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Habitat characterization of deep-water coral reefs in La Gaviera Canyon (Avilés Canyon System, Cantabrian Sea)

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ABSTRACT

Surveys conducted at the complex Avilés Canyon System (southern Bay of Biscay) in order to identify vulnerable habitats and biological communities revealed the presence of noteworthy deep-water coral reefs in one of the tributaries of the system (La Gaviera Canyon). The aim of the present study is to determine why this deep-sea canyon provides suitable environmental conditions for corals to grow. This hanging canyon is characterized by an irregular U-shaped floor with two narrow differentiated flanks. Sand ripples and rocky outcrops structured in diverse W–E directed steps are observed on the canyon floor, suggesting intense hydrodynamic activity. Accordingly, high-frequency near-bottom current and thermal structure profiles showed that there occur strong shifts in currents/hydrography behaving as front-like features at each tidal cycle. These involve the sudden increase of along-axis velocities to over 50 cm/s and vertical velocities of over 5 cm/s in each tidal cycle associated with the passage of sharp thermal fronts and thermal inversions suggesting overturning. A year-long near-bottom current record showed events with near-bottom velocities well over 1 m/s lasting for several days.

Three cold-water coral settings were distinguished: a dense coral reef located on stepped rocky bottoms of the eastern and western flanks, carbonate mounds (20–30 m high) located on the canyon floor, and a cluster of shallower water dead coral framework at the head sector of the canyon. Video and still images from a towed sled and ROV verified the presence of dropstones and rippled sand sheets surrounding the mounds and revealed changes in the coral population (alive or dead; total or patchy coverage) in coral reef and carbonate mound areas. The dominant species of the reef are *Lophelia pertusa* and *Madrepora oculata*, which considerably increase the habitat's complexity and biodiversity in relation to other facies described in the canyon. The presence of living cold-water reefs is directly related to a high-energy environment at depths between 700 and 1200 m in the levels between the lower bound of Eastern North Atlantic Central Water (ENACW) and the core of Mediterranean Water (MW). Such level matches the water density range σ_θ=27.35–27.65 kg m^{-3} which has been identified as limits for cold-water coral distribution in the North Atlantic.

1. Introduction

Deep-water corals are widely distributed in all the worlds' oceans and are currently the subject of intensive research (see Freiwald and Roberts, 2005; Hovland, 2008; Roberts et al., 2009). These corals inhabit cold-water in total darkness, and can construct reefs under a specific set of environmental conditions. These reefs are very large three-dimensional structures that form distinctive habitats, and their importance in deep-sea biodiversity is widely recognized, as they generate physical structures that modify the habitat and its complexity (Cocito, 2004). The animals associated with these structures are distinct from those that inhabit the surrounding deep-sea habitat. There is high species diversity on the reef because it provides niches for many species by supplying a heterogeneous substrate, shelter and protection (Jensen and Frederiksen, 1992; Jonsson et al., 2004; Rogers, 2004; Mortensen and Fossså, 2006; Roberts et al., 2006).

Deep-sea coral reefs are known worldwide, and are abundant on the continental margin of the northeastern Atlantic in favorable

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conditions. They have been documented mainly at bathyal depths, from Scandinavia, where they can reach a considerable size, to the Gulf of Cadiz, including the Mediterranean Sea (Rogers, 2004; Tursi et al., 2004; Wheeler et al., 2007; Hovland, 2008; Roberts et al., 2009). In most sectors of the northeastern Atlantic they are found between 150 and 1200 m depth (White et al., 2005), although large structures occur in the Norwegian fjords at only 39 m depth (Freiwald et al., 2004).

In the northeastern Atlantic, the most widespread and abundant reef-forming coral species is the scleractinian *Lophelia pertusa*, which can form reefs itself. In fact, in the Scandinavian literature, deep-water coral reefs are frequently called *Lophelia*-reefs (for instance, Husebø et al., 2002; Mortensen and Fosså, 2006). However, two other important scleractinian constructors are currently known to form significant, deep, cold-water coral reef habitats on the European continental margin, *M. oculata* and *Solenosmilia variabilis* (Roberts et al., 2009). These three species may co-occur at the same depth, and grow with each other, or together, in certain areas. However, *S. variabilis* does not reach waters as shallow as the other species and its geographic distribution is slightly different (see Zibrowius, 1980; Roberts et al., 2009). As Zibrowius (1980) stated, the abundance of this species has been neglected as it is confused with other species. In addition, *M. oculata* only makes a small contribution to the reef construction in certain areas (Mortensen et al., 1995).

