Universidade de Aveiro Departamento de Biologia
2009

MARIANA DIAS ALMEIDA

COMUNIDADES BENTÓNICAS DA ESCARPA DE PEN DUICK (GOLFO DE CÁDIS)

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BENTHIC COMMUNITIES IN PEN DUICK ESCARPMENT (GULF OF CADIZ)

Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Biologia Marinha, realizada sob a orientação científica da Professora Doutora Marina Ribeiro da Cunha, Professora Auxiliar do Departamento de Biologia da Universidade de Aveiro

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resumo

Este trabalho foi realizado no Golfo de Cádis, na Escarpa de Pen Duick. Esta escarpa, com cerca de 4,5 Km de comprimento e 100 m de altura, ocorre a 525 m de profundidade na margem continental marroquina (NE Atlântico). É caracterizada pela presença de crostas carbonatadas e recifes de corais pétreos maioritariamente em declínio. Os objectivos principais deste trabalho são: i) a caracterização da composição taxonómica e estrutura das comunidades de macroinvertebrados bentónicos da escarpa de Pen Duick e ii) investigar os padrões de distribuição de acordo com o gradiente de profundidade, o tipo de substrato e a presença de substrato duro (corais pétreos e crostas carbonatadas).

A comunidade bentónica estudada é constituída maioritariamente por espécies de crustáceos, anelídeos e hidrozoários.

Numa análise não quantitativa, encontram-se diferenças significativas nas comunidades em diferentes sub-habitats (presença de coral à superfície, coral coberto por sedimento e ausência de coral) e na cor do sedimento (que pode ser relacionada com as condições biogeoquímicas do sedimento). A riqueza específica é maior nos locais onde se encontram corais do que em locais de sedimento fino. Hidrozoários e poliquetas caracterizam os sub-habitats com corais e os bivalves caracterizam os locais de sedimento fino. Os crustáceos encontram-se distribuídos por todos os sub-habitats.

Numa análise quantitativa, encontram-se diferenças ao longo do gradiente profundidade. A maior diversidade e equitabilidade nas comunidades bentónicas é encontrada a profundidades superiores a 480 m na parte superior e na base da escarpa de Pen Duick. A profundidades inferiores a 480 m as comunidades bentónicas apresentam maior densidade e maior dominância, características estas que podem ser relacionadas com a presença de ambientes sedimentares particulares – as crateras de vulcões de lama.

O elevado número de espécies em comunidades com elevada equitabilidade encontradas na escarpa de Pen Duick, reforçam a hipótese de que os recifes de coral de água fria mesmo em declínio são zonas que contribuem para uma maior heterogeneidade ambiental e proporcionam condições favoráveis à ocorrência de uma elevada diversidade biológica.

Abstract

This work was carried out in the Pen Duick Escarpment, Gulf of Cadiz. This scarp occurs at 525 m depth, and has about 4.5 km in length and 100 m in height. It is characterized by the presence of carbonated crusts and stony coral reefs predominantly in decline. The main objectives of this study are: i) to characterise the composition and structure of the benthic macroinvertebrate assemblages associated with the Pen Duick Escarpment and ii) to identify patterns of distribution according to the depth gradient, sediment type and presence of hard substrate (stony corals and carbonate concretions).

The studied benthic assemblages are composed mainly by crustaceans, annelids and hydrozoans. The non quantitative analysis showed significant differences in the assemblages from different subhabitats (presence of coral at surface, coral in the sediment and absence of coral) and sediment colour (which can be related to the biogeochemical conditions of the sediments). The number of species is higher in samples with coral than in samples with fine sediment. Hydroids and polychaetes characterized the subhabitats with corals and molluscs characterized the subhabitats of fine sediment. Crustaceans occurred in both subhabitats.

The quantitative analysis showed differences along the depth gradient with great diversity and evenness at depths greater than 480 m at the top and base of the escarpment. At depths shallower than 480 m, the benthic assemblages showed higher densities and dominance that can be related to the particular sediment environment – the crater of mud volcanoes.

The high number of species in low dominance assemblages found in the Pen Duick Escarpment reinforce the hypothesis that cold-water coral reefs even declining are areas that enhance habitat heterogeneity and provide environmental that favour high biological diversity.

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1. INTRODUCTION

1.1 THE DEEP-SEA

The deep-sea is the largest ecosystem on Earth, covering nearly two thirds of the earth's surface (Rex 1981). During the last thirty years, exploitation of the deep-sea lead to the discovery of an unsuspected diversity of ecosystems such as hydrothermal vents, cold seeps, cold-water coral carbonate mounds and other habitats with high biodiversity and/or productivity (Pinheiro *et al*. 2003).

The deep-sea is a singular ecosystem with extreme conditions: sun light is absent, temperatures are low and ambient pressure is high. These factors influence the fauna and are associated with a rich radiation of biodiversity in the deep-sea (Gage 2001).

Pressure affects the solubility of calcium carbonate and may have an indirect effect on the fauna in the deep-sea and in the sediment composition (Tyler 1995). Hydrostatic pressure increases one atmosphere (1 bar) per 10 m increase in depth (Gage & Tyler 1991). Many higher taxa, such as decapod crustaceans, anemones and echinoids, do not occur commonly below 6000 m likely owing to direct and indirect effects of pressure, whereas other taxa, such as holothurians and polychaetes appear to show an increased abundance below this depth (Gage & Tyler 1991).

Depth is one of the most intensively studied ecological gradient in the ocean. Changes in geological, hydrological, physical, chemical and biological features with increasing depth allow the identification of relatively well defined bathymetric regions (Curdia 2001). Based on depth and distance from land the ocean can be divided in four zones: the continental shelf (depths up to 200 m), the continental slope (from 200 to 2000 m), the continental rise (2000 to 4000 m) and the abyssal plain (more than 4000 m). According to topographic criteria, the deep-sea begins at the edge of continental shelf but in terms of hydrography it is usually considered to be that region below the permanent thermocline (Gage & Tyler 1991). Ecologically, four depth zones are usually considered, the sublittoral

or subtidal zone (low water to 200 m), the bathyal or archibenthal zone (from 200 to 2000 m), the abyssal zone (2000 to 6000 m) and the hadal zone (more than 6000 m) (Gage & Tyler 1991).

Silt and clay usually dominate sediment composition in the deep-sea, but other substrates can be found. Biogenic oozes can be found when collecting deep-sea benthic samples and manganese nodules provide a rare hard substrate particularly on abyssal plains. Seamounts may have exposed hard rock or be sediment-covered especially at the summit. Other hard substrates include lithohermes, namely authigenic carbonate mounds are found at bathyal depths and also substrates of biogenic origin such as *Lophelia pertusa* and other scleractinian coral reefs (Tyler 1995).

The temperature of the waters below 2000 m, as a general rule, is constant and less than 4°C (Tyler 1995). The salinity is also relatively constant and below 2000 m is close to 34.8psu ± 0.3psu (Gage & Tyler 1991). Generally, the open ocean is well-oxygenated and true anoxic conditions do not prevail. The deep waters from the North Atlantic and the Antarctica have the highest oxygen concentrations (6-7 $ml.l^{-1}$), except at the immediate vicinity of hydrothermal vents where conditions are totally reducing (Tyler 1995).

The concentration of suspended particles decreases with depth in the open ocean such that deep water is remarkably clear (Tyler 2005). The organic content under productive areas may exceed 0.5% whereas beneath unproductive areas it can be less than 0.1% (Gage & Tyler 1991). Surface incident light is not detected below 1000 m which affects primary production and its downward flux to the deep-sea. The deep-sea is essentially a heterotrophic system with primary production being confined to areas of hydrothermal and cold seep activity. The formation of new organic material occurs as a result of chemosynthesis by free-living or symbiotic bacteria which provides dissolved organic matter to the host organism. However, the dominant source of organic matter for heterotrophy comes from the surface production (Tyler 1995).

Particulate Organic Matter (POM) is the major source of organic matter to the deep-sea benthos and includes both large food falls, like animal carcasses and terrigenous and coastal plant debris as well as fine particulate matter mostly from planktonic animals,

including faecal pellets, moults and phytoplankton. In addition, sediments, particularly those in reducing conditions, have been found to contain a relatively large fraction of Dissolved Organic Matter (DOM). This also constitute a significant food source for some biota (Gage & Tyler 1991).

The traditional concept that phytodetritus would reach the deep-sea in small amounts, at relatively regular slow rate, with no seasonal variation has changed. In fact, evidences support the idea of seasonality in the deep-sea. The input of phytodetrital material elicits significant responses in micro- and meiofaunal deep-sea organisms (Tyler 1995). Seasonal pulses of organic matter have also been related to increases of oxygen consumption, probably related to an increase in macrofauna density and biomass, emphasing seasonal variation (Drazen *et al.* 1998).

The perception of a spatial and temporal homogeneity of the deep-sea has changed. Although the deep-sea is generally homogeneous in terms of temperature, physical disturbance and broad topography, there is evidence of variability in particle flux, erosive currents, biogenic disturbance and biogenic subhabitats (Snelgrove & Smith 2002).

1.2 DEEP-SEA DIVERSITY

Perception of the deep-sea benthic environment as a species-poor habitat changed over the last decades and there is increasingly evidence that this is in fact one of the most species-rich environments in our planet (Snelgrove & Smith 2002).

Marine systems and the deep-sea in particular, have higher richness at the phylum or class level than their terrestrial or freshwater counterparts (Snelgrove & Smith 2002). Marine systems contain 90% of all animal families and 28 out of 29 non-symbiotic animal phyla occur in marine environments and from these 13 are exclusively marine (Ray & Grassle 1991). Only the animal phylum Onychophora has no living representative in

marine habitats (Snelgrove & Smith 2002). Despite this, species richness is often considered to be higher in terrestrial habitats (Briggs 1991).

The much greater higher-taxon level representation in the ocean is thought to result from its much greater area and because its biota is much older than on land (Ray & Grassle 1991).

At the infancy of deep ocean discoveries, it was generally accepted that this was a species poor habitat when compared with other marine habitats, and that the diversity would decline with increasing depth and offshore distance (Hessler & Sanders 1967). At that time it was accepted by ecologists and taxonomists that only about 15% of the species on earth were found in the deep oceans, most of them in or on oceanic sediments. This view resulted partly because samples taken in poorly studied areas tended to have high proportions of species already known. According to May (1992) this is one of the reasons why marine environment has been ignored in global estimates. More recently Grassle & Maciolek (1992) made a likely oversized estimate: 75% of total species on earth may occur in the deep-sea.

The rich diversity of species in the deep-sea was first documented by Hessler & Sanders (1967) who demonstrated that species richness of the macrofauna within a site in the deep-sea was comparable to or exceeded available estimates for most of the other marine habitats. Much of this diversity was represented by small polychaete annelids, crustaceans, molluscs and other invertebrate taxa that live within the sediment. In addition, estimates for meiofauna may even exceed macrofauna in total species number. Lambshead (1993) suggested $1x10^8$ species of nematodes alone, from a pooled sample of only 5 m^2.

Grassle & Maciolek (1992) documented the remarkably high diversity of deep-sea benthic communities off the east coast of the USA. From depths ranging from 1500 to 2100 m, a total of 798 macrofaunal species representing 171 families and 14 phyla were found in a total sampled area of 21 m^2. Of the 798 species, 46% were annelids (mainly polychaetes), 23% were arthropods (mainly crustaceans) and 13% were molluscs. They suggested a global estimate of 10^7 macrobenthic species for the ocean floor. This estimate has been

highly debated with support from some authors (eg. May 1992) and refutation by others (eg. Gray *et al.* 1997).

There are three generally accepted gradients of sea diversity that have been summarized by Levinton (1995): i) the variation in benthos diversity from coastal to abyssal plains - increasing diversity to a maximum on the continental rise, and then decreasing towards the abyssal plain; ii) the benthic communities from the open ocean usually showing higher diversity than those form inshore habitats and iii) the increase in benthic species diversity from high to low latitudes.

The first hypothesis has been supported by several studies indicating that diversity-depth patterns in the deep-sea are unimodal with a peak at intermediate depths and depressed diversity at upper bathyal and abyssal depths (Levin *et al.* 2001). Species diversity of benthic macrofauna from NW Atlantic is thought to be relatively low on the continental shelf, increasing rapidly down the continental slope to a maximum at mid-slope depths before decreasing again on the abyssal plain (Rex 1981). A similar depth related parabolic trend was also observed for grain size diversity, emphasing the relationship between this factor and species diversity (Etter & Grassle 1992). Within the Atlantic (North and South pooled) Wilson (1998) observed an increase in the diversity of asellotan isopods with depth and a corresponding decrease in flabelligerian isopods. Therefore, unimodal patterns may not be universal (Rex *et al.* 1997) and where they do occur in other basins have been attributed to varied environmental gradients (Paterson & Lambshead 1995).

Differences between abyssal and bathyal assemblages were also observed (Rex *et al*. 1997), but the boundaries between deep-sea communities are far less distinct than between communities in shallow water (Grassle & Maciolek 1992).

Although some studies suggested that deep-sea and off-shore habitats are more diverse than shallow water habitats (Levinton 1995) other authors suggest that coastal and deep-sea habitats contain similar species richness as exemplified by Gray (2001) for the deep-sea and in coastal areas of Norway and Australia.

The negative relationship between diversity and latitude proposed for some macrofaunal groups is strong in the North Atlantic (Rex *et al.* 2000) and for species richness of

Foraminifera in the North and South Atlantic (Culver & Buzas 2000) but was not observed in isopod data (Poore & Wilson 1993), particularly in the southern hemisphere. Some authors suggest that deep-sea latitudinal gradients remain equivocal because data is inadequate, and the Atlantic may not be the ideal area to derive global patterns because of its evolutionary complexity (Lambshead *et al*. 2000).

In fact, patterns of diversity in the deep-sea depend on a variety of oceanographic and ecological conditions and are complicated to explain (Levin *et al*. 2001). The depth and latitudinal patterns in diversity that have been observed for different areas and different taxa are not always consistent. More sampling and taxonomic investigations are needed, in order to sufficiently describe geographic diversity patterns before inferring on their causes (Rex *et al*. 1997). There are evidences that deep-sea host a large proportion of undiscovered biodiversity in our planet. Although only approximately 0.0001% of the deep-sea floor as so far be subject to biological investigation, the results are already remarkable (UNEP 2007).

The increasing pressure of industrial exploitation of the deep-sea and the need to uncover the consequences of anthropogenic impacts are strong arguments towards the effort to improve our knowledge on marine diversity.

1.3 CORALS AND CARBONATE MOUNDS

During the last decades, sediment sampling, underwater photography and ROV guided video surveys captured during research cruises along the European continental margin have revealed the presence of large mound and reef like structures covered with a thriving living cold-water coral fauna (Mienis 2008).

Cold-water corals are Cnidarians and include the reef building stony corals (Scleractinia), soft corals (Octocorallia), black corals, hydrocorals and often form colonies supported by a common skeleton, providing structural habitat for other species (Roberts *et al*. 2006).

Tropical reef systems, only survive in a narrow window of light, temperature, salinity and depth, which restricts their occurrence to a zone around the equator between 30° N and 30° S. By contrast, cold-water corals lack photosymbionts in their tissue, which enables them to live in a dark and cold environment below the photic zone, often in deep offshore waters (Roberts *et al*. 2006). Cold-water corals are found in oceanic waters with temperatures between 4° and 12°C. These conditions are found in relatively shallow waters (50 – 1000 m) at high latitudes and at depths up to 4000 m beneath warm waters masses at low latitudes. In European waters mounds and reef structures mainly occur in confined depth zones, up to c.1000 m (Roberts *et al.* 2006).

The cold-water scleractinian corals *L. pertusa* and *Madrepora oculata* form mound structures on the continental shelf and slope in the NE Atlantic (Wheeler *et al.* 2007 and references therein) (Figure 1). These structures result from growth of carbonate-producing organisms and (current controlled) sedimentation (UNEP 2007).

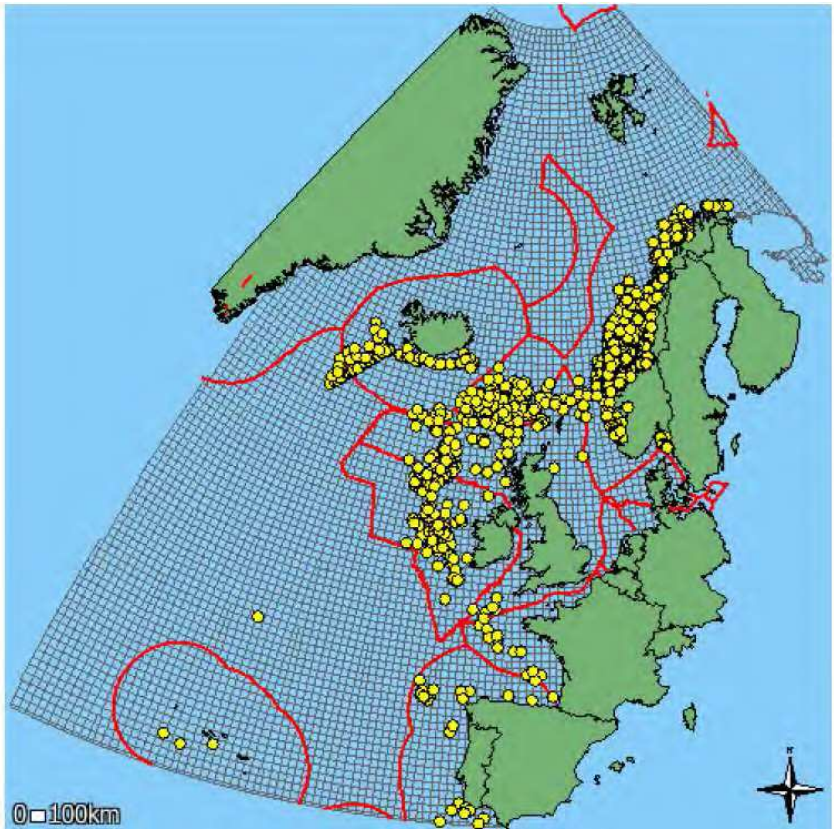

Figure 1 - Locations of *Lophelia pertusa* reefs in the OSPAR database (http://www.ospar.org/).

Along the Norwegian coast occurs one of the largest reef systems, covering a surface area of more than 100 km^2 (Freiwald *et al.* 1997). Cold-water corals may occur as single colonies, like the observed in Rockall Trough or as giant carbonate mounds like in Porcupine Seabight (Irish margin). Similar mound structures, although smaller in size have been observed in the Gulf of Cadiz (Wheleler *et al.* 2007 and references therein).

Little is known about the reproduction processes of cold-water coral species. Most species are gonochoristic and reproduce seasonally, which can be related to food flux associated with spring phytoplankton blooms (Roberts *et al*. 2006).

Different hypothesis explain the presence of cold-water corals and the formation of carbonate mounds. According to Freiwald (2002) the existence of these structures depends on external environmental forcing conditions, including the presence of a stable substrate for settlement, the proper temperature and salinity range and a turbulent hydrodynamic regime, favoring supply of sufficient suspended food and preventing them from getting buried in the sediment. In addition it is suggested that corals may occur in areas of high primary productivity, in the presence of a mechanism to transport food particles, like tidal currents and internal waves, the local benthic fauna and mound structures.

