METEOR-BERICHTE

Cold-water corals in the Bay of Biscay– occurrences and distribution in space and time (TransBiscay)

Cruise No. M84/5

May 31 – June 21, 2011
Vigo (Spain) – Brest (France)

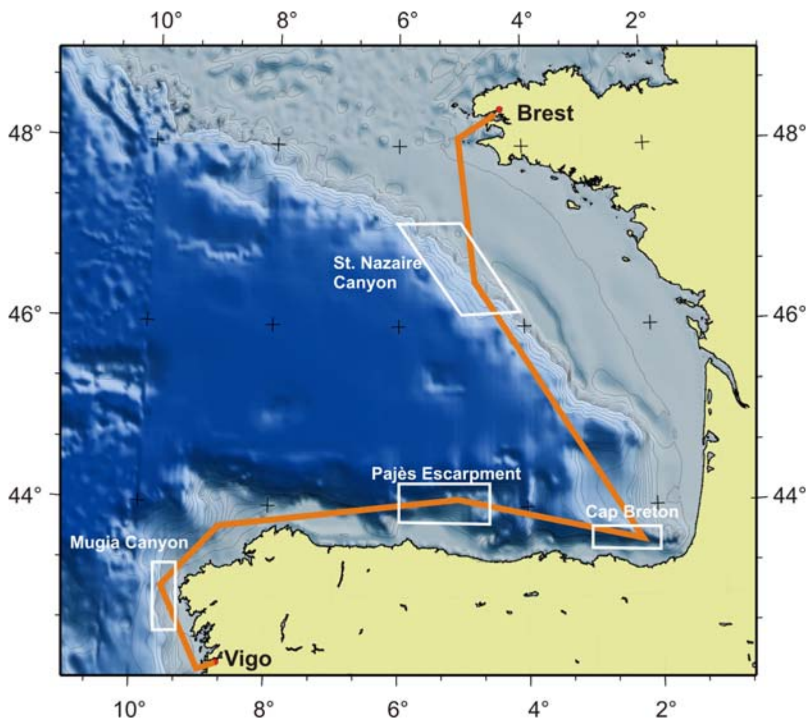

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Table of contents

1 Summary

Abstract – The scientific objectives of METEOR cruise M84/5 focused on the measurement and analysis of the environmental controls of modern and fossil cold-water coral growth along a transect in the Bay of Biscay. In four working areas we successfully deployed lander systems and CTD/Ro's to document the physical and hydrochemical characteristics of bottom water masses and the water column in general. These are used to shed light on potential linkages to modern cold-water coral growth and distribution. These investigations were flanked by plankton tows in surface waters. The base for all investigations was a thorough hydroacoustic survey to characterize potential cold-water coral bearing areas with living colonies. Based on these maps we deployed all video-guided gear such as the OFOS-video sled, the TV grab, and the lander systems. Benthic assemblages and sedimentary structures have been documented and sampled with the OFOS and a box corer. Simultaneously, genetic samples of the living coral material were taken for additional studies. Furthermore, we have taken gravity cores to investigate the paleoceanographic conditions as well as the timing of cold-water coral colonization in the Bay of Biscay. Along with the coring efforts, a detailed sampling and study of porewater properties was performed. An additional aim of this cruise was to investigate the influence of boundary exchange processes on the Neodymium isotopy in bottom waters along the pathway of the Mediterranean Outflow water (MOW) by taking multiple samples with the CTD/Ro.

The new data and samples of this METEOR cruise will provide the framework to investigate the timing of cold-water coral colonization in the Bay of Biscay, as well as its interplay with the ambient hydrography and geochemistry. This successful cruise has provided the basis to investigate the scientific aims of this expedition in great detail.

