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Local variation in the distribution of benthic megafauna species associated with cold-water coral reefs on the Norwegian margin

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ABSTRACT

The spatial variability in the mix of species making up Cold-water coral reef communities is not well known. In this study abundances of a selection of megafauna (*Lophelia pertusa, Madrepora oculata, Paragorgia arborea, Primnoa resedaeformis, Mycale lingua, Geodia baretti, Acesta excavata* and fish) were quantified throughout 9 manned submersible video transects from 3 reef complexes (Røst Reef, Sotbakken Reef and Traena Reef) on the Norwegian margin. Substrate type (coral structure, rubble, exposed hardground or soft sediment) was also recorded. Variations in the densities of these fauna (with respect to both reef complex and substrate type) were investigated, with spatial covariance between species assessed.

For the majority of fauna investigated, densities varied by both reef and substrate. Spatial covariance indicated that some species may be utilising similar habitat niches, but that minor environmental differences may favour colonisation by one or other at a particular reef. Fish densities were generally higher in regions with biogenic substrate (coral structure and coral rubble substrates) than in areas of soft or hardground substrate. Further, fish were more abundant at the northerly Sotbakken Reef at time of study than elsewhere. Community structure varied by reef, and therefore management plans aimed at maintaining the biodiversity of reef ecosystems on the Norwegian margin should take this lack of homogeneity into account.

1. Introduction

Cold-water coral (CWC) reefs are recognised as biodiverse ecosystems throughout the oceans of the world (e.g., Roberts et al., 2006; Duineveld et al., 2007; Henry and Roberts, 2007; Reveillaud et al., 2008; Clark et al., 2010; Henry et al., 2010; Lessard-Pilon et al., 2010; D'Onghia et al., 2010; Mastrototaro et al., 2010). In European seas, these reefs are often located at depths associated with the edge of the continental shelf or deeper, commonly in regions with a hard substrate and high volumes of particulate organic matter regularly delivered to the benthic community. Elevated flow velocities close to the seabed, such as may be found at sills (Lavaleye et al., 2009; Rüggeberg et al., 2011; Wagner et al., 2011), seamounts or mound structures (De Mol et al., 2002; Kenyon et al., 2003; Duineveld et al., 2004; Dorschel et al., 2005; White, 2007; Frank et al., 2009; Rowden et al., 2010; Tracey et al., 2011), within canyons (Taviani et al., 2005; Orejas et al., 2009; Huvenne et al., 2011) or the edge of the continental shelf (Freiwald et al., 2002; Fosså et al., 2005; Wheeler et al., 2007) increase the suspended food flux locally, and may supply a suitable quantity for coral reef development (Duineveld et al., 2004; Davies et al., 2008; Wagner et al., 2011). Periodic downwellings from surface waters of fresh, labile material is an alternative primary food supply mechanism at some reefs (Davies et al., 2009, Duineveld et al., 2012).

Lophelia pertusa (Linnaeus, 1758) is the most common reef building scleractinian coral within the majority of European reef ecosystems (Roberts et al. 2009). With growth, coral polyps secrete an aragonite skeletal cup of ~1 cm diameter, either directly onto the underlying substrate, on top of the dead skeletal remains of previous generations or as a bud from a living parent polyp. Despite a moderate longitudinal growth rate (~1 cm yr^{-1} appears to be a roughly average across European reefs (Mikkelsen et al., 1982; Rogers, 1999; Orejas et al., 2008, 2011; Roberts et al., 2009)), sizable reef frameworks can develop. Geological investigations have indicated that the development of the majority of current North European extant reefs likely commenced shortly after the retreat of ice at the end of the last ice age, ~10,000 years b. p. (Freiwald et al., 1999). From this date, reef complexes on the Norwegian margin have grown to form structures of varying size,

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from those consisting of collections of small coral thickets a few meters in diameter, to large structures many km in length and with heights above the substrate measured in tens of metres (Freiwald et al., 2002). These complex structures greatly increase habitat heterogeneity on the seabed (Reed et al., 1982; Henry and Roberts, 2007; Cordes et al., 2008; Roberts et al., 2009; Buhl-Mortensen et al., 2010). The aragonite skeleton laid down by scleractinian growth provides a hard substrate suitable for settlement by a variety of sessile organisms (Mortensen et al., 1995; Henry, 2001; López Correa et al., 2005; Metaxas and Davis, 2005; Roberts et al., 2006; Orejas et al., 2008; Purser et al., 2009). This skeletal structure also interacts with and impacts on local hydrodynamic flow (White, 2007) providing refuges for fish (Husebø et al., 2002; Auster, 2005; Costello et al., 2005; Edinger et al., 2007; Clark and Tittensor, 2010; Söffker et al., 2011; Baker et al., 2012) and other mobile invertebrate fauna (Reed et al., 1982; Henry and Roberts, 2007; O'Hara et al., 2008; Clark and Rowden, 2009; Lessard-Pilon et al., 2010; Buhl-Mortensen et al., 2010).