The process begins with the settlement of a coral larva. The coral grows and the polyps in older portions die so that the skeleton becomes increasing vulnerable to bioeroders, such as clionid sponges, and mechanical breakage. The skeleton can break and fall to the seabed, expanding the perimeter of the reef and provide a habitat for other species. This process creates the reef framework and over time, baffles and trap mobile sediment, initiating mound formation (Roberts *et al*. 2006). The coral *L. pertusa* forms high and dense coral colonies measuring several meters across and consisting of thousands of polyps. As the colony develops, adjacent branches tend to join together, thus considerably strengthening the entire framework. The branched colonies of *M. oculata* are more fragile than *Lophelia*, and tend to brake easily, thus considerably limiting its framework-building capability (Freiwald *et al.* 2004). The development of deep-water reef mounds and their colonization can be thought to be cyclic, with the associated community varying with the stage of reef development and available subhabitats. The

cold-water corals may have an opportunistic feeding mode whereby carnivorism seems to prevail. They are thought to depend on zooplankton and organic matter that sinks from the productive euphotic zone or organic matter laterally transported by currents for their nutritional requirements (Duineveld *et al.* 2004).

Another hypothesis is that coral banks could be associated with areas of seabed where hydrocarbons seep from the sediment, creating a chemosynthetic food chain which supports cold-water corals and their associated fauna (Hovland *et al.* 1998). This hypotheses was never proved and recent studies on analysis of tissue stable isotopes of these communities revealed that corals and associated species do not show evidence of input of local seep production (Becker 2009; Rodrigues 2009).

With the discovery of more cold-water coral habitats, research on these habitats has received increased attention in science (Roberts *et al.* 2006). Cold-water corals can build-up kilometers long and wide mound and reef structures of up to several hundreds of meters high over many thousands to million years. Because of their age and growth rates, reefs contain records of long-term climate change and deep ocean circulation (Roberts *et al*. 2006). The cold-water coral systems provide niches for a highly diverse community of deep water species. Cold-water coral regions are characterized by a fauna that is several times as diverse as the one found at the surrounding seabed (Henry & Roberts 2007). Although there are few species of framework building corals, more than 1300 different associated species so far were found in cold-water coral habitats in the NE Atlantic, thus classifying cold-water coral reefs as biodiversity hotspots (Roberts *et al*. 2006). Furthermore cold-water corals may be major speciation centers (Roberts *et al.* 2006) especially when associated with seamounts. Seamounts trap ocean currents producing localized circulation patterns which could retain larva and limit species' dispersal, promoting local adaptation and enhance rates of speciation (Rogers 1994).

Despite the world wide recognized importance of these ecosystems, human activities are a major threat for cold-water reefs: bottom trawling causes damage; hydrocarbon drilling has potential impacts; and global ocean acidification has potentially severe damages on calcifying reef fauna (Roberts *et al.* 2006).

1.4 COLD-WATER CORALS AND ASSOCIATED SPECIES

The existence of cold-water corals is known since two centuries ago, however its associated fauna has not been studied as intensively as in their shallow-water counterparts (Miennis 2008).

Cold-water corals are complex habitats in the deep ocean, providing niches for many species. Existing information on biodiversity of cold-water reefs results from visual surveys based on video images and the identification of species present in samples recovered from the reef habitat (Roberts *et al*. 2008).

Studies of species diversity in samples of reef habitat show high diversity associated with coral framework samples (Jensen & Frederiksen 1992) and evidence of characteristic reef species (Henry & Roberts 2007). A parasitic relation exists between corals and foraminifera, which etch deep into the external wall of the coral (Freiwald & Schonfeld 1996). The polychaete *Eunice norvegica* lives in symbiosis with the coral, using the living skeletons of the coral to attach their tubes (Hovland & Mortensen 1999 in Miennis 2008).

Corals are protected on the outside by a mucus layer. Mucus free parts of the coral skeleton and coral debris on the other hand are especially vulnerable to the attachment of all kinds of invertebrates (Beuck & Freiwald 2005). The reefs provide hard bottom substrate, refuge and nursery for a large variety of deep-sea species (Henry & Roberts 2007). Video and photo surveys have shown the presence of numerous associated benthic species, especially molluscs, brachiopods, anemones, bryozoans and sponges. Other associated fauna such as crustaceans, echinoids, crinoids and a variety of fish species is commonly found at and around the carbonate mounds (Mienis 2008 and references therein).

1.5 STUDY CONTEXT

Cold-water coral ecosystems are widely distributed along Europe from northern Norway along the Irish margin to the Gulf of Cadiz and into the Mediterranean Sea and build up carbonate mounds of various sizes and shapes (Wheeler *et al.* 2007).

In the past few years a number of cruises in the Gulf of Cadiz have been carried out in the framework of HERMES (Hotspot Ecosystem Research on the Margins of the Europeans Seas) and other related projects. One of the aims of these cruises was to study cold-water corals ecosystems and to investigate a putative linkage between hydrocarbon seepage and the authigenic carbonate formation, the development of carbonate mounds and cold-water coral reefs.

The biological material for the present work was obtained during the cruises Moundforce2005 (64PE237) and Microsystems2006 (64PE253) (carried out in the Pen Duick Escarpment, Gulf of Cadiz onboard the RV Pelagia respectively in May-June 2005 and Sept -Oct 2006).

The main objectives of the present work are:

i) to characterize the composition and structure of the benthic macroinvertebrate assemblages associated with the Pen Duick Escarpment;

ii) to identify patterns of faunal distribution in relation to the available environmental data.

2. METHODOLOGY

2.1 STUDY AREA

The Gulf of Cadiz is located west of the Strait of Gibraltar (between Spain and Morroco), on the boundary of the African and Iberian plates, in an area with a series of active geological processes. These include the occurrence of mud vulcanism, mud diapirism, the formation of carbonate mounds and chimney structures related to hydrocarbon-rich fluid venting. The Pen Duick Escarpment is one of the major areas of occurrence of carbonate concretion and associated cold-water corals (De Haas *et al*. 2005 and references therein).

The Pen Duick Escarpment, located at about 525 m water depth, forms the SW flank of Renard Ridge. This fault scarp is about 4.5 km long and 100 m high (De Haas *et al*. 2005) (Figure 2).

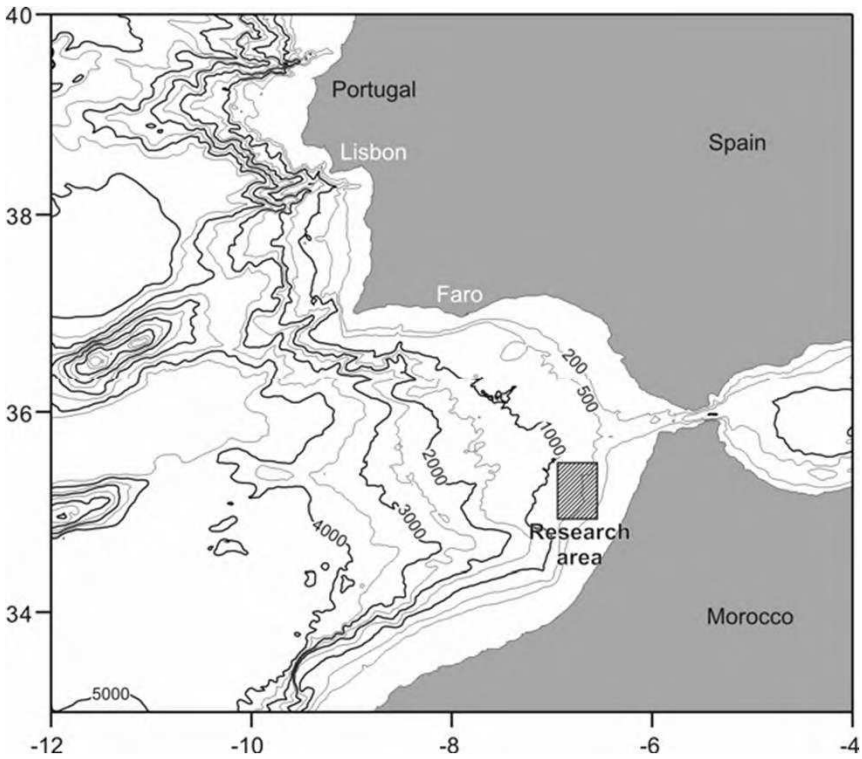

Figure 2 – Map of the Gulf of Cadiz with the research area indicated (De Haas *et al.* 2006).

The Pen Duick Escarpment consists of recent carbonate mounds flanked by giant mud volcanoes and carbonate crusts. These mounds are small in size (at maximum about 50 m high) and consist mainly of fine grained (muddy) sediments and coral debris with some few corals alive in the top of the mounds (De Haas *et al*. 2006).

The most abundant scleractinian species in the Gulf of Cadiz are *Dendrophyllia cornigera*, *D. alternata*, *Eguchipsammia cornucopia*, *M. oculata* and *L.pertusa*. The species *D.cornigera* is the most abundant in the Pen Duick Escarpment (Wienberg *et al.* in press).

These carbonate mounds are comparable to the carbonate mounds founded in the Irish margin (De Haas *et al*. 2006). But in contrast to these and the Norwegian reefs, coral growth has ceased, indicated by findings of almost solely fossil scleractinian corals (Wienberg *et al*. in press). The fossil record studied from sediment cores in the Gulf of Cadiz suggests that the presence of cold-water corals in carbonate mounds is related to interglacial and glacial cycles. Environmental and oceanographic conditions during the recent past (glacial/stadials) were probably more favorable for cold-water coral growth (Miennis 2008; Wienberg *et al.* in press) explaining the present almost complete absence of thriving cold-water corals in the Gulf of Cadiz.

2.2 SAMPLING METHODOLOGY

The Pen Duick Escarpment was sampled during two cruises, Moundforce2005 (64PE237) (May-June 2005) and Microsystems2006 (64PE253) (Sept -Oct 2006) onboard the R.V. Pelagia. A total of 83 box cores were sampled (Annexe I). Figure 3 shows the main sampled areas: the top (B) and the base (C) of the escarpment; the mud volcanoes Lazarillo de Tornes (A) and Gemini (D). The Mercator and Al Idirisi mud vulcanoes were also sampled but are not represented in the bathymetric map.

The 64PE237 transects comprehend 32 sampling sites ranging from 516 m to 680 m, corresponding to different features of the scarp: transects at the top of the escarpment

(B) and at the base of the escarpment (C) and a transect at the Lazarillo de Tornes mud volcano (A). 64PE253 transects include 51 sampling sites ranging from 227 m to 980 m and include transects at the top (B) and the base (C) of the escarpment and also include the Lazarillo de Tornes (A), Gemini (D), Mercator and Al Idirisi mud volcanoes.

Figures 4, 5 and 6 show the stations sampled, for each cruise and for the two cruises together.

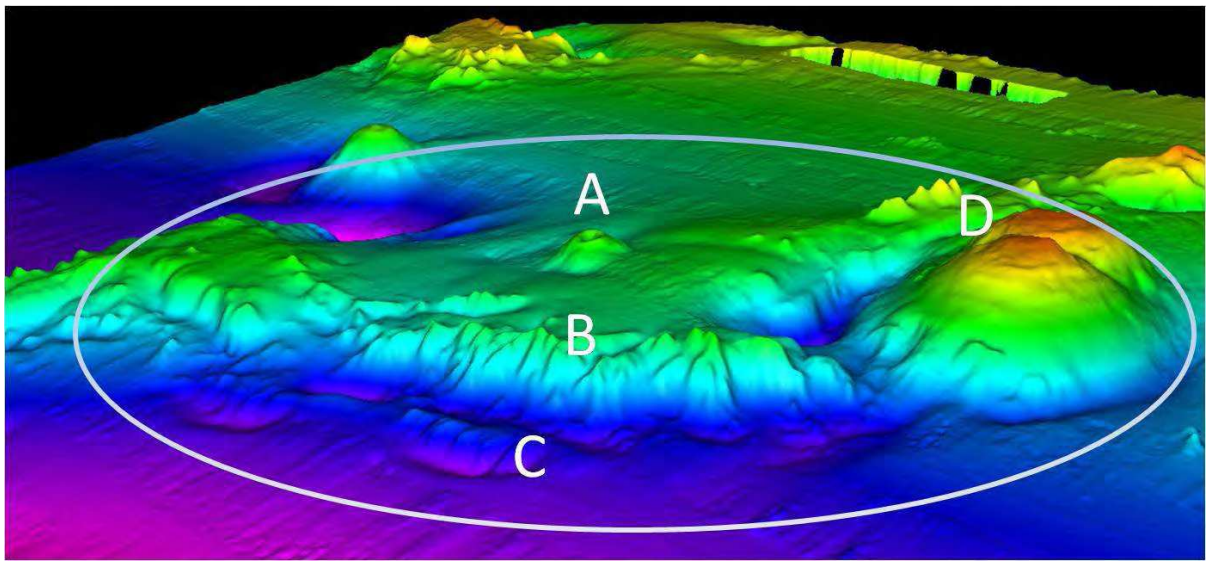

Figure 3 – Bathymetric map of the sampled area indicating the main areas sampled. A: Lazarillo de Tornes mud volcano; B: top of the escarpment; C: base of the escarpment; D: Gemini mud volcano (De Haas et al. 2006).

During the two cruises surface sediment cores have been taken using a box-core with a cylindrical barrel 50 cm in diameter and 55 cm in height (NIOZ box core). After recovery of the core the water overlaying the sediment was siphonated. The surface of the box was photographed and a description was made of the biological and sedimentological characteristics of the box-core.

In 64PE237 cruise the fauna was picked from the surface of the sediments. In one quarter of the box-core a variable volume of superficial sediment (± 25-30 cm) was collected and the sediment was washed through a sieve column (2, 1 and 0.5 mm). The fauna in the two coarser fractions was sorted and kept in 96% ethanol. The finer fraction (0.5 to 1 mm) of

the sieved sediments was preserved in 10% neutralised formaline stained with Rose Bengal and was sorted under a stereoscopic microscope.

In 64PE253 cruise one quarter of the box-core was sliced in 4 sediment layers (0-2 cm, 2-5 cm, 5-10 cm and 10-20 cm). Additional sediment was also collected and was considered as the “all fraction”. The sediment was washed through a sieve column (2, 1 and 0.5 mm). The fauna in the two coarser fractions was sorted and kept in 96% ethanol. The finer fraction (0.5 to 1 mm) of the sieved sediments was preserved in 10% neutralised formaline stained with Rose Bengal and was sorted in laboratory under a stereoscopic microscope.

The organisms were identified to the main taxonomic levels and, whenever possible, to species level. The taxon Anthozoa (Cnidaria) was present in the samples, but was not included in this study (the samples were studied by other participants of the cruises). Nematodes, copepods and ostracods collected were ignored as they are considered as meiofauna groups (Gage & Tyler 1991).

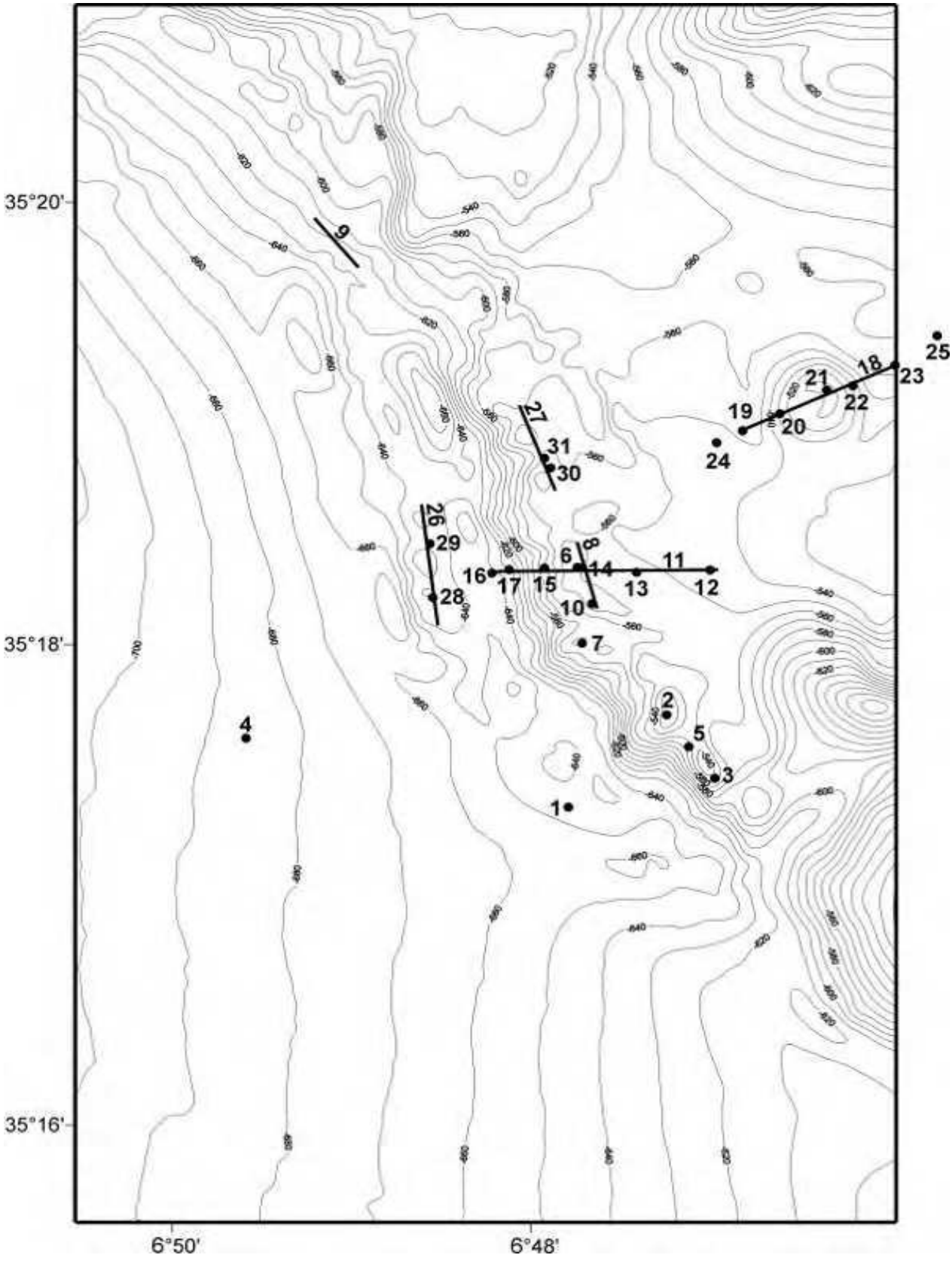

Figure 4 – Sampling locations of the box cores collected in 64PE237 cruise.