Zusammenfassung – Die wissenschaftlichen Ziele der METEOR Fahrt M84/5 umfaßten eine Aufnahme und Analyse der Umweltbedingungen rezenten und fossilen Kaltwasserkorallenwachstums in vier Arbeitsgebieten entlang eines Transektes durch die Biskaya. Durch den Einsatz von Landersystemen und CTD/Ro's wurden dabei die physikalischen und hydrochemischen Charakteristika der Bodenwassermassen und der Wassersäule, sowie deren Zusammenhang mit der rezenten Verbreitung untersucht. Die Untersuchungen wurden durch Planktonnetzfänge im Oberflächenwasser ergänzt. Als Grundlage aller Arbeiten wurden hydroakustische Kartierungen durchgeführt, um die Bathymetrie der potentiell korallenhöffigen Gebiete zu charakerisieren, Darauf basierend wurden erfolgreich videogeführte Geräte, wie der OFOS-Videoschlitten und ein TV-Greifer eingesetzt, als auch der Lander für mehrtägige hydrographische Messungen abgesetzt. Benthische Lebensgemeinschaften und sedimentäre Prozesse wurden mit OFOS Beobachtungen und Oberflächensedimentproben aus dem Kastengreifer dokumentiert. Am lebenden Material wurden begleitend Proben für eine genetische Analyse der Korallen genommen. Des Weiteren wurden paläozeanographische Proben mit dem Schwerelot gewonnen, die eine Untersuchung der Korallenbesiedlungsgeschichte in der Biskaya erlauben. Die Kernarbeiten wurden durch eine umfassende Porenwasseranalytik ergänzt. Darüber hinaus wurde zum ersten Mal der Einfluss von "Boundary Exchange" Prozessen auf die gelöste Neodym-Isotopie in den Bodenwässern entlang des Fließwegs des Mittelmeer Ausstromwassers (MOW) untersucht. Hierzu wurden vor allem Bodenwasserproben mit der CTD/Ro genommen.

Die neuen Daten und Proben von dieser METEOR-Reise werden es ermöglichen, die zeitliche Besiedlung der Biskaya durch Kaltwasserkorallen besser zu verstehen und diese in einen hydrographischen und geochemischen Kontext zu stellen. Der erfolgreiche Verlauf der Reise wird es uns ermöglichen die wissenschaftlichen Ziele der Expedition zu erreichen.

This cruise report is dedicated to

Francesc Pagès (1962-2007) *1

***1** Journal of the Marine Biological Association of the United Kingdom, 2008, 88(8), 1513. doi:10.1017/S002531540800283X

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3 Research program

R/V METEOR cruise M84/5 had two main scientific objectives. The first overarching question was related to the measurement and analysis of the environmental controls of modern and fossil cold-water coral (CWC) growth along a transect throughout the Bay of Biscay – virtually beginning off northwestern Spain. In particular, emphasis was given to the following questions:

(1) Where do living and fossil azooxanthellate corals occur along the transect from Galicia (Mugia Canyon, Spain) to the St. Nazaire canyon (France) section?

(2) What are the driving environmental (physical and biogeochemical factors) of their recent distribution?

(3) How did the cold-water coral ecosystems develop during the Holocene and in comparison to their fossil counterparts, since the last glacial maximum (LGM)?

Our aim was to use lander systems and CTD/Ro's to document the physical and hydrochemical characteristics of the ambient bottom water masses and the water column, as well as to deploy video-guided gear such as the OFOS-video sled to document modern assemblages, living and dead ones. Benthic assemblages and sedimentary structures have been documented with the OFOS were sampled with the box corer and the TV grab. Simultaneously, genetic samples of the living coral material were taken for additional studies. Furthermore, we have taken gravity cores to investigate the paleoceanographic conditions as well as the coral colonization in the Bay of Biscay through time. Along with the coring efforts a detailed sampling and study of porewater properties was performed. Sediment cores from living and fossil reef ecosystems will be used to determine oceanographic and faunal changes through time. Fossil coral samples will be U/Th-dated and investigated using different geochemical approaches to determine the element concentration (Sr/Ca, Mg/Ca, Li/Ca, P/Ca, Ba/Ca; Montagna et al., 2008) and stable isotope ratios ($\delta^{18}O$, $\delta^{13}C$, $\delta^{88/86}Sr$) to reconstruct the paleo-environment of these fossil reefs. In comparison to the present-day setting, the Pleistocene history of cold-water coral migration and development in the Bay of Biscay will be reconstructed.

