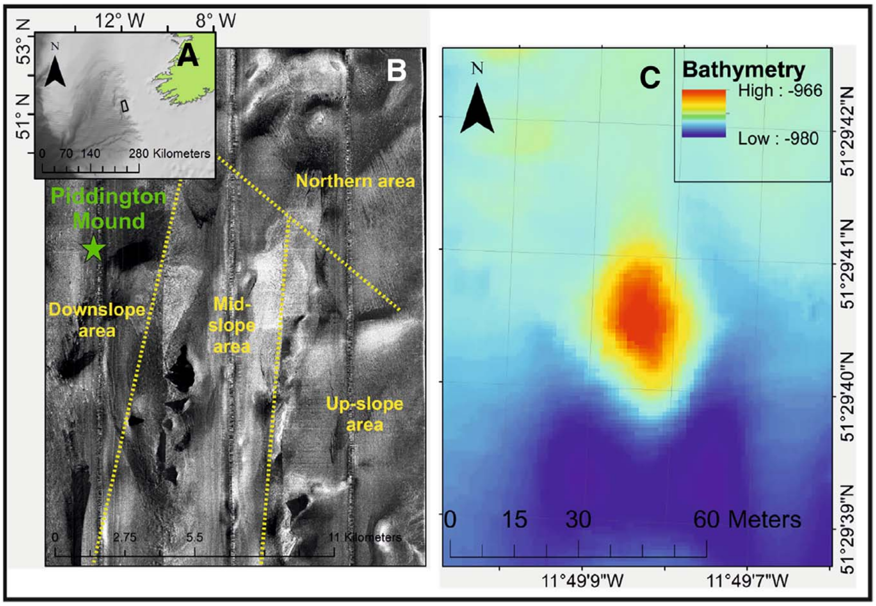

Fig. 1. Location map of study area.
A) Location of Belgica Mound Province (BMP) Special Area of Conservation (SAC) (black box), offshore SW Ireland; B) 30 kHz TOBI side scan sonar imagery of the BMP SAC with areas defined by Wheeler et al., (2011) in yellow and location of Piddington Mound indicated by green star; C) Piddington Mound bathymetry (meters). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and Wilson 1998; Mangini et al. 1998; Mortensen et al. 2001; Roberts et al. 2009). As such, marine remotely-sensed mapping of CWC habitats is becoming progressively more common through the use of side scan sonar (SSS) and multibeam echosounders (MBES). For example, Huvenne et al. (2005) examine the influence of currents and sediment dynamics on the growth of coral and mound development at a mound province scale whereas Dorschel et al. (2009) provide an environmental context to cold-water coral carbonate mound development, both using regional SSS mapping (TOBI 30 kHz SSS). More recently, increased resolution (0.2 m × 0.2 m) SSS surveying has allowed for detailed inspections of coral habitat change in Marine Protected Area's over relatively short timescales (Huvenne et al. 2016). MBES has also proven an integral part of marine habitat mapping for CWC habitats using hull-mounted (Beyer et al. 2003), ROV-mounted (Dolan et al. 2008; Lim et al. 2017), AUV-mounted (Correa et al. 2012) and forward-facing MBES systems (Huvenne et al. 2011).

With recent advances in more accurate underwater positioning for deployed marine sampling/surveying equipment (Chitre et al. 2008; Kinsey et al. 2006), ground-truthing of marine remotely-sensed mapping coverages is now possible with the effective positioning of still camera and video (ROV and drop frame). ROV video has proven useful in both covering large areas (Guinan et al. 2009; Huvenne et al. 2005) and providing baseline studies (Vertino et al. 2010) within CWC habitats. More recently, techniques for imaging complex structures in difficult, deep-water environments have become better developed at higher resolutions (e.g. Robert et al. 2017).

Temporal variability across CWC habitats has been studied at various scales. Lavaleye et al. (2009) utilize long time-series datasets to understand CWC habitat functioning and its effect on the organic biochemistry of the mound-influencing water column. Anthropogenic impact (trawling activities and drill cutting) at CWC habitats have driven some temporal variability research. However, these studies reveal information about temporal mound surface change utilising different approaches to video inspection at 1, 4 or 10 year timescales (Huvenne et al. 2016; Lundälv et al. 2008; Purser 2015).

It is now more common to map (bathymetry and backscatter), physically sample (coring and grabs) and image (ROV video) CWC habitats for research purposes. Various combinations of these data types at differing resolutions in different geographic settings, and quite often with a temporal gap between sampling, are utilised to make parallels and contrasts between these habitats. Although not ideal, this is often done due to the costly and time-consuming nature of deep-water data acquisition under weather- and sea state-dependant conditions. However, a common finding of this research is the heterogeneity of these habitats (Lim et al. 2017; Vertino et al. 2010; Wienberg et al. 2009) stressing the need for local-scale studies (Davies and Guinotte 2011; Dolan et al. 2008; Robert et al. 2016) with a robust sampling density. In light of this, our aim is to identify the minimum amount of imagery needed to accurately quantify the proportion of sediment facies on surface of an individual CWC mound and assess how to best collect this imagery in a representative manner. Furthermore, CWC mounds exist in dynamic environments but how rapidly do these mounds change? Growth rates of corals give us a clue but how does that translate into full-mound surface change? This study therefore also assesses relative temporal change in mound surface facies and uses this data to assess the temporal consistency of data. However, this method should be corroborated in other areas to assess its robustness.

2. Materials and methods

2.1. Study site

The Piddington Mound, a CWC mound in the Belgica Mound Province (BMP), has been selected for this study due to the existence of high-resolution imagery (Video and bathymetry) with sufficient spatial mound coverage as presented in Lim et al. (2017). The BMP is located on the eastern slope of the Porcupine Seabight, NE Atlantic (Fig. 1). Previously designated as a Special Area of Conservation (SAC) under the EU Habitats Directive, the BMP hosts 2 chains of contour-parallel giant CWC carbonate mounds ranging in height from 50 m to 100 m and having a slight elongate to conical morphology (Wheeler, Kozachenko, et al., 2005). A salinity maximum from 600 m to 1000 m water depth marks the depth range of the Mediterranean Outflow Water (MOW), the main mound-influencing water mass in the BMP where intermediate nepheloid layers increase food availability and lateral transport of coral larvae and therefore, influencing their distribution (Dullo et al. 2008; White 2007).

Between and around these chains of giant CWC carbonate mounds, are approximately 250 CWC mounds, referred to as the "Moira Mounds" (Wheeler et al. 2011) of which the Piddington Mound is an example. They are small (typically ~10 m tall and 40 m × 60 m in areal extent) with an ovoid to elongate morphology. It is speculated that they are Holocene in age (Huvenne et al. 2005). They exist in various different settings: at the head of sediment wave trains, within a