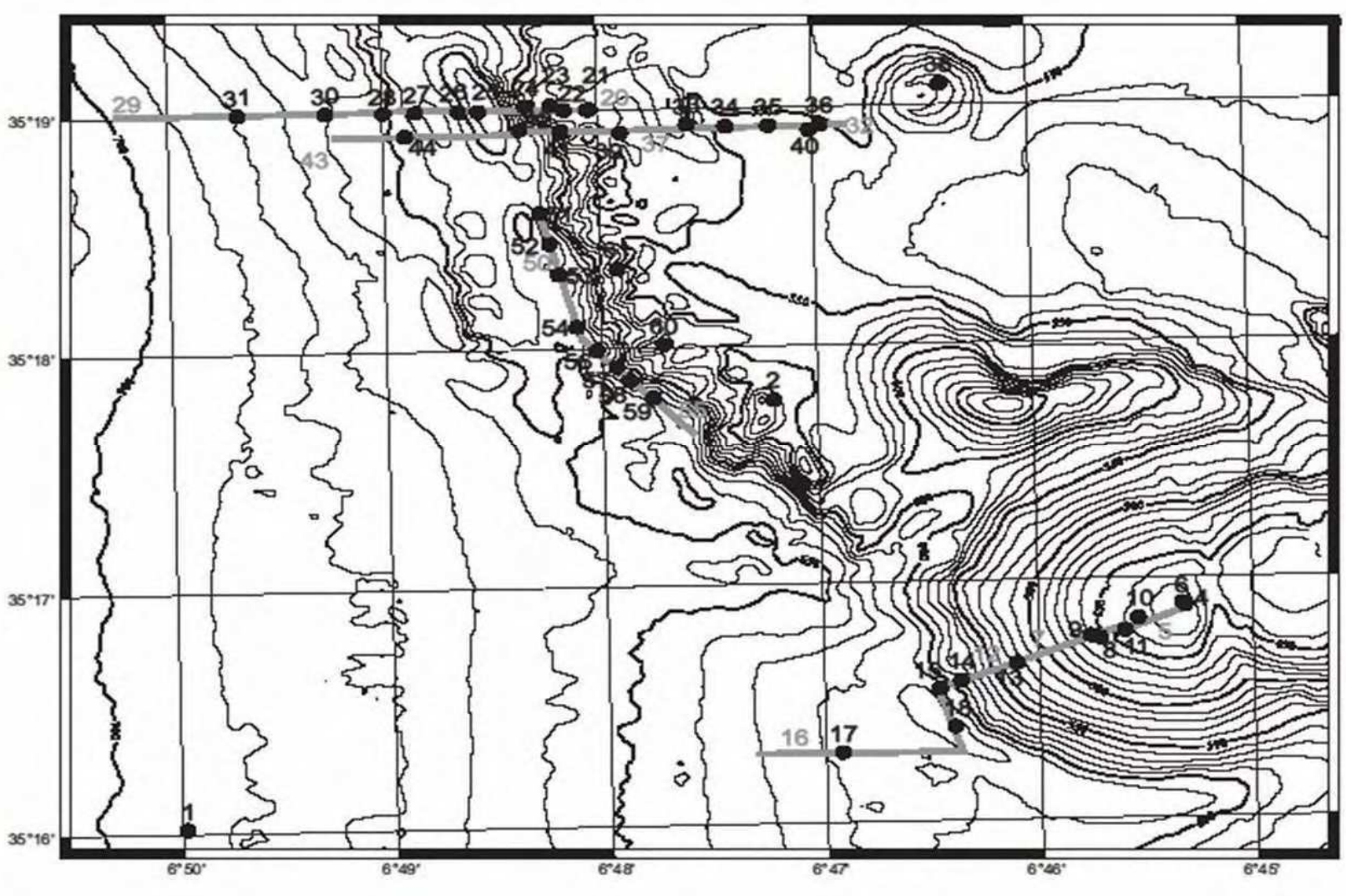

Figure 5 - Sampling locations of the box cores collected in 64PE253 cruise.

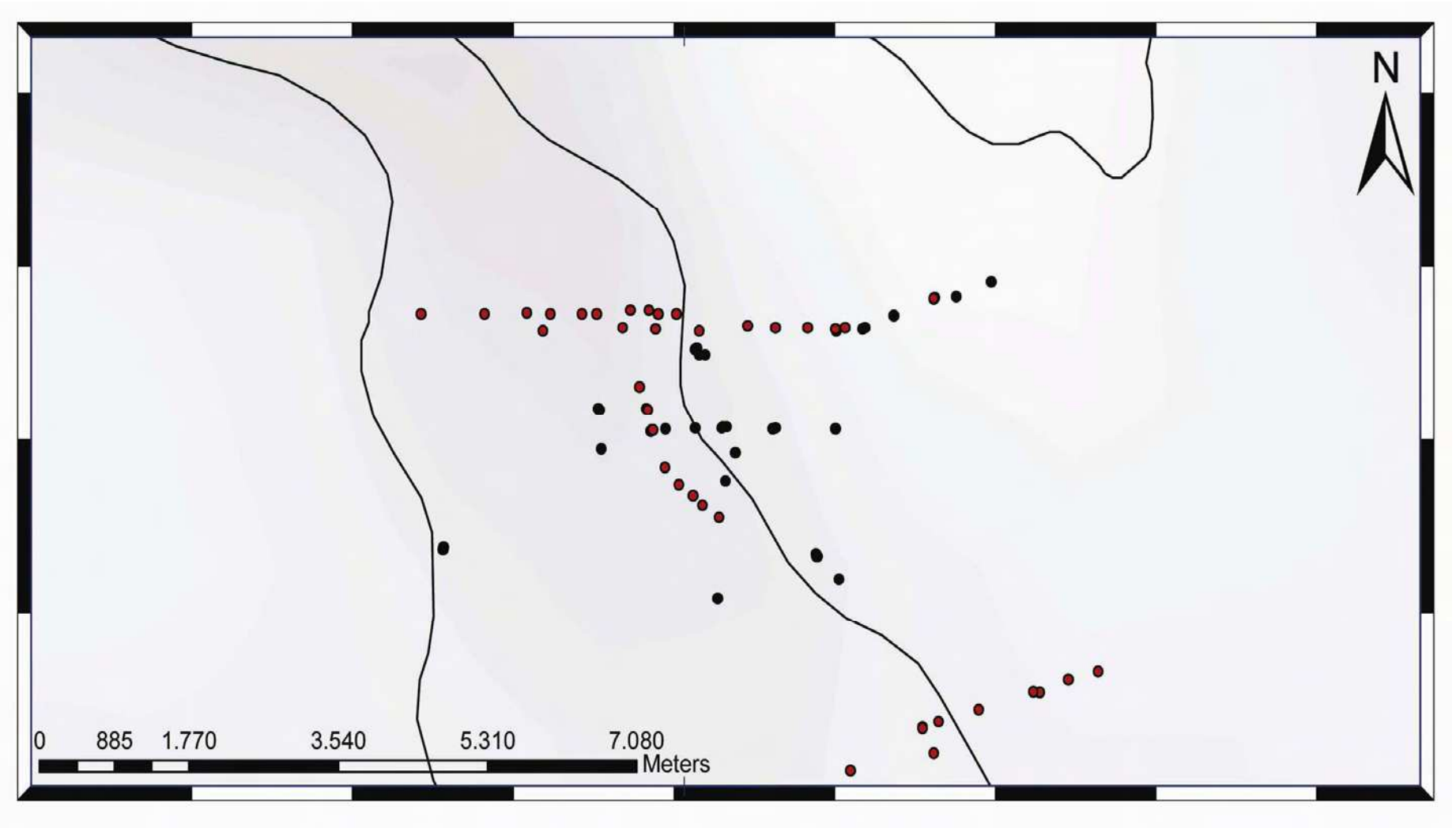

Figure 6 - Sampling locations of the box cores collected in 64PE237 and 64PE253 cruises.

2.3 DATA ANALYSIS

Because sampling of sediment macrofauna was different in the two cruises, two approaches were used. A non quantitative analysis, with biological data collected during both cruises and a quantitative analysis with the biological data collected on the cruise 64PE253. Data analysis was performed using mostly the statistic package Primer V.5 (Clarke & Warwick 2001).

2.3.1 NON QUANTITATIVE ANALYSIS

The biological data was used to calculate the number of species present in all sample sites. The abundance data were first organized into a samples/species matrix. The taxa with less than 2 specimens of the total abundance and the samples with no taxa were discarded. Analyses included modular organisms such as hydrozoans and sponges. Non-metric MDS ordination was performed using Bray-Curtis similarity measure after presence/absence transformation data. An analysis of similarities by randomization/permutation test (ANOSIM) was performed on the MDS results. For the MDS plot of all stations the ANOSIM tests were directed to assess the significance of differences on macrofaunal assemblages based on environmental criteria: depth gradient, sediment type, sediment color and presence of hard substrate (see Annexe II).

According with the depth of stations four groups were considered: the first group includes samples collected up to 380 m (4 stations in Al Idrisi and Mercator mud volcanoes); a second group includes samples from 380 to 480 m (5 stations in Lazarillo de Tornes and Gemini mud volcanoes); the third group includes samples from 480 to 580 m (48 stations mainly at the top of the escarpment) and the fourth group includes the samples collected at more than 580 m (26 stations mainly at the base of the escarpment).

According to the sediment type three groups were considered: the first group characterized mostly by sandy sediments (22 stations); the second group characterized mostly by silty clay sediments (48 stations) and the third group characterized by biogenic sediments (3 stations). For one station there was no available information on the sediment type.

According to the sediment color two groups were considered: the first group characterized mostly by yellowish brown sediments corresponding to well oxygenated hemipelagic sediments (57 stations). The second group characterized mostly by olive sediments usually corresponding to more reduced conditions, typical of mud volcanoes (16 stations). For one station there was no available information on the sediment color.

According to the presence of hard substrate in the samples four groups were considered: the first group contain stations (28) with coral or carbonate concretions at the sediment surface (Figures 7 and 8); a second group include stations (2) with coral covered by sediments at the core surface (Figure 9); a third group include stations (11) with coral in sediments downcore; a fourth group include the stations (27) without coral at the surface or in the sediment (Figure 10). For 6 stations there was no available information on the presence/absence of hard substrate.

The biodiversity of the groups found significantly different by the ANOSIM tests was assessed by rarefaction curves and the characteristic species in each group were sorted out using indices of fidelity and constancy. Rarefaction curves plot the total number of individuals counted with repeated samplings versus the total number of species found in those samplings. The result is a curve that increases steeply at first, then gradually levels off. The point at which it levels off is the point where additional sampling is yielding no additional information about the number of species. This is usually considered the optimal sample size (Gage & Tyler 1991).

The constancy and fidelity indices were calculated for each significant group by the following equations:

$$C = \frac{\text{Frequency of a taxa}}{\text{Total number of samples}} \times 100$$

$$F = \frac{\text{Constancy of a taxon in a sample}}{\text{Sum of the constancies for all groups}} \times 100$$

The different taxa were classified according to their constancy and fidelity:

C ≥ 50	Constant
10≥ C < 50	Accessory
C < 10	Accidental

F > 90	Exclusive
67< F ≤ 90	Elective
50< F ≤ 67	Preferential
20< F ≤ 50	Accompanying
F ≤ 20	Accidental or rare

These formulas, the limits and terms considered in the scales of constancy follow Retiere (1979 in Quintino 1988).

2.3.2 QUANTITATIVE ANALYSIS

The abundance data were first organized into a samples/species matrix. The taxa with less than 2 specimens of the total abundance and the samples with no taxa were discarded. Analyses excluded all modular organisms that could not be counted as individuals (Cnidaria and Porifera). Non-metric MDS ordination was performed using Bray-Curtis similarity measure after square root transformation of the data.

An analysis of similarities by randomization/permutation test (ANOSIM) was performed on the MDS results. For the MDS plot of all stations the ANOSIM tests were directed to assess the significance of differences on macrofaunal assemblages based on

environmental criteria: depth gradient, sediment type, sediment color and presence of hard substrate (see Annexe II).

According to the depth of samples four groups were considered: the first group includes samples (3 stations) collected up to 380 m; a second group includes samples (5 stations) collected from 380 to 480 m; the third group includes samples (13 stations) collected from 480 to 580 m and a fourth group with samples (19 stations) collected at depths greater than 580 m.

According to the sediment type three groups were considered: the first group characterized mostly by sandy sediments (11 stations) the second group characterized mostly by silty clay sediments (29 stations) and a third group characterized by biogenic sediments (one station).

According to the sediment color two groups were considered: the first group characterized mostly by yellowish brown sediments corresponding to well oxygenated hemipelagic sediments (37 stations). The second group characterized mostly by olive sediments usually corresponding to more reduced conditions, typical of mud volcanoes (4 stations).

According to the presence of hard substrate in the samples four groups were considered: the first group contain stations (11) with coral or carbonate concretions at the sediment surface (Figures 7 and 8); a second group includes stations (6) with coral covered by sediments at the core surface (Figure 9); a third group include stations (3) with coral in sediment downcore and a fourth group include stations (21) without coral at the surface or in the sediment (Figure 10).

The biodiversity of the groups found significantly different by the ANOSIM tests was assessed by diversity (Shannon H'), equitability (Shannon J') indices and K-dominance curves. Shannon-Wiener diversity index assumes that individuals are randomly sampled from an "indefinitely large" population and that all species are represented in the sample (Magurram 1988); its values depend on the sample size. Pielou´s evenness index (J') assumes that all species in the community are accounted for in the sample (Magurran 1988), and it varies from 0 to 1.0 (with 1.0 representing a situation where all species are

equally abundant). K-dominance curves consist of plotting the cumulative ranked abundances (y-axis) against species (x-axis) that are ordered by decreasing abundances, in a logarithmic scale (Lambshead *et al*. 1983). The shape and position of the curve allow the interpretation of community structure. Communities dominated by a small number of species have a high value of y-axis intersection point. Curves with a long “tail” indicate a large quantity of rare species in the community.

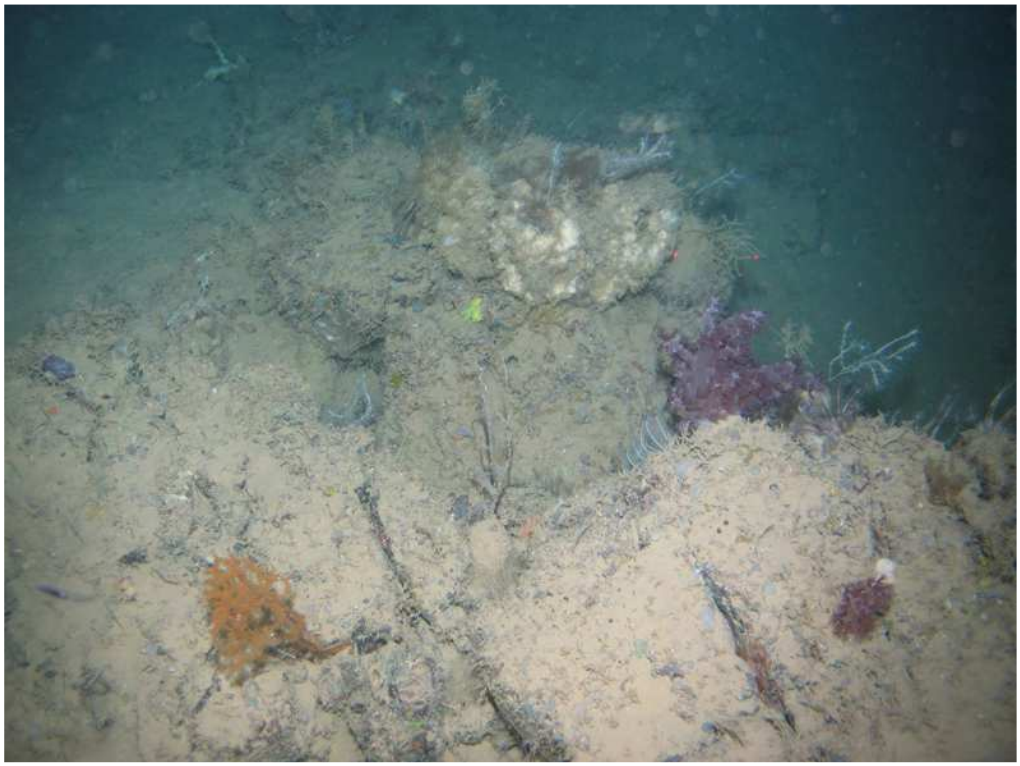

Figure 7 - Carbonate concretions in Pen Duick Escarpment.

Figure 8 - Coral framework in Pen Duick Escarpment.

Figure 9 - Coral debris in Pen Duick Escarpment.

Figure 10 – Soft bottom sediment in Pen Duick Escarpment.

3. RESULTS

A total of 293 taxa were identified from the 83 sampled box cores. The organisms identified are mainly distributed among the taxonomic groups Arthropoda, Annelida and Cnidaria (Figure 11). Arthropods are the most species rich group, comprising 50.2 % of the total number of identified taxa. They are represented mostly by amphipods (23.5%) and isopods (14.0%). The annelids, most of all only determined to family level, comprise 20.1% of the total taxa and are represented mostly by the Aciculata (9.2%). Hydrozoans are represented by 14.7% of the total taxa. Other groups are less represented, such as molluscs with 9.2% and echinoderms with 4.1%. The taxa Porifera, Nemertina, Sipuncula and Echiura (represented in figure as Others) account only for 1.4% of the total taxa.

Most taxa were identified until the species level except for the Porifera, Nemertina, Sipuncula, Echiura and most of the Anellida and therefore the overall species richness has been most likely underestimated in this study. The complete species list at the highest taxonomic resolution available at present is given in Annexe III.

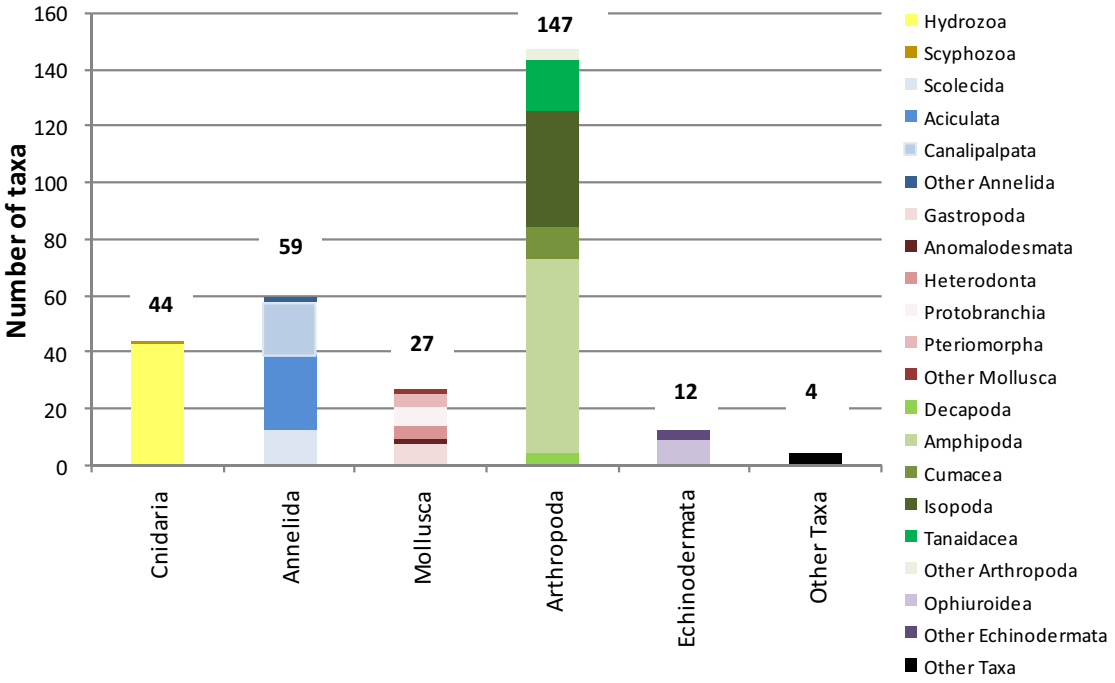

Figure 11 – Total number of taxa of the major faunal groups identified from all box cores. Numbers on the top of bars represent the total number of taxa in each Phylum.

The rarefaction curve based on all available macrofauna data is presented in figure 12. The curve shows an attenuation towards the asymptotic value suggesting that the available dataset is a good representation of the macrofaunal assemblage in the studied area and that a more intensive sampling will probably only yield a small number of additional species.

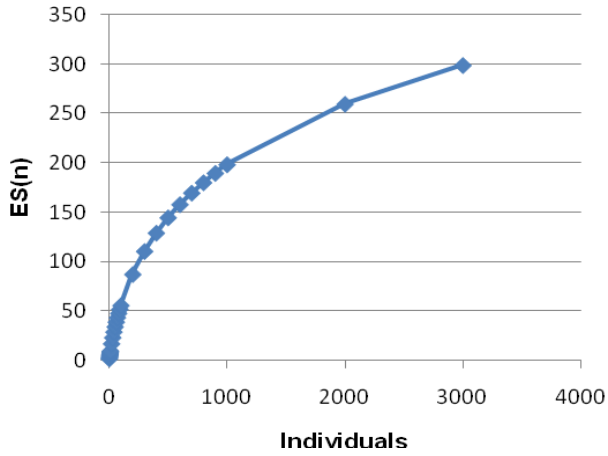

Figure 12 – Hulbert´s rarefaction curves for the complete macrofaunal dataset. ES(n): expected number of species for a given number of individuals (n).