The second aim of this cruise was to investigate the evolution of the radiogenic Neodymium (Nd) isotope signature of Mediterranean Outflow Water (MOW) along its flow path in the Bay of Biscay and the potential influence of weathering contributions from land.
One of the two arms of MOW flows along the continental shelves of Portugal and Spain to the North. This component has an isotopic signature (ε_{Nd}) of -9.4 at its source in the Strait of Gibraltar. Surrounding water masses above and below have a significantly more negative signature (ε_{Nd} = -11 to -13.5). The detailed sampling of the water column along the cruise track allowed us to trace the proceeding mixing of MOW with North Atlantic waters and its reflection in the Nd-isotopic signature. These signatures will be compared with past seawater data extracted from pelagic sediments in the Bay of Biscay. These data will allow us to reconstruct the intensity and flow pattern of MOW in the past.
Simultaneously, we sampled bottom waters directly at the sediment-water interface to investigate the interaction of MOW with the sediment. Thus, giving us the chance to directly

investigate the influence of these "Boundary Exchange" processes on the dissolved Nd-isotopic signature in bottom waters where the paleo proxy signature is formed.

4 Narrative of the Cruise

The first members of the scientific crew arrived on RV METEOR on the 29th of May, 2011 to unpack most of the containers as well as technical and lab equipment. The scientific crew was completed on the 30th to finalize all necessary preparations since rough weather was expected at sea. RV METEOR left the port of Vigo at 9:00 in the morning on May 31st.

As expected, 3+ meter waves were waiting for the METEOR outside Vigo where we immediately began the scientific program with a calibration of the multibeam and parasound system by representatives of Kongsberg and Bremen University. After a successful calibration we started mapping our first working area – Mugia Canyon NW of Vigo in the early morning hours of the 1st of June. The extensive mapping formed the base for all other deployments and investigations such as CTD casts and the TV/video sled. First signs of living cold-water corals (*Lophelia pertusa*) were encountered in a water depth of 1800 m. Most of the area is characterized by a thin sediment cover and dead coral rubble. We aimed for a deployment of our oceanographic lander system. Due to bad weather with wind gusts of up to force 9, a safe deployment and recovery was impossible. Instead we ran the TV sled until the 3rd of June when weather conditions calmed down. On the 3rd, we performed two successful TV grabs with samples of *Solenosmilia* colonies, brachiopods, mollusks, and even a Cretaceous belemnite. This was followed by box cores and repeated CTD casts. On Saturday, 4th of June we left for La Coruna to drop our multibeam calibration team.

From La Coruna we steamed to our second working area, Pagès escarpment west of the Le Danois Bank. Here we initiated our investigations with a thorough bathymetric survey followed by promising observations with the TV sled (OFOS). These indicated potential coral sites in water depths of 820-900 m. Additional OFOS transects showed only few living corals on various substrates while dead coral rubble was abundant. TV grabs verified these observations with samples of dead and sub-fossil calcareous organisms, brachiopods, stony corals as well as pieces of *Desmophyllum*, a solitary coral. In the afternoon 9th of June we recovered our benthic lander system after 3.5 days (776 m water). Preliminary data show a strong tidal signal while bottom currents were rather slow. This was followed by multiple gravity cores with a length of up to 2.70 m.

Early on the 10th of June we left for our third working area, Cap Breton Canyon in the SE most corner of the Bay of Biscay. We began our work with a sound velocity profile for the multibeam mapping survey. On the 11th, this was followed by intense OFOS tracks which revealed a rather monotonous seafloor with dominating fine and soft sediment. This was confirmed by multiple TV grabs. These findings resulted in the decision to leave for our final working area, St. Nazaire Canyon on the French shelf/slope. After sailing 160 nm to the North we arrived at our first CTD station on the 13th. Our plan was to focus on St. Nazaire Canyon (46°13.9'N und 004°20.5'W) and its tributaries. Our schedule of mapping and video observations (13th and 14th of June) was kept and thus we found very promising coral bearing sites (dead and living) on various ridges in the area. On the 15th we deployed our lander system for the last time during this cruise, this time in a water depth of 804 m. Additional TV grabs and box cores (up to 400 cm) on the ridges were very successful, delivering abundant living corals (*Lophelia pertusa*) and associated fauna.