The scleractinian coral fauna has been intensively explored in the Bay of Biscay. Its southern sector off Spain (43°N–45°N) has high biodiversity, with 46 species known so far, which is only surpassed in the Azores and Madeira Islands, considering the 17 sectors for northeastern Atlantic fauna suggested by Zibrowius (1980) (Altuna, 2012). This fauna includes the three main constructional species. White and yellow coral banks were mapped by Joubin (1922a, 1922b, 1923) and Le Danois (1948) in the Bay of Biscay, and there is additional information in Zibrowius (1980). The present state of knowledge in the area and updated maps are given in Reveillaud et al. (2008). These authors considered that the information on the distribution of corals in the area was limited, and that historical information needed to be verified and updated.

Referring to the reefs in the southern sector of the Bay of Biscay, Le Danois (1948) mentioned a "groupe iberique" with "massifs coralliens" located in different areas off the north of Spain, mainly off Asturias and Galicia. Although it has been mentioned in the literature that many invertebrates use constructional corals as a substrate in the Bay of Biscay, no studies have been carried out off Spain to evaluate the extension and biodiversity of these reefs. A study of this kind is available in the northern sector of the bay (De Mol et al., 2011). Studies in the north-Iberian bathyal would be of interest, as the biodiversity of the European cold-water reefs is comparable to that found in some tropical coral reefs, but there are few quantitative studies that would allow regional comparisons (Roberts et al., 2006).

Currently cold-water coral reefs are protected by European directives and there are international efforts to identify and locate the areas where these threatened habitats occur. In early 2005, the Spanish authorities decided to initiate and enhance studies aimed at identifying the main vulnerable marine ecosystems (VMEs) in Spanish waters in order to create a coherent network of marine protected areas (MPAs) to be included in the Natura 2000 network. The process began with the creation in 2008 of the first offshore Spanish MPA, called "El Cachucho", which includes the Le Danois Bank and the intraslope basin that separates the bank from the

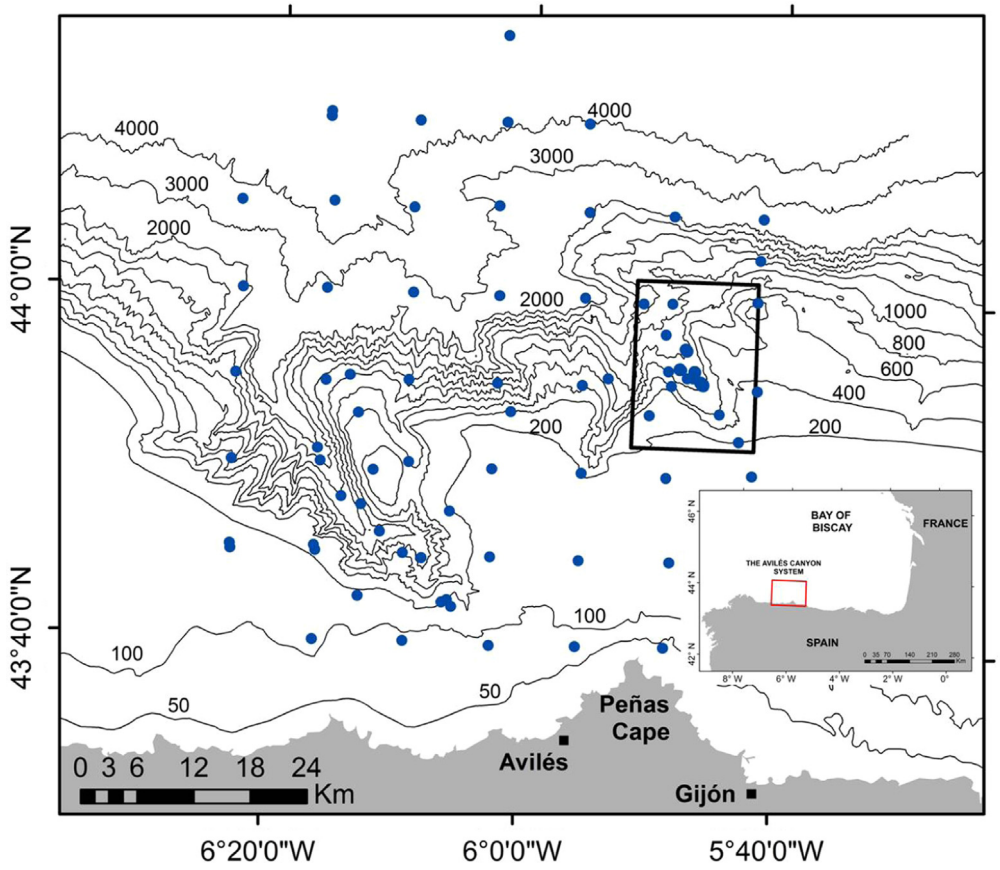

Fig. 1. Location of the study site, La Gaviera Canyon, on the Avilés Canyon system. Location of hydrographic stations used in this study (blue dots). Water depth contours in meters.