3.1 NON QUANTITATIVE ANALYSIS - RESULTS FROM CRUISES 64PE237 AND 64PE253

3.1.1. MULTIVARIATE ANALYSIS

DEPTH GRADIENT

Figure 13 show the results of the MDS plot for the samples collected at different depths. The communities from depths shallower than 380 m (Depth 1) and from 380 m to 480 m (Depth 2) occupy defined positions in the plot, but the two other depth groups show a high dispersion of the samples. The ANOSIM tests indicate that the variability in the assemblages from different depth groups is not statistically significant (R= -0.023; Significance level= 68.3%).

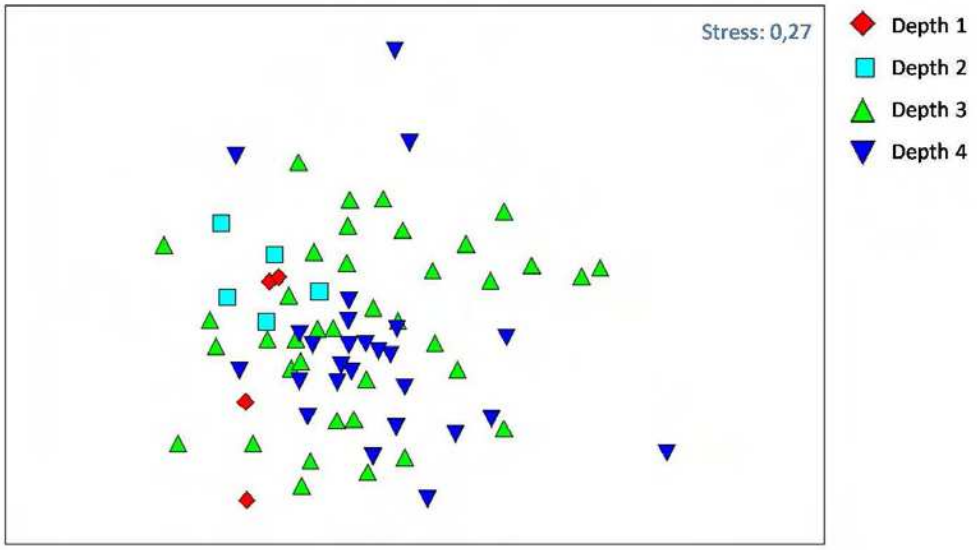

Figure 13 – Multidimensional scaling results of the analysis performed on non quantitative data (presence/absence). Similarity between depth groups was assessed by the Bray-Curtis coefficient. Depth 1: < 380 m; Depth 2: 380 – 480 m; Depth 3: 480 -580 m; Depth 4: > 580 m.

SEDIMENT TYPE - GRAIN SIZE

Figure 14 shows the MDS plot for the analysis performed on sediment type. The MDS plot do not show a clearly separation between the sediment type groups. The results from ANOSIM tests confirm that the variability in the assemblages from different sediment type groups is not statistically significant (R= -0.009; Significance level= 54.2%).

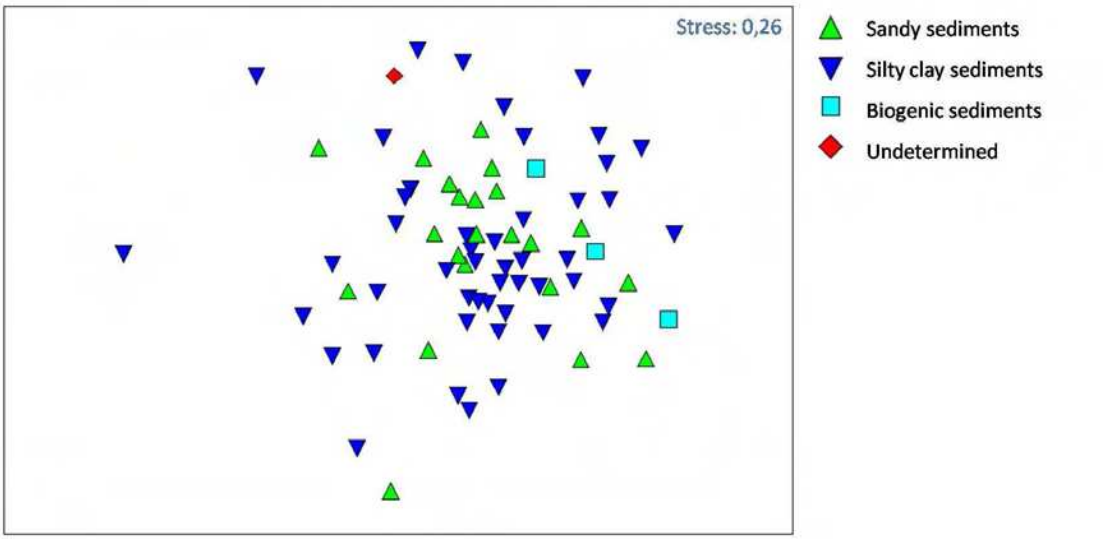

Figure 14 – Multidimensional scaling results of the analysis performed on non quantitative data (presence/absence). Similarity between sediment type groups was assessed by the Bray-Curtis coefficient.

SEDIMENT TYPE – COLOR/BIOGEOCHEMISTRY

The MDS plot (Figure 15) for samples with different sediment color show overlap between the two groups, with a relatively high dispersion of the samples coded “olive”. Nevertheless, the ANOSIM tests indicate that differences in the assemblages from the two sediment color groups are highly significant (R= 0.311; Significance level= 0.1% **) suggesting that different biogeochemical conditions of the sediment may be correlated to differences in the taxonomic composition of the macrofaunal assemblages in the Pen Duick Escarpment.

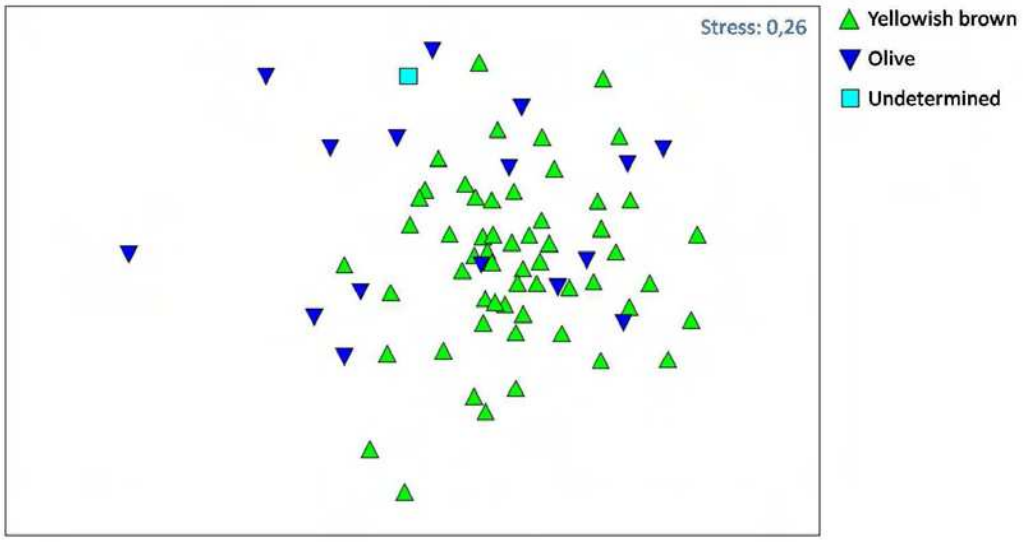

Figure 15 – Multidimensional scaling results of the analysis performed on non quantitative data (presence/absence). Similarity between sediment color groups was assessed by the Bray-Curtis coefficient.

PRESENCE OF HARD SUBSTRATE

The results of the MDS and ANOSIM tests for the assessment of the variability in macrofaunal assemblages in relation to the presence of hard substrate are shown in Figure 16 and Table I. The segregation of the samples according to the presence of hard substrate is not obvious. Nevertheless, the ANOSIM global test indicates that differences in macrofaunal assemblages are highly significant although with a relatively low R value (0.187). The pairwise tests further confirm the statistical significance of differences between groups except for the combination involving the samples coded “SS” (hard substrate covered by sediments at the core surface). This may be explained by the insufficient number of replicates for this group (only two cores were ascribed to this group).

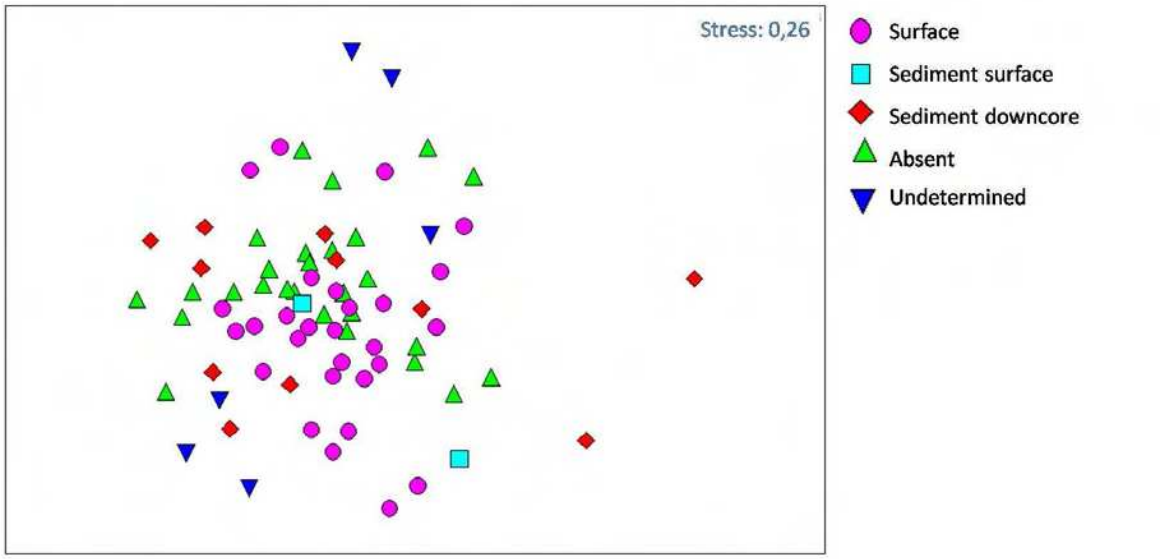

Figure 16 – Multidimensional scaling results of the analysis performed on non quantitative data (presence/absence). Similarity between hard substrate groups was assessed by the Bray-Curtis coefficient. Surface: coral or carbonate concretions at the sediment surface; Sediment surface:coral covered by sediments at the core surface; Sediment downcore: coral in sediments downcore; Absent: absence of coral at the surface or in the sediment; Undetermined: no available information on the presence/absence of hard substrate.

Table I- Results of the ANOSIM global and pairwise tests, given by a one-way analysis with hard substrate groups for the MDS performed for all hard substrate groups. S: coral or carbonate concretions at the sediment surface; SS:coral covered by sediments at the core surface; D: coral in sediments downcore; A: absence of coral at the surface or in the sediment. *:Significance level ≤ 5%; **:Significance level ≤1%.

	Sample statistic (R)	Permutations used	Significant Statistics	Significance level%
Global test	0.187	999	0	0.1**
Pairwise tests				
A, SS	0.240	406	69	17.0
A, D	0.199	999	23	2.4*
A, S	0.050	999	22	2.3*
SS, D	-0.075	78	38	48.7
SS, S	0.160	435	93	21.4
D, S	0.230	999	13	1.4*

3.1.2. CHARACTERIZATION OF THE ASSEMBLAGES

Based on the results of the multivariate analyses we used the four groups related to the presence of hard substrate to further characterize the macrofaunal assemblages and investigate the differences in composition and biodiversity that can be correlated with this environmental driver. The characteristics of the macrofaunal assemblage are easily compared especially between the group of samples with exposed hard substrate (cold-water corals and carbonate concretions) at the surface (S) and the group of samples where hard substrate was absent (A), because both groups were represented by a similar number of samples (28 and 27, respectively). The first group shows a higher number of taxa (170) than the second (152). A clear difference between the presence of exposed hard substrate at surface and the absence of hard substrate is in the number of hydrozoans, which is higher in the first case and in the number of arthropods which is higher in the second case (Figure 17).

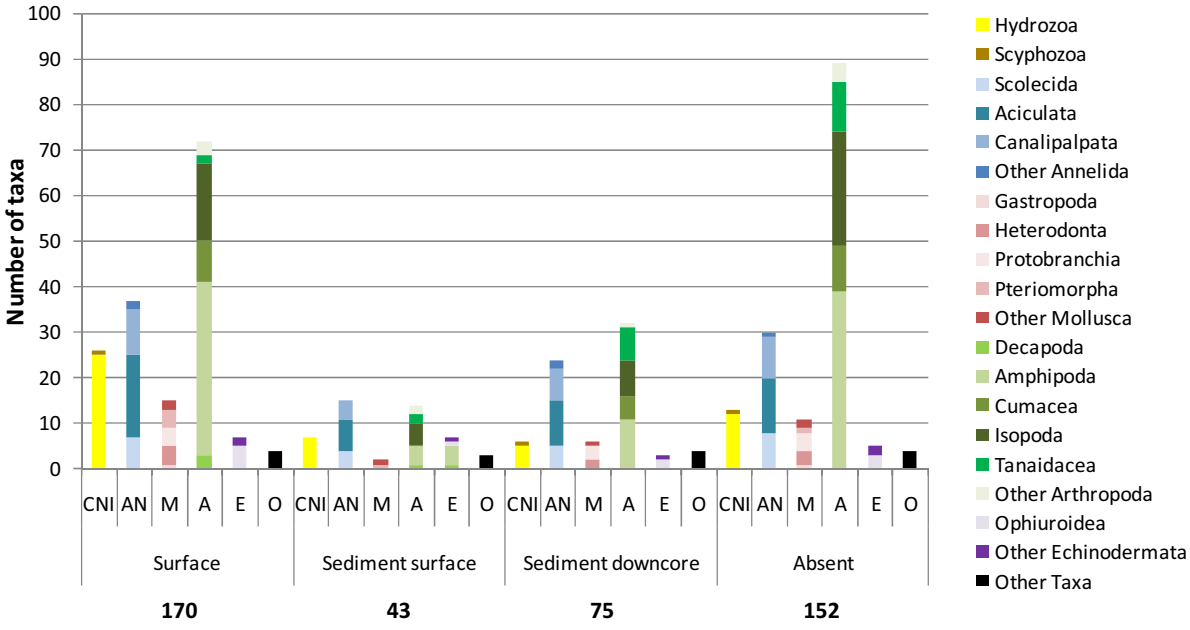

Figure 17 – Total number of taxa of the major faunal groups in the different "hard substrate" groups. Numbers are taxa richness for hard substrate groups. Surface: coral or carbonate concretions at the sediment surface; Sediment surface:coral covered by sediments at the core surface; Sediment downcore: coral in sediments downcore; Absent: absence of coral at the surface or in the sediment. CNI: Cnidaria; AN: Annelida; M: Mollusca; A: Arthropoda; E: Echinodermata; O: Others.

The presence of hard substrate appears to enhance the total taxa richness at surface, but for the coral within the sediment (D), the number of species declines (75), although we must consider that the number of samples in this group (11) is less than half of the other groups. The lowest taxa richness (43) was found in the group "SS" (covered hard substrate near the core surface) represented by only two samples.

The rarefaction curves based on the expected number of species by number of sampled individuals (Figure 18) indicate a slightly higher biodiversity of the assemblages collected from samples with hard substrates at the surface either covered by sediments (groups SS) or exposed (S). The lowest biodiversity is found in the samples representing buried coral and carbonate mounds (D).

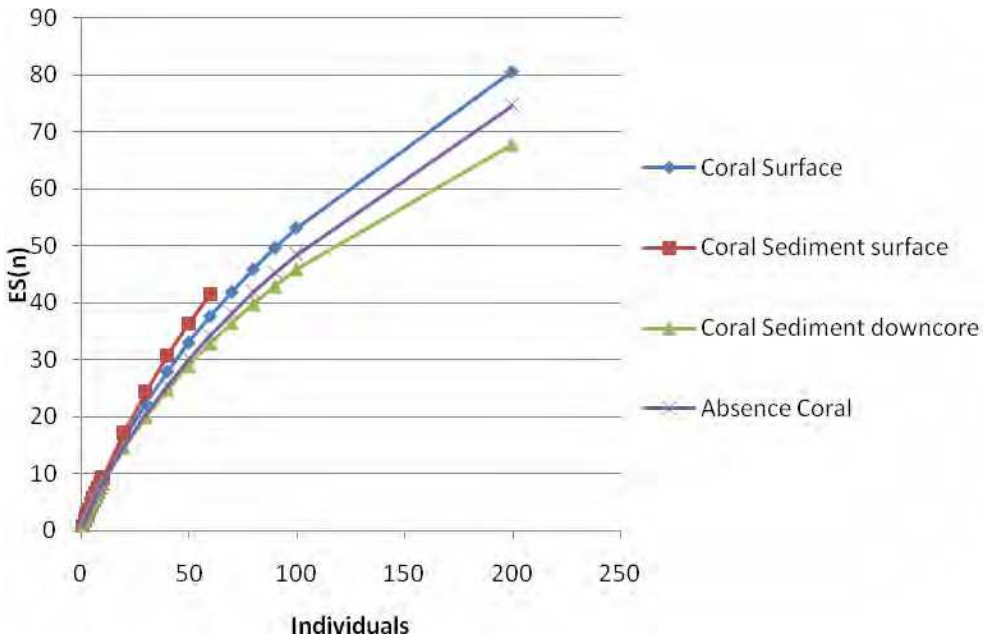

Figure 18 – Hulbert´s rarefaction curves for the assemblages found in different hard substrate groups. Surface: coral or carbonate concretions at the sediment surface; Sediment surface:coral covered by sediments at the core surface; Sediment downcore: coral in sediments downcore; Absent: absence of coral at the surface or in the sediment. ES(n): expected number of species for a given number of individuals (n).

The assessment of the most characteristic taxa in the different hard substrate groups was made by using fidelity and constancy indices that are suitable for non quantitative data. The selected taxa for each hard substrate group are presented in Table II. Only the taxa

with a constancy ≥10 (constants, C ≥50, and accessory, 10≤ C <50) and a fidelity ≥67 (exclusive, F <90, and elective, 67< F ≤90) were considered. According to these criteria, the group with the stations with coral at sediment downcore showed no characteristic species.

Table II- List of the taxa considered species fidelity for each hard substrate group. S: coral or carbonate concretions at the sediment surface; SS:coral covered by sediments at the core surface; Absent: absence of coral at the surface or in the sediment.