Unfortunately, we had to leave the area because of a low pressure system (985 hPa) coming our way. Instead of waiting we sailed back to the Cap Breton area to investigate open questions such as 'pockmarks'. But these did not show any active venting. Instead we sampled some shallow corals for genetic studies in water depth of 200 m. Improving weather conditions allowed us to return to St. Nazaire Canyon on the 18th. Here, we finished our work a successful lander recovery and final mapping efforts before we sailed to Brest. We arrived at Brest in the early morning hours of the 21st of June 2011.

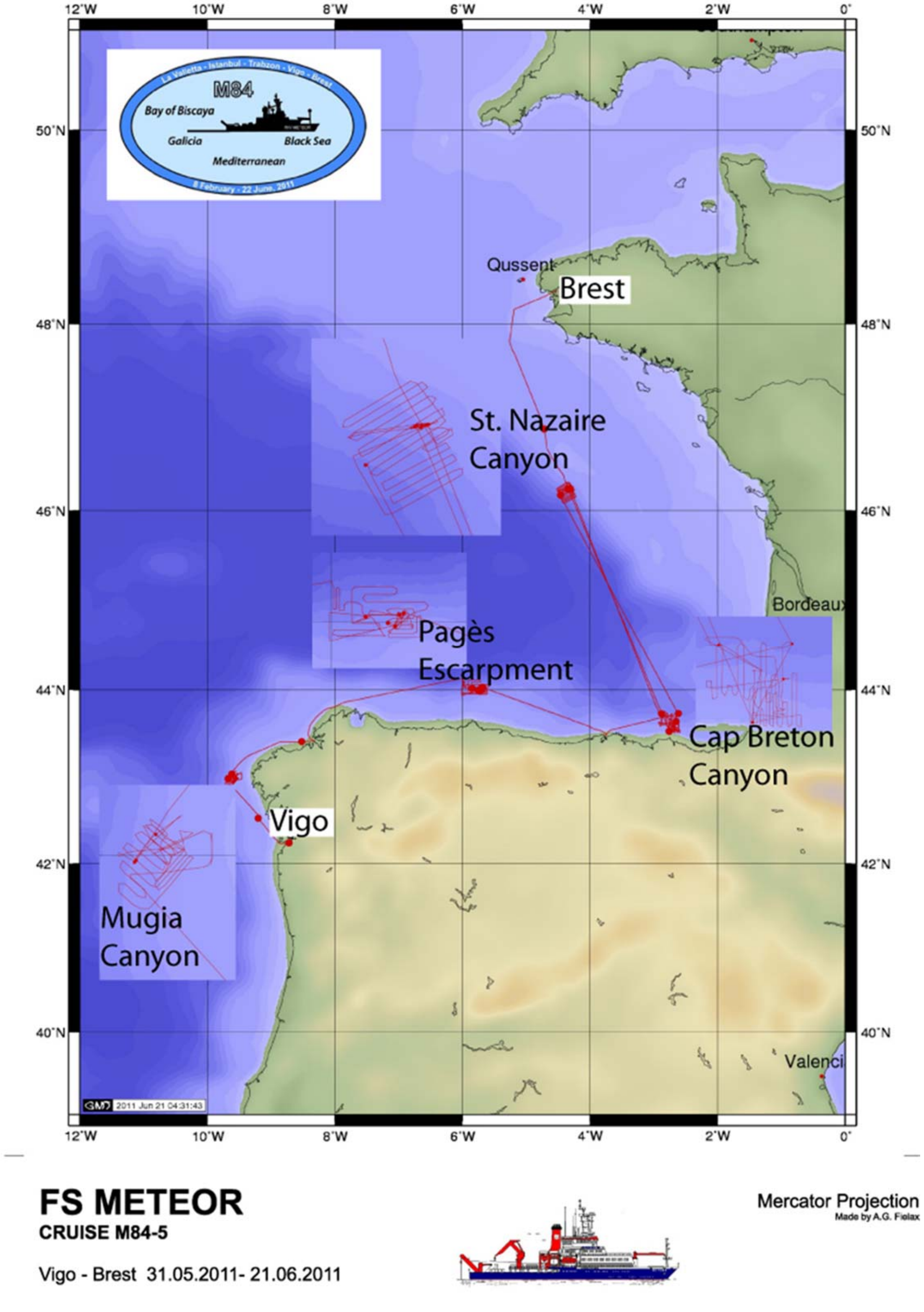

Fig. 1 Map of Galician waters and the Bay of Biscay including the working areas visited during M84/5.