The extensive acoustic mapping of the continental margins and subsequent Remote Operated Vehicle (ROV), submersible or drop-cam investigations carried out in the last decade has increased our knowledge on the distribution of CWC ecosystems on the European margins (Fosså et al., 2005; Davies et al., 2008; Dolan et al., 2008; Guinan et al., 2009; Orejas et al., 2009; Roberts et al., 2009; Schmiing et al. 2009; Fosså and Skjoldal, 2010; Vertino et al., 2010; Huvenne et al., 2011; Tong et al., 2012). Surveys of fauna within these ecosystems have however varied in overall aim, approach and methodology. Grab sampling and trawling have confirmed the presence of a high number of species at many reefs (Mortensen et al., 1995; Rogers, 1999; Roberts et al., 2006; Henry and Roberts, 2007; Cordes et al., 2008). Video transect data analysis has shown that at the majority of reefs distinct habitat zones are present, differentiated by substrate type (Jonsson et al., 2004; Buhl-Mortensen et al., 2010, Tong et al. 2012). These zones can be summarised as: (1) regions of high density, live scleractinian growth (the 'live reef zone'), (2) dead skeletal regions (the 'dead coral zone') and (3) a surrounding area made up of many broken coral fragments and occasional patches of living polyps (the 'rubble zone') (Buhl-Mortensen et al., 2010). The percentage of reef ecosystem made up of each of these habitat types differs between reefs, likely in response to differences in hydrodynamic regime, food supply or substrate availability (Kenyon et al., 2003; Wheeler et al., 2007; Wagner et al., 2011). Anthropogenic impact has also had an influence on shaping the physical form of many European reefs (Fosså and Skjoldal, 2010).

To date few studies have investigated how densities of species associated with CWC reefs may vary across and between reef habitat zones at individual reefs, or between different reef complexes. Where published, species occurrence data often reports abundances from reefs as a whole (Jensen and Frederiksen, 1992; Henry and Roberts, 2007), with a lesser number of studies attempting to assess beta diversity variation across individual reefs, reef complexes or the surrounding ecosystems (Jonsson et al., 2004; Raes and Vanreusel, 2006; Henry and Roberts, 2007; Rossi et al., 2008; Henry et al., 2010). The role of terrain morphology in influencing gorgonian coral distributions across several reefs was recently investigated on the Norwegian margin (Tong et al., 2012). In Orejas et al. (2009) small scale spatial distribution patterns of a selection of CWC species within a Western Mediterranean canyon system were investigated by using spatial pattern analyses developed for use in terrestrial environments. In this study we used a similar methodology to investigate small scale spatial distribution of a selection of benthic megafaunal species associated with CWC reefs on the Norwegian margin. This area of the continental shelf is rich in CWC ecosystems, as well as being an area of significant human utilisation, with an active fishery and offshore oil and gas exploration and production ongoing (Fosså and Skjoldal, 2010).

The main aims of our investigation were: (1) to try and determine whether or not the distribution of associated benthic megafauna species varied by reef, substrate type, or with variation in the densities of other megafauna species and (2) to try and determine whether or not the occurrence and the abundance of fish varied with reef, substrate type, or the densities of the investigated seafloor species.

2. Materials and methods

2.1. Survey sites

Three Norwegian reef complexes, Røst Reef, Traena Reef and Sotbakken Reef (Table 1, Fig. 1), were investigated with the 'RV Polarstern' during cruise ARKXXII/1a, June 2007 (Klages and Thiede, 2011). All three reefs are exposed primarily to the Norwegian North Atlantic Current, flowing SW–NE parallel to the Norwegian coast (Dullo et al., 2008).

The Røst Reef complex is one of the most spatially extensive in Norwegian waters (Thorsnes et al., 2004; Dullo et al., 2008; Wehrmann et al., 2009), and has been protected from bottom trawling since 2003 (Fosså et al., 2005; Hall-Spencer et al., 2008). The complex is formed from a number of healthy coral banks located on the crests of ridges running parallel to the edge of the continental margin, formed by the Traenadjupet landslide during the Cenozoic (Damuth, 1978). Between each coral bank there are depressed regions of coral rubble and less vigorously growing coral thickets (Wehrmann et al., 2009).

The Traena Reef complex contains a number of elongated coral structures, each up to ~150 m in length, growing into the prevailing current direction on the continental shelf. Previous investigation has shown these coral structures to consist of a live coral 'head' or upstream section, downstream of which is a more degraded region of coral structure where sparse living coral growth can be found, trailed and surrounded by an area of coral rubble (Fosså et al., 2005; Buhl-Mortensen et al., 2010; Tong et al., 2012).

The Sotbakken Reef has not been visited often by the research community. Mapping and preliminary oceanographic data from the reef are presented in the G.O. Sars cruise 2005108 and Polarstern FS70 cruise reports (Fosså, 2005; Klages and Thiede, 2011). A recent paper (Tong et al., 2012) relates gorgonian distribution at the reef to physical terrain variables such as seabed slope and orientation, though no other fauna are investigated. At 70°45′N the reef is close to the northerly limit of (documented) *L. pertusa* occurrence (Fosså et al., 2000).

2.2. Video sampling

The manned submersible JAGO (IFM-Geomar) was used to collect high definition (HD) quality video data with imbedded universal time code (UTC) throughout dives at each reef (Table 1, Fig. 1). The submarine dives were planned to cross cut reef structures, either by travelling from the deepest depths of reef structure occurrence to the shallowest (Røst Reef and Sotbakken Reef) or by passing along the length of the cigar-like reef structures (Traena Reef). Submarine positioning was maintained throughout the dives via a LinkQuest TrackLink 1500 HA USBL positioning system. A pair of parallel laser pointers (positioned 50 cm apart) were used to provide image scale. The camera provided a view of roughly 10 m^2 of seabed, given a submarine altitude of ~1 m above seafloor. The videos were replayed using the Adobe CS4 Premiere Pro software package and the passage of