S	SS	A
Hydrozoa	**Hydrozoa**	**Bivalvia**
Fillelum cf. *serratum*	*Levinsenia gracilis*	*Ennucula aegensis*
Lafoeina tenuis	*Clytia linearis*	*Ennucula bushae*
Nemertesia UND	*Clytia hemispherica*	**Amphipoda**
Nemertesia sp1	*Halecium tenellum*	*Ampelisca dalmatina*
Nemertina UND	*Modeeria rotunda*	*Harpinia* spp.
Zygophylax biarmata	*N.* cf. *antennina*	cf.*Hippomedon* sp.
Polychaeta	*Sertularella gayi robusta*	*Metaphoxus simplex*
Amphinomidae UND	**Polychaeta**	**Cumacea**
Nephtydae UND	*Eunice dubitatus*	*Campylaspis affinis horrida*
Sabellidae UND	*Laubieriopsis cabiochi*	**Isopoda**
Goniadidae UND	*Pholoides*	*Eugerdella* Und species
Oligochaeta UND	*dorsipapillatus*	*Eugerda* cf. *tetarta*
Amphipoda	**Bivalvia**	
Lembos spp.	*Delectopecten vitreus*	
Gammaropsis sp.	**Sessilia**	
c.f. *Nannonyx* sp.	*Verruca* sp.	
cf. *Andaniexis* sp.	**Amphipoda**	
Harpinia spp.	*Carangolia barnardi*	
Cumacea	*Ampelisca brevicornis*	
Campylaspis spp.	*Ampelisca tuenicornis*	
Eudorella sp.	**Isopoda**	
Tanaidacea	*Austrofilius* sp.	
Apseudes spp.	*Eugerdella affinis*	
Tanaella cf. *unguicillata*	*pugilator*	
	Haplomesus sp.	

The taxa typical of habitats with the exposed hard substrate are hydrozoans, aciculate polychaetes, and a several peracarid crustaceans. In the group of samples with covered hard substrates the characteristic taxa are again hydrozoans, aciculate polychaetes and peracarid crustaceans but also the cirriped *Verruca sp*. and the bivalve *Delectopecten vitreus* (Table II). These assemblages are therefore characterized by sessile species that use the hard substrate for their settlement and associated epibenthic species with high mobility such as aciculate polychaetes, that are relatively large-sized and mostly carnivores, or peracarid crustaceans that are usually small sized and comprehend a variety of feeding types.

In the absence of hard substrates the soft bottom sediments (A) are characterized by the bivalves *Ennucula aegensis* and *Ennucula bushae*, both deposit feeders that live buried at the sediment subsurface and several small-sized peracarid crustaceans.

3.2 QUANTITATIVE ANALYSIS - RESULTS FROM CRUISE 64PE253

3.2.1. MULTIVARIATE ANALYSIS

DEPTH GRADIENT

The results of the MDS and ANOSIM tests for the assessment of the variability in macrofaunal assemblages in relation to depth based on quantitative (abundance) data are shown in Figure 19 and Table III. The MDS plot (Figure 19) shows a clear separation between Depth 1 (depths shallower than 380 m) and Depth 3 (depths from 480 m to 580m). The groups Depth 2 (depths from 380 m to 480 m) and Depth 4 (depths more than 580 m) appear interspersed and overlapping.

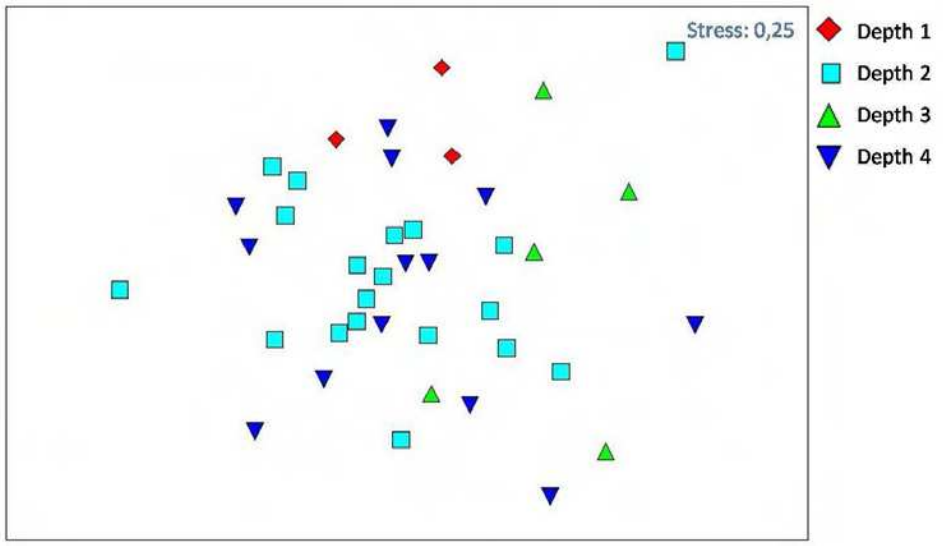

Figure 19 – Multidimensional scaling results of the analysis performed on quantitative data (abundance). Similarity between depth groups was assessed by the Bray-Curtis coefficient. Depth 1: < 380 m; Depth 2: 380 – 480 m; Depth 3: 480 -580 m; Depth 4: > 580 m.

The significance of the variability in the composition and structure of the benthic assemblages in relation to depth is supported by the ANOSIM tests (Table III). Pairwise tests further confirm the significance of the difference between group Depth 2 with both Depth 3 and Depth 4, suggesting important differences found in the assemblages collected from the crater of mud volcanoes (Depth 2) and from the escarpment (Depth 3 and Depth 4). The lack of statistical significance of the pairwise tests involving the group Depth 1 may be partially explained by the low number of replicates (only three cores were ascribed to this group). There was no significant difference between the groups Depth 3 and Depth 4, despite the high number of samples ascribed to each one of these groups (13 and 19, respectively). This result suggests that the benthic assemblages in the top and at the base of the Pen Duick Escarpment are similar.

Table III - Results of the ANOSIM global and pairwise tests for the MDS performed on depth groups. 1: < 380m; 2: 380- 480m; 3: 480 -580m; 4: >580m. *: Significance level ≤ 5%.

	Sample statistic (R)	Permutations used	Significant Statistics	Significance level%
Global test	0.154	999	10	1.1 *
Pairwise tests				
2, 3	0.244	999	40	4.1 *
2, 4	0.383	999	15	1.6 *
2, 1	0.415	56	4	7.1
3, 4	0.025	999	298	29.9
3, 1	0.104	560	151	27.0
4, 1	0.178	999	183	18.4

SEDIMENT TYPE –GRAIN SIZE

The MDS plot for the analysis performed on sediment type (Figure 20) shows an apparent separation between the groups but this is not confirmed by the results from the ANOSIM tests indicating that faunal assemblages are not significantly different in the different sediment type groups (R= -0.063; Significance level= 22.5%).

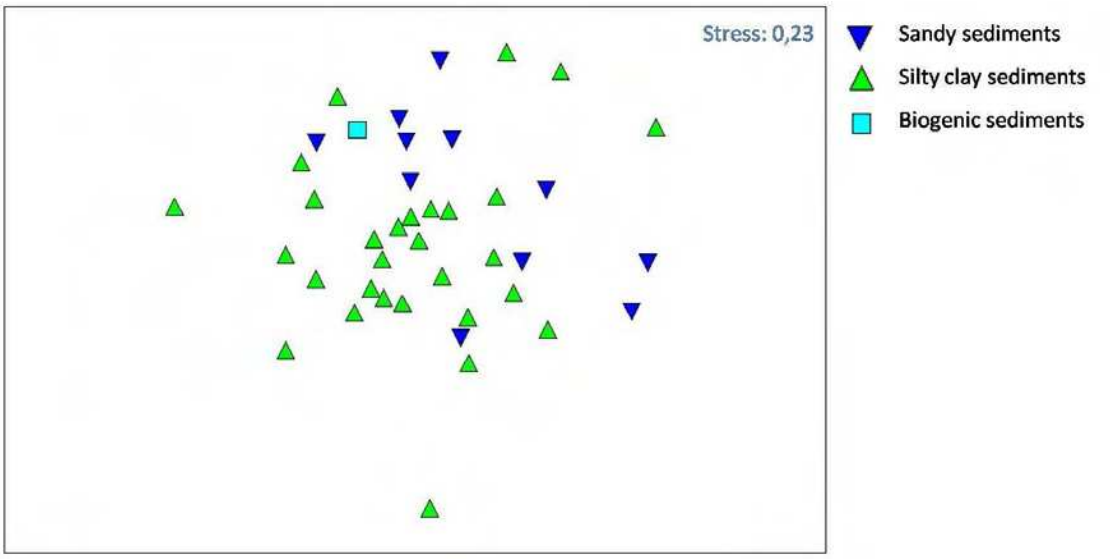

Figure 20 – Multidimensional scaling results of the analysis performed on quantitative data (abundance). Similarity between sediment type groups was assessed by the Bray-Curtis coefficient.

SEDIMENT TYPE – COLOR/BIOGEOCHEMISTRY

The MDS plot (Figure 21) for samples with different sediment colour do not show a clearly separation between the sample groups and this is confirmed by the non significant results of the ANOSIM global test (R= -0.095; Significance level= 71.0%).

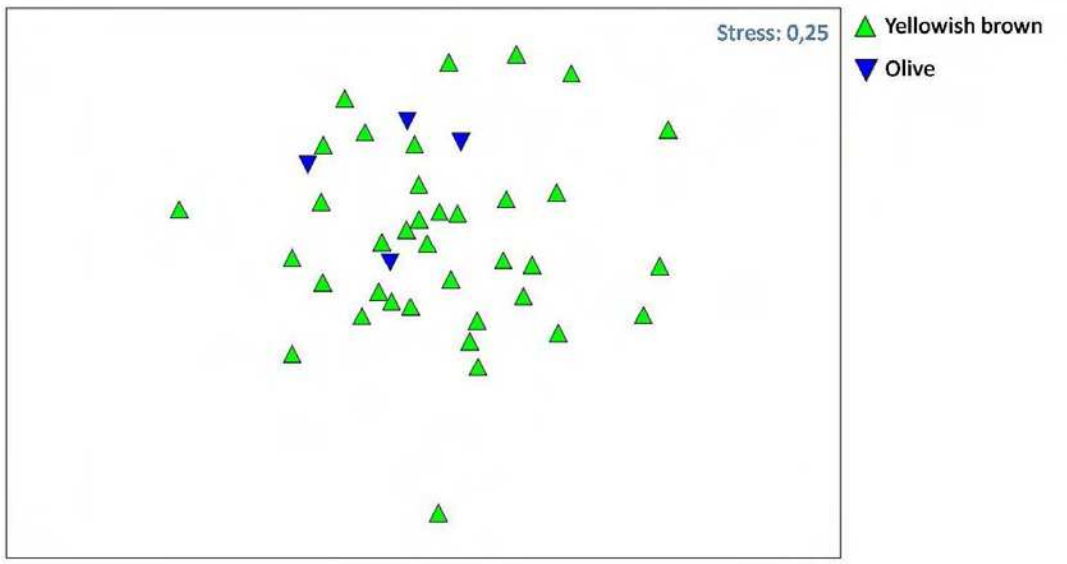

Figure 21 – Multidimensional scaling results of the analysis performed on quantitative data (abundance). Similarity between sediment color groups was assessed by the Bray-Curtis coefficient.

PRESENCE OF HARD SUBSTRATE

When quantitative samples are allocated to hard substrate groups the MDS plot (Figure 22) shows a great overlap among groups which is further confirmed by the non significant results of the ANOSIM global test (R= 0.02; Significance level= 38.3%).

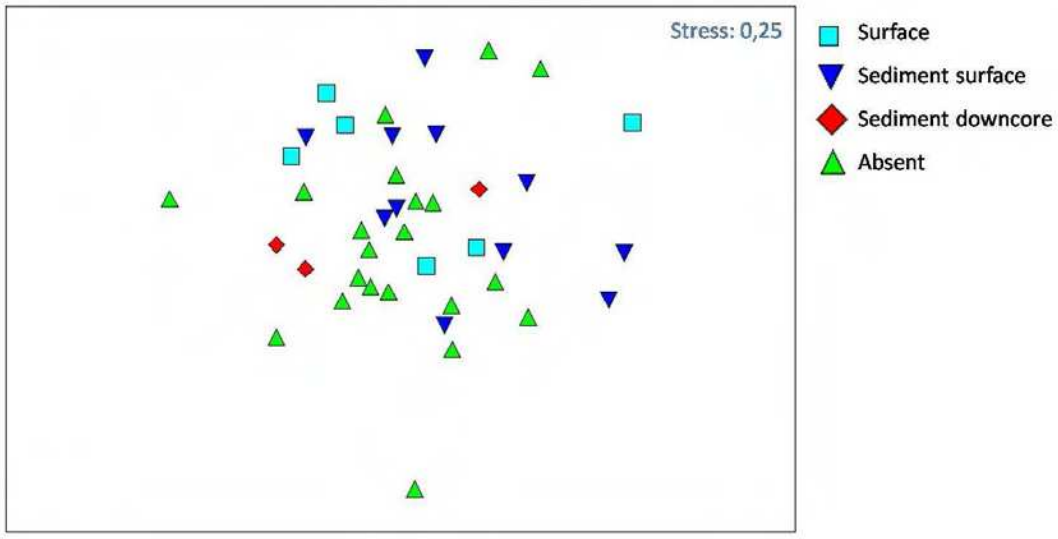

Figure 22 – Multidimensional scaling results of the analysis performed on quantitative data (abundance). Similarity between hard substrate groups was assessed by the Bray-Curtis coefficient. Surface: coral or carbonate concretions at the sediment surface; Sediment surface:coral covered by sediments at the core surface; Sediment downcore: coral in sediments downcore; Absent: absence of coral at the surface or in the sediment.

3.2.2. CHARACTERIZATION OF THE ASSEMBLAGES

Based on the results of the multivariate analyses we used the four groups related to depth to further characterize the macrofaunal assemblages and investigate their differences in composition and biodiversity. The 1186 specimens collected during the cruise 64PE253 were sorted and identified into 92 taxa. Note that for this analysis the sessile modular taxa were excluded. According to the depth gradient (Figure 23) there is a slight increase in the number of taxa with increasing depth mostly owing to the increase in arthropod species. The higher number of taxa found in the Depth 3 (480 - 580 m) and Depth 4 (> 580 m) groups may be strongly affected by the higher sampling effort at these depths (13 and 19 cores, respectively) than in Depths 1 (< 380 m) and 2 (380 - 480 m) (3 and 5 cores, respectively).

At Depth 1 (< 380 m), the 133 individuals were ascribed to 39 taxa mainly annelids and crustaceans. Ophiuroids attain their highest species richness at this depth. At Depth 2

(380 - 480 m), a similar number of individuals (173) yielded 54 taxa. In the best sampled groups at Depths 3 and 4 (> 480 m), the number of individuals collected almost doubled (242 and 333 individuals, respectively) but the increase in the number of taxa was relatively modest (60 taxa in each group). Depth 3 (480 -580 m) showed the highest number of molluscs taxa while the arthropods attained their maximum at Depth 4 (> 580 m) (Figure 23).

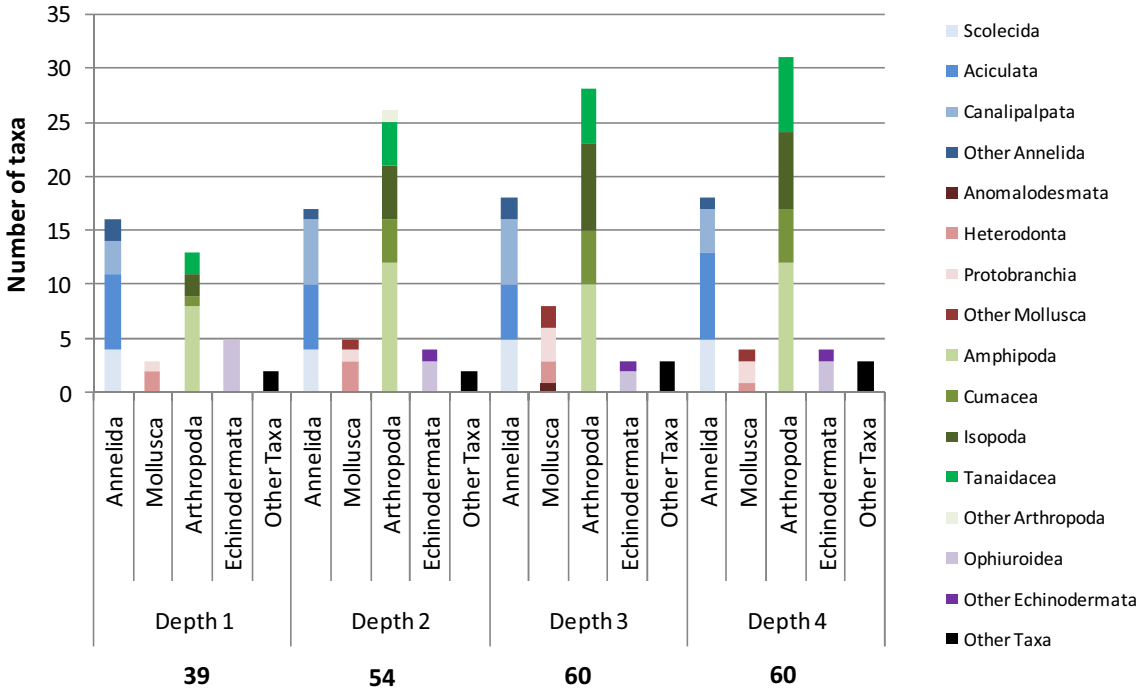

Figure 23 – Number of taxa of the major faunal groups in the different depth groups. Numbers are taxa richness for depth groups. Depth 1: < 380 m; Depth 2: 380 – 480 m; Depth 3: 480 -580 m; Depth 4: > 580 m.

The taxa richness and the density of the assemblages showed opposite trends with increasing depth. Macrofaunal densities (Figure 24) were highest at the shallower depths (903.2±190.14 ind.m^{-2} (mean ± standard error) at Depth 1 (< 380 m) and 704.9±323.30 ind.m^{-2} (mean ± SE) at Depth 2 (380 – 480 m)) and about half of these values at greater depths (377.7±70.40 ind.m^{-2} (mean ± SE) at Depth 3 (480 -580 m) and 357.0±49.10 ind.m^{-2} (mean ± SE) at Depth 4 (> 580 m)).

There were significant differences in the variance of the assemblages between Depth 2 (380 – 480 m) with both Depth 3 (480 – 580 m) and Depth 4 (> 580 m) (Table IV).

However the differences in the densities between these groups were not significant (Table V). This could be related with the high variance in Depth 2 (380 – 480 m).

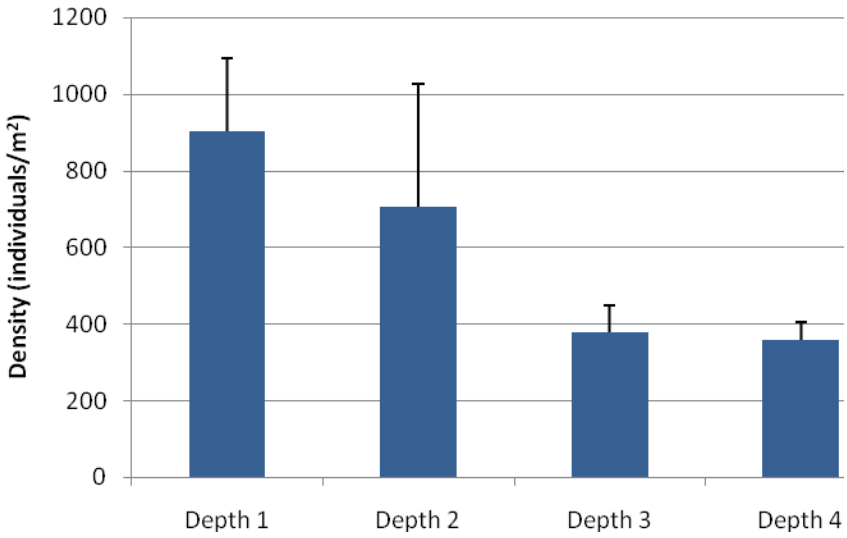

Figure 24 –Total density (individuals.m^{-2}) and standard error bars for all depth groups. Depth 1: < 380 m; Depth 2: 380 – 480 m; Depth 3: 480 -580 m; Depth 4: > 580 m.