5 Preliminary Results

5.1 Hydrographic Measurements and Water Sampling

5.1.1 CTD casts (C. Dullo, T. Garlichs)

Water masses in the Gulf of Biscay
The major objective of the CTD measurements during cruise M84/5 was to determine general water mass characteristics and the influence of physical parameters of water masses bathing (living) cold-water corals in the Gulf of Biscay. Additionally, we wanted to get an overview of the variability of water masses in the ultimate vicinity of these coral habitats in space (locally-regionally) and time (tidal cycles). Bottom water samples were taken at all localities to get an overview of the geochemical characteristics of these water masses as well as samples from chosen intervals in the water column. Furthermore, we supplied other scientific groups on the vessel with data on physical properties of the water masses within all working areas visited during this cruise.

We studied four sites along the European continental margin of the Bay of Biscay during the cruise M84/5. The Mugia Canyon is located on the Galician margin in the west, the Pagès Escarpment W' of Le Danois Bank is located on the Cantabrian Margin, while Cap Breton can already be ascribed as part of the Aquitaine Margin. The northern part of the Bay of Biscay, the Armorican margin, is characterized by a broad shelf having a steep slope which is characterized by numerous spurs and canyons among which St. Nazaire Canyon was investigated.

The water masses present in this area are predominantly of North Atlantic and Mediterranean origin (Pollard et. al 1996). The surface water is the Eastern North Atlantic Central Water (ENACW) and extends down to 450 and 550 m respectively. Pingree and Le Cann (1989) measured average velocities of 4 cm/s in the cyclonically moving water mass. The lower part of the ENACW seems to be laterally influenced by the Subarctic Intermediate Water (SAIW) indicated by very little to almost no change in density and a salinity minimum around 35.60 psu. Below, salinity increases rapidly indicating the Mediterranean Outflow Water (MOW), which extends down to a depth of around 1500 m. Salinity maxima around 35.80 and 36.17 occur between 900 m and 1100 m respectively. MOW forms the contour current along the continental margin and is controlled by the Coriolis force and the seafloor morphology. Pingree and Le Cann observed current velocities between 2 and 3 cm/s. The North Atlantic Deep Water (NADW) underlies the MOW between 1500 m and 3000 m. A small but pronounced salinity decrease around 1800 m is indicative for the influence of the Labrador Sea Water (LSW) according to Pingree (1973) and Gonzáles-Pola et al. (2006).

Sampling and methods
The Conductivity-Temperature-Depth (CTD) profiler used for investigations of the water column during Meteor 84/5 was a Seabird "SBE 9 plus" underwater unit and a Seabird "SBE 11plus V2" deck unit. Additionally, it was equipped with two dissolved oxygen sensors, a chlorophyll-a sensor and a Seabird bottle release unit including a rosette water sampler. For the analysis and interpretation of the measurements, the downcast raw data were processed with "SBE Data Processing" software. For the visualisation of the data we used "Ocean Data View (mp-Version 3.3.2)". The CTD system provided by GEOMAR operated very reliable. Measured O_2 values were verified by using the Winkler titration method (Winkler, 1888). We

performed a total of 49 CTD casts comprising 8 yoyo casts on the Galicia Margin, 16 yoyos on the Pagès Escarpment and 11 casts repeatedly in a narrowly spaced section within the St. Nazaire Canyon. Yoyo-CTDs comprised 13 hours to cover one complete cycle of the semidiurnal tides.