Table IV - Results of the F test performed on depth groups. 1: < 380m; 2: 380- 480m; 3: 480 -580m; 4: >580m. ns: non significant; *: p<0.05.

	F_s	$F_{0.05}$	Significance level
1, 2	4.819	19.2	ns
1, 3	1.683	3.89	ns
1, 4	2.368	3.68	ns
2, 3	8.110	3.26	*
2, 4	11.409	3.06	*
3, 4	1.407	2.48	ns

Table V - Results of the Z test performed on depth groups. 1: < 380m; 2: 380- 480m; 3: 480 -580m; 4: >580m. ns: non significant; *:p<0.05.

	Z test	**$t_{0.05}$**	**Significance level**
1, 2	0.529	2.447	ns
1, 3	2.592	2.145	*
1, 4	2.781	2.086	*
2, 3	0.989	2.120	ns
2, 4	1.064	2.074	ns
3, 4	0.240	2.042	ns

Figure 25 illustrates the abundance structure of the assemblages in each depth group. Annelids are highly dominant at Depth 1 (Al Idrisi and Mercator mud volcanoes) where the Ophiuroids also reach their highest contribution to the total abundance in the benthic assemblage. Depth 2 (Gemini and Lazarillo de Tornes mud volcanoes) are characterised by the numerical dominance of crustacean specimens (especially the Leptostracan *Nebalia* sp. in one of the stations) and the lowest contribution of annelids. The graphs for Depth 3 (480 – 580 m) and Depth 4 (> 580 m) confirm the high similarity of the assemblages collected from the top (Depth 3) and base (Depth 4) of the Pen Duick Escarpment. The assemblage is slightly more dominated by annelids at Depth 3 while at Depth 4 the densities of annelids and arthropods are almost even. These two depth groups present the highest contribution of molluscs in the benthic assemblage.

The diversity and equitability indexes estimated for the pooled assemblages in each depth group (Table VI) are globally high, being slightly higher at the top and base of the Pen Duick Escarpment sampled at greater depths than in the mud volcanoes sampled at lower depths. These values are confirmed by the graphic analysis of the community structure (Figure 26) that shows slightly more elevated k-dominance curves in the mud volcanoes than in the escarpment. The similarity of the assemblages at the top and base of the escarpment is again illustrated by the almost complete overlap of the k-dominance curves at Depths 3 and 4.

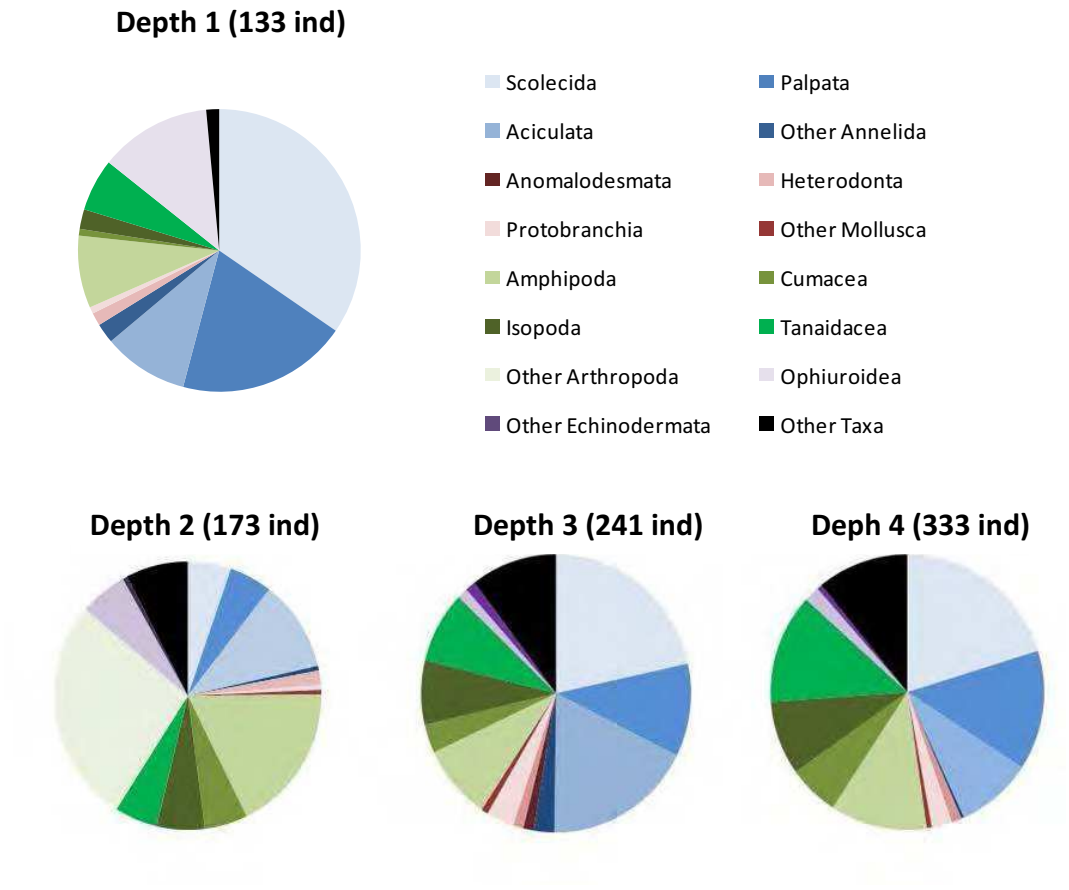

Figure 25 –Pie charts for all depth groups with the abundance of the major faunal groups in the assemblages. Depth 1: < 380 m; Depth 2: 380 – 480 m; Depth 3: 480 -580 m; Depth 4: > 580 m.

Table VI – Total individuals per depth group (N), number of stations per depth group, Shannon equitability index (J') and Shannon diversity index (H'). Depth 1: < 380 m; Depth 2: 380 – 480 m; Depth 3: 480 -580 m; Depth 4: > 580 m.

	N	Nº stations	J'	H'(loge)
Depth 1	133	3	0,8422	3,0853
Depth 2	173	5	0,8239	3,2710
Depth 3	241	13	0,8680	3,5539
Depth 4	333	19	0,8426	3,4501

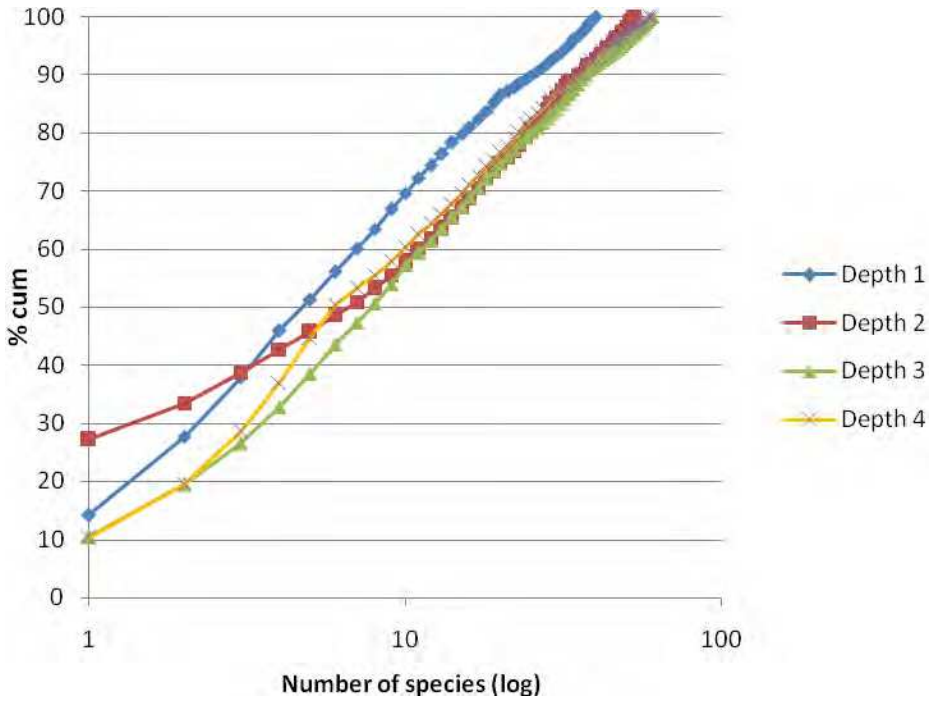

Figure 26 - k-dominance curves for Total Macrofauna contrasted between depths. Depth 1: < 380 m; Depth 2: 380 – 480 m; Depth 3: 480 -580 m; Depth 4: > 580 m. % cum: Percentage cumulative abundance.

The differences and similarities among the depth groups are shown in more detail in table VII that ranks the six most abundant taxa at each group, with relatively low dominances of all taxa, except for *Nebalia* sp. at Depth 2 (Gemini and Lazarillo de Tornes mud volcanoes). At Depth 1 (Mercator and Al Adrisi mud volcanoes) all the dominant taxa are polychaete families while at Depth 2 the dominance is shared by crustaceans, polychaetes, sipunculids and ophiuroids. At Depths 3 and 4 (Pen Duick Escarpment) the assemblages share five out of the six most abundant taxa (Maldanidae, Sipuncula, Onuphidae, Paraonidae and *Apseudes* spp.) that show great evenness in their contributions to the total abundance.

Table VII- Six most abundant taxa for each depth group. Depth 1: < 380 m; Depth 2: 380 – 480 m; Depth 3: 480 -580 m; Depth 4: > 580 m.

Depth 1	%	Depth 2	%	Depth 3	%	Depth 4	%
Ampharetidae UND	14,19	*Nebalia* sp.	27.17	Maldanidae UND	10,37	Sipuncula UND	10,21
Amphinomidae UND	13,51	Sipuncula UND	6,36	Sipuncula UND	9,13	Onuphidae UND	9,31
Capitellidae UND	10,14	Stenothoidae UND	5,20	Onuphidae UND	7,05	*Apseudes* spp.	9,01
Cirratulidae UND	8,11	Sabellidae UND	4.05	*Siboglium* UND	6,22	Paraonidae UND	8,41
Fauvelopsidae UND	5,41	*Siboglium* sp.	2.89	Paraonidae UND	5,81	Maldanidae UND	7,81
Glyceridae UND	4,73	Ophiuroidea UND	2.89	*Apseudes* spp.	4,98	Fauvelopsidae UND	5,71

4. DISCUSSION

A total of 293 of benthic invertebrates were identified in the Pen Duick Escarpment. The arthropods were the most speciose group followed by the annelids, the hydrozoans and molluscs. From the results of the global rarefaction curve, it appears that additional sampling would not greatly increase the number of taxa sampled.

Table VIII summarises some data on the faunal assemblages studied in different cold-water coral regions of the North Atlantic. A study of the associated fauna of *L. pertusa* coral reefs (live and dead) in Gulf of Mexico revealed a total of 142 taxa of benthic invertebrates from which 66 were Porifera and 57 were Cnidaria (Reed *et al*. 2006). In a quantitative analysis of live and dead colonies of *Lophelia*, Jensen and Frederiksen (1992) found 298 species dominated by polychaetes (67), bryozoans (45), molluscs (31), sponges (29), and crustaceans (15). A recent study in the carbonate mounds in the Porcupine Seabight, revealed a total of 349 species, where the annelids and crustaceans were the most speciose groups followed by molluscs and cnidarians (Henry & Roberts 2007).

Table VIII – Studies of macrofauna of deep-water coral *L. pertusa* indicating locality, number of stations, area sampled, method used, depth range and total taxa or species collected.

Locality	Nº of stations	Area (m^2)	Method	Total number of taxa	Depth (m)	
Faroe shelf	25		Dredge	298 (species)		Jensen & Frederiksen 1992
Gulf of Mexico	6		ROV observ.	142		Reed *et al.* 2006
Porcupine Seabight	11	2.75	Box-core	349 (species)	798 - 942	Roberts *et al.* 2007
Pen Duick	83	----	Box-core	293	227 -682	This study
Pen Duick	41	2.01	Box-core	93	227 -678	This study

The comparison among the biodiversity of the different studied regions is difficult because the disparity of values for taxonomic richness reported in the different studies is

likely to be strongly influenced by the different methods used and areas sampled (Table VIII).

Carbonate mounds from Pen Duick Escarpment are similar to the ones found in the Porcupine Seabight, Irish margin. They have fine and grained sediments and scleractinian coral debris. However no dense coverage of living reef-building scleractinian coral comparable to the Irish margin has been observed in Pen Duick Escarpment (Wienberg *et al*. in press). The presence of live coral in Porcupine Seabight could likely account for the higher number of taxa collected from a similar area sampled. However, we also must consider that the number of taxa reported from the quantitative study in the Pen Duick Escarpment is probably underestimated because some important taxonomic groups were not identified to species level (eg. the Annelida) and other were not accounted for (eg. the Porifera and Cnidaria). The inclusion of these groups if an identification to species level becomes available in the future will greatly decrease the difference in species richness between these two cold water coral regions. The numerical dominance of crustaceans and annelids appears to be a common feature of the cold water corals' associated fauna both in the Porcupine Seabight and the Pen Duick Escarpment.

4.1 DEPTH GRADIENT

Scleractinian cold-water corals were observed in Golf of Cadiz in waters of 280 m down to 2200 m depths but the majority was found at depths between 600 and 1000m (Wienberg *et al*. in press). This study represent only a small window of the bathymetric range of corals as only depth groups 3 and 4 (~480-700m) can be strictly associated to this habitat. In fact, the variability in the composition and structure of the macrofauna was only significant for the quantitative analysis (the sessile fauna was not accounted for) and it is more likely related to the different environments sampled, mud volcanoes at shallower depths and corals and carbonate concretions at greater depths than to the depth gradient itself.

The number of taxa collected was higher in the Pen Duick Escarpment than in the mud volcanoes while the macrofaunal density showed the opposite trend. The shallow mud volcanoes are sites of high and diversified availability of food owing to the proximity to coastal and euphotic waters together with the enhanced chemosynthetic production which leads to the presence of a number of opportunistic species, high densities and usually higher dominance. In these mud volcanoes there is a high penetration of background fauna including a high number of crustaceans (amphipods, isopods, tanaidaceans and cumaceans), polychaetes and ophiuroids (Rodrigues 2009).

At the top and base of the Pen Duick Escarpment the values of diversity and equitability indexes suggest that the macrofaunal assemblages are more diverse and even despite the lower densities. These results are in agreement with the ones reported by Roberts *et al* (2007) who also found low dominances in cold water coral mounds and adjacent off-mound habitats in the Porcupine Seabight. The high habitat heterogeneity of the coral framework provides a number of niches that favour the settlement of a variety of species with different life styles and feeding types and thus the assemblage is structured by low levels of competition favouring high species richness.

4.2 SEDIMENT TYPE

According to Etter and Grassle (1992) relationships occur between species diversity and sediment heterogeneity. They suggested that sediment particle size diversity has an important role in determining the number of species within a community. In this study no significant differences were found between the sediments with smaller grain sizes, that is, silty clay, sandy and biogenic sediments. These results are comparable to another work by Roberts *et al.* (2008) who studied the differences on megafaunal communities in coral carbonate mounds on Hatton Bank, NE Atlantic according to different subhabitats. This study revealed that there were no differences between the assemblages found in cobbles, sand or mud.

However, our study showed significant differences in the non quantitative analysis of macrofaunal assemblages from samples ascribed to different sediment colour groups. As mentioned before, olive sediments reflect the reducing conditions of the sediments typical from mud volcanoes, while yellow-brown sediments reflect oxygenated conditions of hemipelagic materials that sediment over the corals and carbonate mounds. Therefore, and as in the case of the depth gradient the differences between sediment colour are likely to reflect differences in the habitat types and related environmental conditions.

4.3 PRESENCE OF HARD SUBSTRATE

Differences in different subhabitats were statistically supported in non quantitative analysis. The assemblages associated with hard substrates such as cold-water corals and carbonate concretions have a higher number of taxa compared with the assemblages from soft bottom sediments. The taxonomic composition of the assemblages from these two different habitats also showed notable differences. Hard substrates are typically colonized by hydozoans and other sessile fauna whose settlement depends on the availability of such substrates and that have feeding modes extremely dependent on moderate current speeds. These animals are filter feeders (eg. Porifera, the cirriped *Verruca sp*. and the bivalve *Delectopecten vitreus*) or carnivores (many cnidarians) that depend on the currents to capture small zooplankton preys. The coral framework as well as the settlement of cnidarians and sponges enhances the tridimensionality and overall structural complexity of the habitat providing refuge for a wealth of small crustaceans with diversified life styles (swimmers, crawlers, tube-dwellers) and feeding modes (mostly suspension and detritus feeders). These crustaceans and also many small polychaetes are attractive preys for other macrofaunal groups. The aciculate polychaetes such as Amphinomidae, Eunicidae, Nephtydae, Goniadidae and Pholoidae families that are found associated to these habitats are large-sized, highly mobile and mostly carnivores that are known to prey upon small crustaceans and other polychaetes (Rouse & Pleijel 2001).

These are strongly contrasting with the ones from soft sediments where the presence of sessile fauna is rare and most animals are small sized surface and sub-surface detritivores such as the common bivalves *Ennucula aegensis* and *Ennucula bushae* and many peracarid crustaceans.

It is noteworthy, that when the sessile fauna was removed from the quantitative analysis the significance of the difference between subhabitats was not recognized by the ANOSIM tests illustrating that this fauna is likely the most important component of the assemblages associated with hard substrates.

The enhancement of species richness favoured by the heterogeneity characteristic of hard substrate habitats and particularly coral framework has been repeatedly reported. An example is the study on the megafauna associated *to L. pertusa* reef in the Norwegian margin by Mortensen *et al.* (1995) who found a fauna with three times higher diversity than the fauna on the surrounding soft-bottoms. In another recent study, on megafauna diversity in the Porcupine Seabight, Roberts *et al*. (2008) found that the richest communities were associated with coral-structured (rubble and framework) and rocky macrohabitats.

5. CONCLUSIONS

One of the main difficulties faced during this work was the scarcity of published environmental data in the Pen Duick Escarpment and the inexistence of published macrofauna data in this area. Moreover, even available publications from other cold water coral regions are rare and the methodologies for the study of their associated fauna is far from being standardized which impedes objective comparisons.

During this work different aspects of the macrofauna assemblages associated to the presence of hard substrates (cold-water corals and carbonate concretions) in the Pen Duick Escarpment were investigated. The multivariate analyses performed assessed significant differences related to the presence/absence of hard substrates and to the sediment type/color (non quantiative analysis), and depth (quantitative analyses). These differences could be characterized in terms of the biodiversity and structure of the assemblages. Our results are consistent with the work by other authors that hypothesize an enhancement of the biodiversity in assemblages associated with coral framework.

Deep-water coral reefs consist of a complex three-dimensional framework with many subhabitats. Because cold water coral reefs In the Pen Duick Escarpment are mostly dead, these subhabitats include exposed dead coral framework, sediment-clogged dead coral framework and the coral rubble surrounding a reef. Coral debris and coral framework support a high diversity of macrofaunal species, and these associated assemblages are composed mainly by hydrozoans, crustaceans and polychates.

The high habitat heterogeneity of the coral framework provides a number of niches that favour the settlement of a variety of species with different life styles and feeding types and thus the assemblage is structured by low levels of competition favouring high species richness.

The biodiversity values estimated for the Pen Duick cold-water coral region are probably underestimates as some important taxa were not identified to species level. Future work

must be carried out in order to enhance the taxonomic resolution of the available data and obtain more accurate estimates on the biodiversity of this interesting area.

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ANNEXE I

Table I – Sampling date, geographic location (Latitude and Longitude), depth and sites analysed in this study (M2005 – Cruise 64PE237; M2006 – Cruise 64PE253).

Cruise	Station	Date	Latitude (N)	Longitude (W)	Depth (m)
M2005	**M2005-01**	02-jun-05	35º 17.306'	6º 47.800'	640
M2005	**M2005-03**	21-may-05	35º 17.425'	6º 47.006'	517
M2005	**M2005-04**	21-may-05	35º 17.613'	6º 49.537'	680
M2005	**M2005-04B**	21-may-05	35º 17.601'	6º 49.539'	682
M2005	**M2005-05**	21-may-05	35º 17.561'	6º 47.141'	529
M2005	**M2005-05B**	21-may-05	35º 17.571'	6º 47.151'	535
M2005	**M2005-05C**	21-may-05	35º 17.563'	6º 47.149'	533
M2005	**M2005-06A**	24-may-05	35º 18.322'	6º 47.754'	544
M2005	**M2005-06B**	24-may-05	35º 18.331'	6º 47.749'	546
M2005	**M2005-07**	24-may-05	35º 18.005'	6º 47.728'	570
M2005	**M2005-10**	24-may-05	35º 18.173'	6º 47.667'	538
M2005	**M2005-12**	25-may-05	35º 18.316'	6º 47.027'	538
M2005	**M2005-13**	25-may-05	35º 18.323'	6º 47.412'	546
M2005	**M2005-13B**	25-may-05	35º 18.317'	6º 47.430'	547
M2005	**M2005-14**	25-may-05	35º 18.330'	6º 47.724'	546
M2005	**M2005-15**	25-may-05	35º 18.326'	6º 47.927'	570
M2005	**M2005-16A**	26-may-05	35º 18.310'	6º 48.205'	660
M2005	**M2005-16B**	26-may-05	35º 18.303'	6º 48.210'	665
M2005	**M2005-17**	26-may-05	35º 18.315'	6º 48.115'	618
M2005	**M2005-19A**	30-may-05	35º 18.915'	6º 46.840'	547
M2005	**M2005-19B**	30-may-05	35º 18.914'	6º 46.853'	547
M2005	**M2005-20**	30-may-05	35º 18.988'	6º 46.853'	516
M2005	**M2005-21**	30-may-05	35º 19.084'	6º 46.397'	498
M2005	**M2005-22**	30-may-05	35º 19.105'	6º 46.256'	518
M2005	**M2005-23**	30-may-05	35º 19.186'	6º 46.029'	559
M2005	**M2005-28A**	31-may-05	35º 18.200'	6º 46.527'	622
M2005	**M2005-28B**	31-may-05	35º 18.200'	6º 46.527'	622
M2005	**M2005-29A**	01-jun-05	35º 18.440'	6º 46.544'	628
M2005	**M2005-29B**	01-jun-05	35º 18.431'	6º 46.539'	628
M2005	**M2005-30A**	01-jun-05	35º 18.755'	6º 47.863'	556
M2005	**M2005-30B**	01-jun-05	35º 18.755'	6º 47.895'	550
M2005	**M2005-31**	01-jun-05	35º 18.794'	6º 47.925'	559

Table I – *Continued.*

Cruise	Station	Date	Latitude (N)	Longitude (W)	Depth (m)
M2006	**M2006-06**	Oct 06 2006	35°16.88'	6°45.35'	418
M2006	**M2006-08**	Oct 07 2006	35°16.75'	6°45.72'	444
M2006	**M2006-09**	Oct 07 2006	35°16.76'	6°45.76'	451
M2006	**M2006-10**	Oct 07 2006	35°16.83'	6°45.54'	432
M2006	**M2006-11**	Oct 07 2006	35°16.79'	6°45.59'	438
M2006	**M2006-13**	Oct 08 2006	35°16.65'	6°46.11'	516
M2006	**M2006-14**	Oct 08 2006	35°16.58'	6°46.37'	575
M2006	**M2006-15**	Oct 08 2006	35°16.54'	6°46.47'	600
M2006	**M2006-17**	Oct 08 2006	35°16.29'	6°46.93'	612
M2006	**M2006-18**	Oct 08 2006	35°16.39'	6°46.40'	608
M2006	**M2006-19**	Oct 09 2006	35°11.31'	7° 4.30'	908
M2006	**M2006-21**	Oct 10 2006	35°19.00'	6°48.05'	560
M2006	**M2006-22**	Oct 10 2006	35°19.00'	6°48.16'	557
M2006	**M2006-23**	Oct 10 2006	35°19.02'	6°48.22'	557
M2006	**M2006-24**	Oct 10 2006	35°19.02'	6°48.34'	571
M2006	**M2006-25**	Oct 10 2006	35°19.00'	6°48.56'	648
M2006	**M2006-26**	Oct 10 2006	35°19.00'	6°48.65'	628
M2006	**M2006-27**	Oct 10 2006	35°19.00'	6°48.85'	622
M2006	**M2006-28**	Oct 10 2006	35°19.01'	6°49.00'	642
M2006	**M2006-30**	Oct 11 2006	35°19.00'	6°49.27'	651
M2006	**M2006-31**	Oct 11 2006	35°19.00'	6°49.68'	671
M2006	**M2006-33**	Oct 11 2006	35°18.93'	6°47.59'	542
M2006	**M2006-34**	Oct 11 2006	35°18.92'	6°47.41'	542
M2006	**M2006-35**	Oct 11 2006	35°18.92'	6°47.21'	542
M2006	**M2006-36**	Oct 12 2006	35°18.92'	6°46.97'	497
M2006	**M2006-38A**	Oct 12 2006	35°19.09'	6°46.40'	494
M2006	**M2006-38B**	Oct 12 2006	35°19.09'	6°46.40'	497
M2006	**M2006-38C**	Oct 12 2006	35°19.09'	6°46.40'	497
M2006	**M2006-38D**	Oct 12 2006	35°19.09'	6°46.40'	497
M2006	**M2006-38E**	Oct 12 2006	35°19.10'	6°46.39'	497
M2006	**M2006-38F**	Oct 12 2006	35°19.09'	6°46.40'	497
M2006	**M2006-39**	Oct 13 2006	35°18.90'	6°47.90'	560
M2006	**M2006-40**	Oct 13 2006	35°18.90'	6°47.02'	542

Table I – *Continued.*

Cruise	Station	Date	Latitude (N)	Longitude (W)	Depth (m)
M2006	**M2006-40A**	Oct 13 2006	35°18.91'	6°47.03'	560
M2006	**M2006-41**	Oct 13 2006	35°18.91'	6°48.18'	568
M2006	**M2006-42**	Oct 13 2006	35°18.92'	6°48.39'	637
M2006	**M2006-44**	Oct 13 2006	35°18.90'	6°48.90'	640
M2006	**M2006-44A**	Oct 13 2006	35°18.90'	6°48.90'	640
M2006	**M2006-46**	Oct 14 2006	35°13.86'	6°36.60'	228
M2006	**M2006-46A**	Oct 14 2006	35°13.86'	6°36.60'	228
M2006	**M2006-46B**	Oct 14 2006	35°13.85'	6°36.59'	227
M2006	**M2006-48**	Oct 14 2006	35°17.90'	6°39.00'	376
M2006	**M2006-49**	Oct 14 2006	35°17.90'	6°38.64'	360
M2006	**M2006-51**	Oct 15 2006	35°18.57'	6°48.28'	624
M2006	**M2006-52**	Oct 15 2006	35°18.43'	6°48.23'	622
M2006	**M2006-53**	Oct 15 2006	35°18.31'	6°48.20'	651
M2006	**M2006-54**	Oct 15 2006	35°18.09'	6°48.12'	634
M2006	**M2006-56**	Oct 15 2006	35°17.99'	6°48.03'	622
M2006	**M2006-57**	Oct 16 2006	35°17.92'	6°47.94'	598
M2006	**M2006-58**	Oct 16 2006	35°17.86'	6°47.88'	606
M2006	**M2006-59**	Oct 16 2006	35°17.79'	6°47.77'	637

ANNEXE II

Table I – Description of the sedimentological characteristics of the box core for the stations sampled according with the following criteria: presence of hard substrate (coral or carbonate concretions), sediment type and sediment color.

	Presence of hard substrate	Sediment type	Sediment color
M2005-01	Absent	Silty clay	Yellowish brown
M2005-03	Coral at surface	Sandy	Yellowish brown
M2005-04	Absent	Sandy	Yellowish brown
M2005-04B	Undetermined	Sandy	Undetermined
M2005-05	Undetermined	Silty clay	Undetermined
M2005-05B	Undetermined	Silty clay	Undetermined
M2005-05C	Coral at sediment surface	Silty clay	Yellowish brown
M2005-06A	Undetermined	Silty clay	Olive
M2005-06B	Coral at sediment dowcore	Silty clay	Olive
M2005-07	Coral at sediment dowcore	Biogenic	Yellowish brown
M2005-10	Coral at sediment dowcore	Sandy	Yellowish brown
M2005-12	Coral at surface	Silty clay	Yellowish brown
M2005-13	Absent	Silty clay	Olive
M2005-13B	Undetermined	Undetermined	Yellowish brown
M2005-14	Coral at surface	Sandy	Olive
M2005-15	Coral at surface	Silty clay	Olive
M2005-16A	Coral at sediment surface	Sandy	Olive
M2005-16B	Coral at sediment dowcore	Silty clay	Yellowish brown
M2005-17	Coral at sediment dowcore	Silty clay	Olive
M2005-19A	Absent	Silty clay	Olive
M2005-19B	Undetermined	Undetermined	Undetermined
M2005-20	Absent	Silty clay	Yellowish brown
M2005-21	Coral at surface	Undetermined	Undetermined
M2005-22	Coral at surface	Sandy	Yellowish brown
M2005-23	Coral at surface	Silty clay	Yellowish brown
M2005-28A	Coral at surface	Silty clay	Olive

Table I – *Continued.*

	Presence of hard substrate	Sediment type	Sediment color
M2005-28B	Coral at sediment dowcore	Silty clay	Olive
M2005-29A	Absent	Silty clay	Olive
M2005-29B	Undetermined	Undetermined	Undetermined
M2005-30A	Coral at sediment dowcore	Silty clay	Yellowish brown
M2005-30B	Undetermined	Silty clay	Undetermined
M2005-31	Coral at surface	Silty clay	Yellowish brown
M2006-06	Absent	Silty clay	Olive
M2006-08	Absent	Silty clay	Yellowish brown
M2006-09	Coral at surface	Sandy	Yellowish brown
M2006-10	Absent	Silty clay	Yellowish brown
M2006-11	Coral at surface	Sandy	Yellowish brown
M2006-13	Absent	Silty clay	Yellowish brown
M2006-14	Absent	Silty clay	Yellowish brown
M2006-15	Absent	Silty clay	Yellowish brown
M2006-17	Absent	Silty clay	Olive
M2006-18	Coral at surface	Sandy	Yellowish brown
M2006-19	Absent	Sandy	Yellowish brown
M2006-21	Absent	Silty clay	Yellowish brown
M2006-22	Coral at surface	Silty clay	Olive
M2006-23	Coral at surface	Silty clay	Yellowish brown
M2006-24	Coral at surface	Sandy	Yellowish brown
M2006-25	Coral at sediment dowcore	Silty clay	Yellowish brown
M2006-26	Absent	Silty clay	Yellowish brown
M2006-27	Absent	Silty clay	Yellowish brown
M2006-28	Absent	Silty clay	Yellowish brown
M2006-30	Absent	Silty clay	Yellowish brown
M2006-31	Coral at surface	Sandy	Yellowish brown
M2006-33	Absent	Sandy	Olive
M2006-34	Coral at surface	Silty clay	Yellowish brown

Table I—*Continued.*

	Presence of hard substrate	Sediment type	Sediment color
M2006-35	Absent	Silty clay	Yellowish brown
M2006-36	Absent	Silty clay	Yellowish brown
M2006-38A	Coral at surface	Sandy	Yellowish brown
M2006-38B	Coral at surface	Sandy	Yellowish brown
M2006-38C	Absent	Sandy	Yellowish brown
M2006-38D	Undetermined	Sandy	Undetermined
M2006-38E	Undetermined	Undetermined	Undetermined
M2006-38F	Coral at sediment dowcore	Sandy	Yellowish brown
M2006-39	Absent	Silty clay	Yellowish brown
M2006-40	Coral at surface	Sandy	Yellowish brown
M2006-40A	Coral at surface	Sandy	Yellowish brown
M2006-41	Coral at sediment dowcore	Silty clay	Yellowish brown
M2006-42	Coral at surface	Sandy	Yellowish brown
M2006-44	Undetermined	Undetermined	Undetermined
M2006-44A	Absent	Silty clay	Yellowish brown
M2006-46A	Coral at sediment dowcore	Biogenic	Yellowish brown
M2006-46B	Coral at surface	Biogenic	Yellowish brown
M2006-48	Coral at surface	Sandy	Yellowish brown
M2006-49	Coral at surface	Sandy	Olive
M2006-51	Absent	Silty clay	Yellowish brown
M2006-52	Coral at sediment dowcore	Silty clay	Yellowish brown
M2006-53	Absent	Silty clay	Yellowish brown
M2006-54	Coral at surface	Silty clay	Yellowish brown
M2006-56	Absent	Silty clay	Yellowish brown
M2006-57	Coral at surface	Silty clay	Yellowish brown
M2006-58	Coral at surface	Silty clay	Yellowish brown
M2006-59	Coral at surface	Silty clay	Yellowish brown

ANNEX III

Preliminary list of taxa founded in Pen Duick Escarpment. Taxonomic data according with WoRMS – World Register of Marine Species (http://www.marinespecies.org).

Phyllum PORIFERA Grant, 1836

Porifera Undetermined (several species)

Phyllum CNIDARIA Hatscheck, 1888

Class Hydrozoa Owen, 1834

Hydrozoa Undetermined

SubClass Hydroidolina

Order Anthoathecatae Cornellius, 1992

SubOrder Filifera Kühn, 1913

Family Eudendriidae L. Agassiz, 1862

Genus *Eudendrium* Ehrenberg, 1834

***Eudendrium* sp6**

Eudendrium rameum (Pallas, 1766)

Family Tubiclavoididae Moura, Cunha & Schuchert, 2007

Genus *Tubiclavoides* Moura, Cunha & Schuchert, 2007

Tubiclavoides striatum Moura, Cunha & Schuchert, 2007

Order Leptothecatae

Family Aglaopheniidae Marktanner-Turneretscher, 1890

Genus *Aglaophenia* Lamouroux, 1812

Aglaophenia lophocarpa Allman, 1877

Genus ***Lytocarpia*** Kirchenpauer, 1872

Lytocarpia myriophyllum (Linnaeus, 1758)

Genus *Streptocaulus* Allman, 1883

Streptocaulus* cf. *corneliusi Ramil & Vervoot, 1992

Family Campanulariidae

Genus *Campanularia* Lamarck, 1816

Campanularia hincksii Alder, 1856

Genus *Clytia* Lamouroux, 1812

***Clytia* sp.**

Clytia glacilis (Sars, 1850)

Clytia hemisphaerica (Linnaeus, 1767)

Clytia* cf. *hemisphaerica (Linnaeus, 1767)

Clytia linearis (Thornely, 1899)

Genus *Obelia* Péron & Lesueur, 1810

Obelia* cf. *dichotoma (Linnaeus, 1758)

Obelia geniculata (Linnaeus, 1758)

Family Campanulinidae Hincks, 1868

Genus *Campanulina* van Beneden, 1847

Campanulina paniculata Sars, 1873

Genus *Lafoeina* G.O. Sars, 1874

Lafoeina tenuis G.O. Sars, 1874

Family Haleciidae Hincks, 1868

Genus *Halecium* Oken, 1815

***Halecium* sp.1**

Halecium sessile Norman, 1867

Halecium sibogae marocanum Billard, 1934

Halecium tenellum Hincks, 1861

Family Halopteridae Millard, 1962

Genus *Antennella* Allman, 1877

Antennella secundaria (Gmelin, 1791)

Family Lafoeidae A. Agassiz, 1865

Lafoeidae Undetermined

SubFamily Lafoeinae A. Agassiz, 1865

Genus *Acryptolaria* Norman, 1875

Acryptolaria conferta (Allman, 1877)

Genus *Filellum* Hincks, 1868

***Filellum* sp.**

Filellum* cf. *serratum (Clarke, 1879)

Genus *Lafoea* Lamouroux, 1821

Lafoea dumosa (Fleming, 1820)

SubFamily Zygophylacinae Quelch, 1885

Genus *Zygophylax* Quelch, 1885

***Zygophylax* sp.**

***Zygophylax* Undescribed species**

Zygophylax biarmata Billard, 1905

Zygophylax levinseni (Saemundsson, 1911)

Family Lovenellidae Russel, 1953

Genus *Lovenella* Hincks, 1868

Lovenella producta (G.O. Sars, 1874)

Family Mitrocomidae Haeckel, 1879 (part); Torrey, 1909

Genus *Tiaropsidium* Torrey, 1909

***Tiaropsidium* sp.**

Family Oceaniidae

Genus cf. *Corydendrium* van Beneden, 1844

cf. *Corydendrium* sp.

Genus Turritopsis McCrady, 1859

Turritopsis Undescribed species

Family Plumulariidae McCrady, 1859

Plumariidae sp.2

Genus *Nemertesia* Lamouroux, 1812

***Nemertesia* sp.**

***Nemertesia* sp.1**

Nemertesia* cf. *antennina (Linnaeus, 1758)

Genus *Polyplumaria* Sars, 1873

Polyplumaria flabellata Sars, 1873

Family Sertulariidae Lamouroux, 1812

Genus *Sertularella* Gray, 1848

Sertularella gayi robusta Allman, 1873

Family Tiarannidae Russel, 1940

Genus *Modeeria* Forbes, 1848

Modeeria rotunda (Quoy & Gaimard, 1827)

SubPhyllum Medusozoa

Class Scyphozoa Götte, 1887

Order Coronatae

Family Nausithoidae

Genus *Nausithoe* Kölliker, 1853

***Nausithoe* sp.**

Phyllum NEMERTINA

Nemertina Undetermined

Phyllum SIPUNCULA

Sipuncula Undetermined

Phyllum ECHIURA

Echiura Undetermined

Phyllum ANNELIDA

Class Clitellata

… Subclass Oligochaeta

Oligochaeta Undetermined

Class Polychaeta Grube 1850

Polychaeta Undetermined

Subclass Scolecida

Order Capitellida

Family Capitellidae Grube, 1862

Capitellidae Undetermined

Genus *Notomastus* Sars, 1850

***Notomastus* sp.**

Family Maldanidae Malmgren, 1867

Maldanidae Undetermined

Maldanidae sp4

Order Cossurida

Family Cossuridae Day, 1963

Cossuridae Undetermined

Order Opheliida

Family Opheliidae Malmgren, 1867

Ophelidae Undetermined

Family Scalibregmidae Malmgren, 1867

Scalibregmidae Undetermined

Order Orbiniida

Family Orbiniidae Hartman, 1942

Orbiniidae Undetermined

Genus *Leitoscoloplos* Day, 1977

Leitoscoloplos* cf. *mammosus Mackie, 1987

Family Paraonidae Cerruti, 1909

Undetermined (several species)

Genus *Aricidea* Webster, 1879

Aricidea suecica meridionalis Laubier & Ramos, 1974

Genus *Levinsenia* Mesnil, 1897

Levinsenia gracilis (Tauber, 1879)

Subclass Palpata

(Aciculata)

Order Amphinomida

Family Amphinomidae Savigny *in* Lamarck, 1818

Amphinomidae Undetermined

Family Euphrosinidae Williams, 1851

Euphrosinidae sp1

Order Eunicida

Family Eunicidae Savigny 1818

Eunicidae Undetermined

Genus *Eunice* Cuvier, 1817

Eunice dubitatus Fauchald, 1974

Genus *Lysidice* Lamarck 1818

Lysidice ninetta Audouin & Milne-Edwards, 1833

Genus *Nematonereis* Schmarda, 1861

Nematonereis unicornis Schmarda, 1861

Family Lumbrineridae Malmgren, 1867

Lumbrineridae Undetermined

Genus *Augeneria* Monro, 1930

***Augeneria* sp.**

Genus *Lumbrineriopsis* Orensanz, 1973

Lumbrineriopsis paradoxa (Saint Joseph, 1888)

Family Onuphidae Kinberg, 1865

Onuphidae Undetermined

Genus *Paradiopatra* Ehlers, 1887

Paradiopatra hispanica Amoureux 1972

Order Phyllodocida

Family Glyceridae Grube, 1850

Glyceridae Undetermined

Genus *Glycera* Savigny, 1818

Glycera lapidum Quatrefages, 1865

Family Goniadidae Kinberg, 1866

Goniadidae Undetermined

Family Hesionidae Sars, 1862

Hesionidae Undetermined

Family Lacydoniidae Bergström, 1914

Lacydoniidae Undetermined

Family Nephtyidae Grube, 1850

Nephtyidae Undetermined

Family Nereididae Johnston, 1865

Nereididae Undetermined

Family Pholoidae Kinberg, 1857

Pholoidae Undetermined

Genus *Pholoides* Pruvot, 1895

Pholoides dorsipapillatus (Marenzeller, 1893)

Family Phyllodocidae Williams, 1851

Phyllodocidae Undetermined

Phyllodocidae sp1

Family Pilargidae Saint-Joseph, 1899

Pilargidae Undetermined

Family Polynoidae Kinberg, 1856

Polynoidae Undetermined

cf. *Harmothoe evei* Kirkegaard, 1980

Family Sigalionidae Kinberg, 1856

Sigalionidae Undetermined

Family Syllidae Grube, 1850

Syllidae Undetermined

(Canalipalpata)

Order Fauveliopsida

Family Fauvelopsidae

Fauvelopsidae Undetermined

Genus *Lauberiopsis* Petersen, 2000

Lauberiopsis cabiochi (Amoureux, 1982)

Order Oweniida

Family Oweniidae Rioja, 1917

Oweniidae Undetermined

Order Sabellida Malmgren, 1867

Family Sabellidae

Sabellidae Undetermined

Family Siboglinidae

Genus *Siboglinum* Caullery, 1914

"*Siboglinum*" sp.