Results

The salinity minimum of the ENACW was almost identical in all sites along the continental margin of the Biscaya. We recorded values between 35.60 (Pagès Escarpment) and 35.62 (Mugia Canyon). The influence of the MOW was highest in the sites on the Galicia margin, where we observed 36.17 psu, while its effect slightly decreased gradually from 35.83 (Pagès Escarpment) to 35.79 (St. Nazaire Canyon). The core of the LSW within the NADW was only seen in the deep cast on the Galicia Margin and the Cantabrian margin (Figure 2).

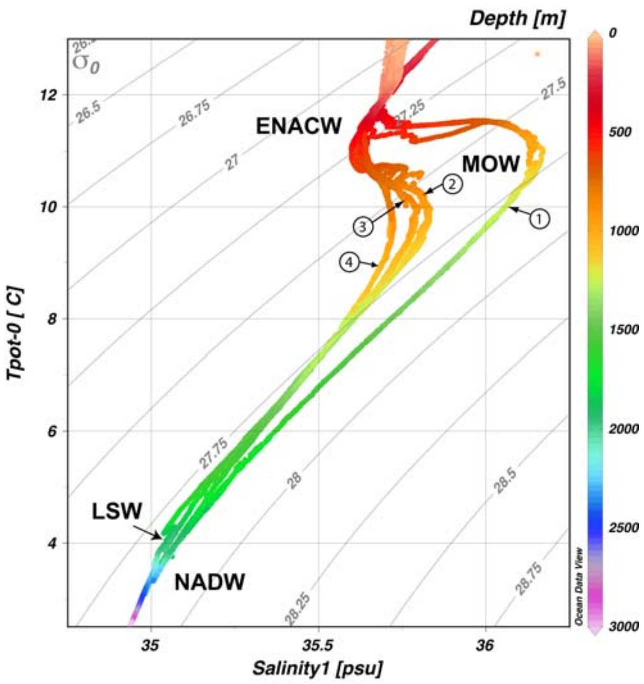

Fig. 2 TS-Plot of all CTD stations including yoyo casts. ENACW = Eastern North Atlantic Central Water, MOW = Mediterranean Outflow Water, LSW = Labrador Sea Water, NADW = North Atlantic Deep Water; 1 = Mugia Canyon, 2 Pagès Escarpment, 3 = Cap Breton and off St. Nazaire, 4 = St. Nazaire Canyon. Note the drastic decline in MOW influence from S to N.

Potential temperature profiles were almost identical in all sites, exept the data from the Mugia Canyon showed lightly increased values between 500 m and 12 m well above 11°C. The critical density envelope of σ_{Θ} of 27.5 ± 0.15 indicative for the occurrence of living *Lophelia pertusa* (Dullo et al. 2008) occurred between 714 and 865 m on the Pagès Escarpment and 601 and 772 in the Mugia Canyon. On the Galicia Margin and and the Armorican Margin this density code was verified by van Rooij et al. (2010) and De Mol et al. (2011) and supported by our own observations:

All Yoyo-CTDs reveal the semidiurnal tidal cycle by showing lower potential temperatures, increased salinity and density values during high tide. Figure 3 displays the time series measured on the Pagès Escarpement. Although, the displayed depth range would indicate the occurrence of living *Lophelia pertusa* and *Madrepora oculata*, the OFOS-transects #2 and #3 revealed only little amounts of scleractinians alive. *L. pertusa* occurred mainly as dead coral rubble fitting well to the observed to the observed quantity of fishing lines and lost fishing gear on that site. These CWC sites are extremely threatened.

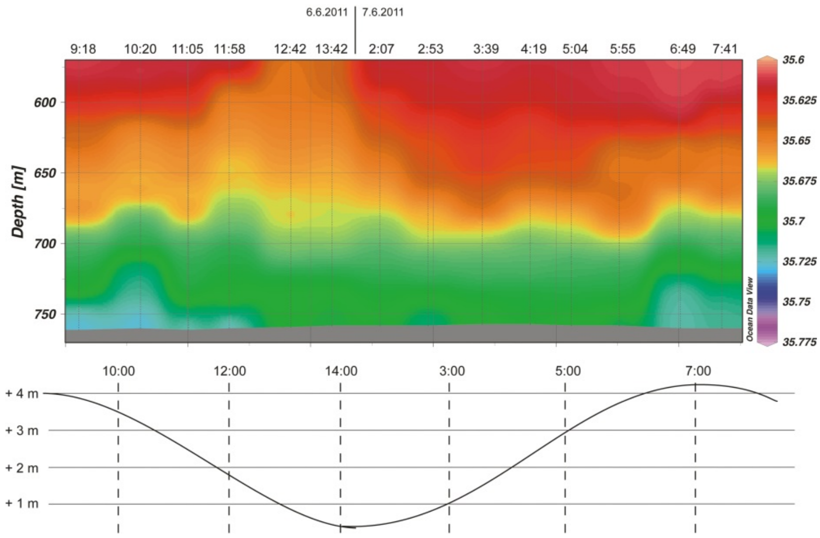

Fig. 3 Yoyo-CTD from the Pagès Escarpment combined from two time series between the 6th and the 7th of June 2011. Increased salinities in the bottom water are clearly seen during high tide of the semidiurnal cycle.

5.1.2 Nd and Hf water sampling (M. Frank, M. Zieringer)

Water samples on METEOR cruise M84/5 were taken using the shipboard rosette and CTD equipped with 24 10-L Niskin® water sampling bottles, that were electronically triggered to close at given depths on the up-cast of the CTD profiles. In this mode of operation distinct water masses in the eastern North Atlantic were sampled. The CTD operations were carried out by Christian Dullo and Thorsten Garlichs.

Radiogenic isotopes

Hydrographic parameters including temperature, salinity, and chlorophyll content were recorded and oxygen concentrations were determined in the lab on board. Sampling of the water column had the main objective to characterize the concentrations and radiogenic isotope compositions of neodymium (Nd) and hafnium (Hf) of all water masses present in the Bay of Biscay. The realized cruise track of M84/5 gave the opportunity to sample the Mediterranean Outflow Water (MOW) at various locations on its northward flow into the North Atlantic. This water mass is of special interest because it is known that MOW leaves its source area with a relatively radiogenic Nd isotope signature (eNd = -9.4) and then flows northward along the Iberian margin into the Bay of Biscay at water depths of its core near 900 m. The fact that surrounding waters in the eastern North Atlantic have significantly less radiogenic Nd isotope signatures (εNd = -11 to -13.5, Lacan et al., 2005b) enables to follow the progressive mixing of MOW with North Atlantic water masses and its reflection by the dissolved Nd isotope composition and for the first time also by its radiogenic Hf isotope signatures.

Another main objective was to investigate the interaction and exchange of MOW and its surrounding water masses with shelf sediments. It is assumed that during these so-called "boundary exchange" processes geochemical and radiogenic isotope composition of a water mass are modified significantly. However, available data directly monitoring these effects are still sparse. For this purpose several near bottom water samples were collected along the cruise track of M84/5, which will be compared to the isotopic composition of the underlying surface sediments.

To complete the investigation of the distribution of dissolved Nd and Hf isotopes in the Bay of Biscay, six large volume (140 l) surface water samples were collected along the cruise track using the shipboard seawater membrane pump.

A detailed list of all samples collected for the radiogenic isotope analysis during M84/5 is provided in Table 4 (Appendix).

5.1.2 Nutrients - water sampling (F. Mienis, T. Garlichs)

Nutrient sampling

During this cruise water samples were obtained from the CTD rosette sampler for nutrient analyses (ammonium, phosphate and nitrate plus nitrite (Nox)). Altogether, 48 water samples were filtered over a 0.20 µm acrodisc filter and were stored in the freezer in polyethylene vials. After the cruise all samples were analyzed on a Technicon TrAAcs 800 autoanalyzer at the NIOZ. The different nutrients were determined colorimetrically as described by Grashoff (1983). Standards are prepared fresh every day by diluting the stock solutions of the different nutrients in nutrient depleted surface ocean water. This water is also used as baseline water. Each run of the system had a correlation coefficient for the standards of at least 0.9999. The samples were measured from the lowest to the highest concentration in order to keep the carry over effects as small as possible.