Order Spionida

Family Chaetopteridae

Chaetopteridae Undetermined

Chaetopteridae sp.2

Family Cirratulidae Ryckholt, 1851

Cirratulidae Undetermined

Family Magelonidae Cunningham & Ramage, 1888

Magelonidae Undetermined

Family Spionidae G.O. Sars, 1872

Spionidae Undetermined

Genus *Prionospio* Malmgren, 1867

***Prionospio* sp**.

Order Terebellida

Family Ampharetidae Malmgren, 1866

Ampharetidae Undetermined

Ampharetidae sp10

Genus *Eclysippe* Eliason, 1955

cf. *Eclysippe vanelli* (Fauvel, 1936)

Genus *Melinnopsis* McIntosh, 1885

***Melinnopsis* sp.**

Family Sabellariidae

Sabellariidae Undetermined

Family Terebellidae Mamlgren, 1865

Terebellidae Undetermined

Family Trichobranchidae Malmgren, 1865

Trichobranchidae Undetermined

Phyllum MOLLUSCA

Class Gastropoda Cuvier, 1795

Gastropoda Undetermined (4 species)

SubClass Caenogastropoda Cox, 1960

Order Neogastropoda

Family cf. Eulimidae

cf. **Eulimidae Undetermined**

SubClass Prosobranchia Milne-Edwards, 1848

Order Mesogastropoda Thiele, 1925

Family cf. Rissoidae Gray, 1847

Genus *Alvania* Risso, 1826

cf. *Alvania testae* (Aradas & Maggiore, 1844)

Family cf. Triviidae Trochel, 1863

cf. **Triviidae Undetermined**

Class Bivalvia Linnaeus, 1758

Bivalvia Undetermined

Order Anomalodesmata

Family Cuspidariidae Dall, 1886

Genus *Cuspidaria* Nardo, 1840

***Cuspidaria* sp**.

Genus *Tropidomya* Dall & Smith, 1886

Tropidomya abbreviata (Forbes, 1843)

SubClass Heterodonta Neumayr, 1884

Incertae sedis

Family Kelliellidae Fischer, 1887

Genus *Kelliella* M. Sars, 1870

Kelliella abyssicola (Forbes, 1844)

Family Semelidae Stoliczka, 1870

Genus *Abra* Leach in Lamarck, 1818

Abra longicallus (Scacchi, 1834)

Family Thyasiridae Dall, 1901

Thyasiridae Undetermined

Genus *Thyasira* Leach in Lamarck, 1818

Thyasira obsoleta (Verrill & Bush, 1898)

Family Vesicomyidae

Genus *Vesicomya* Dall, 1886

Vesicomya atlantica (Smith, 1885)

SubClass Protobranchia

Order Nuculanoida

Family Nuculanidae Meek, 1864

Genus *Ledella* Verrill & Bush, 1897

Ledella messanensis (Jeffreys, 1870)

Family Yoldiidae Habe, 1977

Genus *Microgloma* Sanders & Allen, 1973

***Microgloma* sp.**

Microgloma pusilla (Jeffreys, 1879)

Microgloma tumidula (Monterosato, 1880)

Order Nuculoida

Family Nuculidae Gray, 1824

Genus *Ennucula* Iredale, 1931

Ennucula aegeensis (Forbes, 1844)

Ennucula bushae (Dollfus, 1898)

SubClass Pteriomorpha

Order Arcoida Stoliczka 1871

Family Arcidae Lamarck, 1809

Genus Bathyarca Kobelt, 1891

Bathyarca phyllippiana (Nyst, 1848)

Family Limopsidae Dall, 1895

Limopsidae Undetermined

Genus *Limopsis* Sassi, 1827

Limopsis minuta (Philippi, 1836)

Incertae sedis

Family Pectinidae Rafinesque, 1815

Genus *Delectopecten* Stewart, 1930

Delectopecten vitreus (Gmelin, 1791)

Family Propeamussiidae R.T. Abbott, 1954

Genus *Cyclopecten* A. E. Verrill, 1897

Cyclopecten hoskynsi (Forbes, 1844)

Class Scaphopoda Bronn, 1862

Scaphopoda Undetermined

Phyllum ARTHROPODA

Class Pycnogonida Latreille, 1810

Order Pantopoda Gerstäcker, 1863

Pantopoda Undetermined

Class Maxillopoda Dahl, 1956

InfraClass Cirripedia Burmeister, 1834

Order Sessilia Lamarck, 1818

Family Verrucidae Darwin, 1854

Verrucidae Undetermined

Genus *Verruca* Schumacher, 1817

***Verruca* sp**.

Class Malacostraca

Superorder Eucarida Calman, 1904

Order Decapoda Latreille, 1803

Infraorder Caridea Dana, 1852

Family Alpheidae Rafinesque, 1815

Genus *Alpheus* Weber, 1795

***Alpheus* sp.**

Infraorder Anomura

Family Galatheidae Samoelle, 1819

Genus Munida *Leach, 1820*

***Munida* sp.**

Infraorder Brachyura Linnaeus, 1758

Family Leucosiidae Samouelle, 1819

Genus *Ebalia* Leach, 1817

Ebalia nux A. Milne-Edwards, 1883

Family Xanthidae MacLeay, 1815

Genus Monodaeus Guinot, 1967

Monodaeus couchi (Couch, 1851)

Superorder Leptostraca

Order Nebaliacea

Family Nebaliidae Samouelle, 1819

Genus *Nebali*a Leach, 1814

***Nebalia* sp.**

Superorder Peracarida Calman, 1904

Order Amphipoda Latreille, 1816

Amphipoda Undetermined

Suborder Corophiidea

Family Aoridae Walker, 1908

Aoridae Undetermined

Genus *Lembos* Bate, 1857

***Lembos* spp. (2 species)**

Family Caprellidae Leach, 1814

Genus *Liropus* Mayer, 1890

Liropus elongatus Mayer, 1890

Genus *Phtisica* Slabber, 1778

Phtisica marina Slabber, 1769

Family Ischyroceridae Stebbing, 1899

Ischyroceridae Undetermined

Genus Notopoma

***Notopoma* Undescribed species**

Family Photidae Boeck, 1871

Genus *Gammaropsis* Liljeborg, 1855

***Gammaropsis* sp.**

Genus *Megaphompus* Norman, 1869

***Megamphopus* sp.**

Genus *Photis* Krøyer, 1842

Photis sp.

Suborder Gammaridea Latreille, 1802

Family Ampeliscidae Costa, 1857

Ampeliscidae Undetermined

Genus *Ampelisca* Krøyer, 1842

***Ampelisca* sp.**

Ampelisca brevicornis (Costa, 1853)

Ampelisca* cf. *dalmatina Karaman, 1975

Ampelisca tenuicornis Liljeborg, 1855

Genus *Byblis* Boeck, 1871

Byblis* cf. *guernei Chevreux, 1888

Genus Haploops Liljeborg, 1856

Haploops cf. setosa Boeck, 1871

Family Amphilochidae Boeck, 1871

cf. Amphilochidae Undetermined

Genus *Amphilochoides* Sars, 1892

Amphilocoides serratipes (Norman, 1869)

Family Atylidae G.O. Sars, 1882

Genus *Atylus* Leach, 1815

***Atylus* sp**.

Family Carangoliopsidae Bousfield 1977

Genus *Carangoliopsis*

Carangoliopsis spinulosa Ledoyer, 1970

Family Cressidae Stebbing, 1899

Genus Cressa

Cressa cristata Myers, 1969

Family Leucothoidae Dana, 1852

Genus *Leucothoe* Leach, 1814

Leucothoe incisa Robertson, 1892

Family Liljeborgiidae Stebbing, 1899

Genus *Liljeborgia* Bate, 1862

***Liljeborgia* sp**.

Family Lysianassidae Dana, 1849

Lysianassidae Undetermined

Genus *Hippomedon* Boeck, 1871

cf. *Hippomedon* sp.

Hippomedon bidentatus Chevreux, 1903

Genus *Lepidepecreum* Bate & Westwood, 1868

Lepidepecreum subclypeatum *R*uffo & Schiecke, 1977

Genus *Lysianassa* Milne-Edwards, 1830

Lysianassa* cf. *plumosa Boeck, 1871

Genus cf. *Nannonyx* Sars, 1890

cf. *Nannonyx* sp.

Genus *Paracentromedon* Chevreux & Fage, 1925

Paracentromedon crenulatum Chevreux, 1900

Genus *Perrierella* Chevreux & Bouvier, 1892

Perrierella audouiniana (Bate, 1857)

Genus *Tryphosella* Bonnier, 1893

Tryphosella cf. longidactyla Ruffo, 1985

Family Melitidae Bousfield, 1973

cf. Melitidae Undetermined

Genus *Eriopisa* Wrzesniovsky, 1890

Eriopisa elongata (Bruzelius, 1859)

Family Melphidippidae Stebbing, 1899

Genus Melphidippella Sars, 1894

Melphidippella macra (Norman 1869)

Family Oedicerotidae Lilljeborg 1865

Oedicerotidae Undetermined

Genus *Bathymedon* Sars, 1892

***Bathymedon* sp.**

Bathymedon acutifrons Bonnier, 1896

Genus *Monoculodes* Stimpson, 1853

***Monoculodes* sp.**

Monoculodes acutipes Ledoyer, 1983

Monoculodes packardi Boeck, 1871

Genus *Oediceroides* Stebbing, 1888

Oediceroides pilosa Ledoyer, 1983

Genus *Perioculodes* Sars 1895

Perioculodes longimanus (Bate & Westwood, 1868)

Genus *Synchelidium* Sars, 1892

Synchelidium maculatum Stebbing 1906

Genus *Westwoodilla* Bate 1862

Westwoodilla cf. caecula (Bate, 1857)

Family Opisidae

Opisa Boeck, 1876

***Opisa* sp.**

Family Pardaliscidae Boeck, 1871

Parladiscidae Undetermined

Genus *Halice* Boeck, 1871

Halice cf. abyssi Boeck, 1871

Genus *Nicippe* Bruzellius, 1859

Nicippe tumida Bruzelius, 1859

Family Phoxocephalidae Sars, 1891

Phoxocephalidae Undetermined

Genus *Harpinia* Boeck 1876

***Harpinia* Undetermined**

***Harpinia* spp. (4 species)**

Harpinia cf. agna Karaman, 1987

Harpinia* cf. *antennaria Meinert, 1890

***Harpinia* crenulata** (Boeck, 1871)

Harpinia dellavallei Chevreux, 1910

Genus *Leptophoxus* Sars, 1891

Leptophoxus falcatus (Sars, 1883)

Genus *Metaphoxus* Bonnier, 1896

Metaphoxus simplex (Bate, 1857)

Family Stegocephalidae Dana, 1855

Genus cf. *Andaniexis* Stebbing, 1906

cf. Andaniexis sp.

Genus *Stegocephaloides* Sars, 1895

***Stegocephaloide*s sp.**

Family Stenothoidae Boeck ,1871

Stenothoidae Undetermined

Genus *Stenothoe* Dana 1852

Stenothoe cf. marina (Bate, 1856)

Family Synopiidae Dana 1853

Genus *Syrrhoe* Chevreux, 1908

Syrrhoe cf. affinis Chevreux, 1908

Family Urothoidae Bousfield, 1978

Genus *Carangolia* J.L. Barnard, 1961

Carangolia barnadi Jaume & Sorbe, 2001

Order Cumacea

Cumacea Undetermined

Family Diastylidae Bate, 1856

Diastylidae Undetermined

Family Lampropidae Sars, 1878

Genus Platysympus Stebbing, 1912

Platysympus typicus (Sars, 1870)

Family Leuconidae Sars, 1878

Leuconidae Undetermined

cf. Leuconidae Undetermined

Genus *Eudorella* Norman, 1867

Eudorella sp.

Genus *Leucon* Krøyer, 1846

***Leucon* spp.**

Family Nannascitidae Bate 1866

Nannascitidae Undetermined

Genus *Campylaspis* G.O. Sars, 1865

***Campylaspis* spp**.

Campylaspis cf. horrida Sars, 1870

Campylaspis cf. sulcata Sars, 1870

Order Isopoda Latreille, 1817

Isopoda Undetermined

Suborder Asellota Latreille, 1802

Family Desmosomatidae G. O. Sars, 1897

Desmosomatidae Undetermined

Genus *Chelator* Hessler, 1970

***Chelator* spp.**

Chelator cf. insignis (Hansen, 1916)

Chelator cf. verecundus Hessler, 1970

Genus *Eugerda* Meinert, 1890

Eugerda sp.

Eugerda* cf. *tetarta Hessler, 1970

Genus *Eugerdella* Kussakin 1965

Eugerdella* cf. *ischnomesoides Hessler, 1970

Eugerdella* cf. *pugilator Hessler, 1970

***Eugerdella* Undescribed species**

Genus *Mirabilicoxa* Hessler, 1970

cf. *Mirabilicoxa*

Mirabilicoxa* cf. *acuminata Hessler, 1970

Mirabilicoxa similis Hansen, 1916

Genus *Prochelator* Hessler, 1970

***Prochelator* sp.**

Family Ischnomesidae Hansen, 1916

Genus *Haplomesus* Richardson, 1908

***Haplomesus* sp**.

Family Janirellidae Menzies 1956

Genus *Janirella* Menzies, 1956

***Janirella* sp.**

Janirella* cf. *nanseni Bonnier, 1896

Family Janiridae Sars, 1897

Genus *Austrofilius* Hodgson, 1910

***Austrofilius* sp.**

Genus *Janira* Leach, 1814

Janira maculosa Leach, 1814

Family Munnidae Sars, 1897

Genus *Munna* Krøyer, 1839

***Munna* sp.**

Family Munnopsidae Lilljeborg, 1864

Genus *Disconectes* Wilson & Hessler, 1981

***Disconectes* sp.**

Genus *Eurycope* Sars, 1864

***Eurycope complanata* complex**

Genus *Ilyarachna* Sars, 1870

***Ilyarachna* spp. (3 species)**

Family Paramunnidae Vanhöffen, 1914

Genus *Notoxenoides* Menzies, 1962

Notoxenoides sp.

Genus *Pleurogonium* G.O. Sars, 1864

***Pleurogonium* sp.**

Pleurogonium* cf. *pulchrum Hansen, 1916

Family Thambematidae Stebbing, 1913

Thambematidae Undetermined

Suborder Cymothoida Wägele, 1989

Family Cirolanidae Dana, 1852

Metacirolana* cf. *hanseni (Bonnier, 1896)

Genus *Natatolana* Bruce, 1981

***Natatolana* sp.**

Family Gnathiidae Leach, 1814

Gnathiidae Undetermined (2 species)

Family Hyssuridae Wägele, 1981

Hyssuridae Undetermined

Hyssuridae Undetermined (3 species)

Family Leptanthuridae Poore, 2001

Leptanthuridae Undetermined

Order Tanaidacea Dana, 1849

Tanaidacea Undetermined

SubOrder Apseudomorpha Miller, 1940

Family Apseudidae Leach 1814

Apseudidae Undetermined

Genus *Apseudes* Leach, 1814

***Apseudes* spp**. (4 species)

Family Sphyrapidae Gutu, 1980

Genus *Sphyrapus* Sars, 1882

***Sphyrapus* sp.**

Sphyrapus malleolus Norman & Stebbing, 1886

SubOrder Tanaidomorpha Sieg, 1980

Family Agathotanaidae Lang, 1971

Agathotanaidae Undetermined

Family Colletteidae Larsen & Wilson, 2002

Colletteidae Undetermined

Genus *Collettea* Lang, 1973

***Collettea* sp.**

Family Leptognathiidae Lang, 1976

Leptognathidae sp1

Family Pseudotanaidae Sieg, 1976

Pseudotanaidae Undetermined

Family Tanaellidae Larsen and Wilson, 2002

Genus *Tanaella* Norman & Stebbing, 1886

Tanaella cf. unguicillata Norman & Stebbing, 1886

Family Typhlotanaidae Sieg, 1986

Genus *Typhlotanais* Sars, 1882

***Typhlotanais* sp.**

Phyllum ECHINODERMATA

Class Crinoidea

Suborder Comatulidina A.H. Clark, 1908

Family Antedonidae Norman, 1865

Genus *Antedon* de Freminville, 1811

***Antedon* sp.**

Class Echinoidea

Order Spatangoida

Family Brissidae

Genus *Brissopsis* L. Agassiz, in L. Agassiz & Desor, 1847

Brissopsis lyrifera (Forbes, 1841)

Classe Holothuroidea

Holothuroidea Undetermined

Class Stelleroidea Lamarck, 1816

Subclass Ophiuroidea Gray, 1840

Order Ophiurida Müller & Troschel, 1840

Family Amphilepididae Matsumoto, 1915

Genus *Amphilepis* Ljungman, 1867

Amphilepis ingolfiana Mortensen, 1933

Genus *Amphipholis* Thomas, 1966

Amphipholis squamata (Delle Chiaje, 1829)

Genus *Amphiura* Forbes, 1843

***Amphiura* sp**.

Amphiura filiformis (O.F. Müller, 1776)

Amphiura grandisquama Lyman, 1869

Family Ophiacanthidae Perrier, 1891

Genus *Ophiacantha* Koehler, 1911

Ophiacantha aculeata Verrill, 1885

Ophiacantha cf. spinosella Mortensen, 19