In every run a mixed nutrient standard containing silicate, phosphate, ammonium and nitrate in a constant and well known concentration, a so called nutrient-cocktail, was measured in duplo. This cocktail is used as a guide to check the performance of the analysis. The reduction efficiency of the cadmium column on the NOx manifold was as least 97 % and measured in each run.

Chemistry

Phosphate reacts with ammoniummolybdate at pH 1.0, and potassiumantimonyl-tartrate was used as an inhibitor. The yellow phosphate-molybdenum complex was reduced by ascorbic acid and measured at 880nm.

Nitrate plus nitrite (Nox) was mixed with a buffer imidazol a pH 7.5 and reduced by a copperized cadmium column to nitrite. The nitrite was diazotated with sulphanylamide and naphtylethylenediamine to a pink colored complex and measured at 550 nm.

Ammonium reacts with phenol and sodiumhypochlorite to a indophenolblue complex at pH=10.5. Sodium prusside is used as an inhibitor and sodiumcitrate is added as a buffer and complexant for calcium and magnesium. The obtained complex was measured at 630 nm.

Statistics

The standard deviation within a run:

PO_4: 0.002 uM 0.13% of full scale value
NH_4: 0.007 uM 0.16% of full scale value
NOx: 0.020 uM 0.13% of full scale value
SiO_2: 0.029 uM 0.17% of full scale value

The standard deviation between the runs are:
PO_4: 0.004 uM 0.30% of full scale value
NH_4: 0.030 uM 0.27% of full scale value
NOx: 0.051 uM 0.34% of full scale value
SiO_2: 0.047 uM 0.28% of full scale value

Suspended particulate matter sampling
Suspended particulate matter (SPM) was collected from a selection of Rosette water samples to determine the concentration and composition of suspended matter at different levels in the water column. From each Rosette water sample 5 liter sub samples were drawn off. The subsamples were filtered on board through pre-weighed Poretics 0.45 µm polycarbonate filters, applying under pressure with a vacuum pump. After filtration salt was removed by passing Milli-Q water through the filter, after which the filters were stored in petri-dishes in the freezer for further analyses on land.

5.2 Plankton sampling

5.2.1 Plankton net operations (A. Movellan)

Planktic foraminifers were sampled with a 100-µm ring net (KC WP2 net, Denmark, 57 cm diameter) from 0-100 m and 0-50 m water depth. Vertical hauls were carried out at a 30 cm per second. The sampled water volume was registered using a analogical flow meter. The average water volume sampled was 108 m^3 for the 0-50 m samples and 283 m^3 for the 0-100 m samples. Two samples were taken at each sampling area. In total, eight plankton samples were obtained (Table 5 (Appendix)). Planktic foraminifers were frequent, and 17 species were present in the upper 100 m of the water column. The assemblages were dominated by *Orbulina universa*, *Globigerina bulloides*, *Globigerinoides sacculifer*, *Neogloboquadrina pachyderma* (sinistral), and *Globorotalia inflata*. Less frequent species were *Hastigerina pelagica*, *Turborotalia quinqueloba*, *Globigerinoides ruber* (white), *Globorotalia scitula*, and *Globigerinita glutinata*. *Neogloboquadrina incompta*, *N. pachyderma* (dextral), *Globigerinella siphonifera*, *Globigerinita uvula*, *Globigerinoides conglobatus*, *Globigerina falconensis*, and *Globorotalia hirsuta* were rare.

Live specimens were collected from each sample, and immediately analysed on board for their protein content. Protein content was analysed with a spectrophotometer (NanoDrop 2000; Thermo Scientific) using bicinchonic acid method. The method has been developed by Smith (1985), and has been applied on various organisms (Zubkov and Sleigh, 1995, 1998; Zubkov et al., 1999; Mojtahid et al., 2011). The method has been specially adapted for the use on planktic foraminifera and allows preservation of the test for further analyses. It is quick and easy to apply in the laboratory and onboard ships, and the data are reproducible. The tests of the analysed specimens will be analysed for their weight and morphometric parameters at BIAF, Angers University, France.

5.3 Hydroacoustics (G. Obermüller)

5.3.1 System overview and operations

The hydroacoustic instruments encompassed two parametric sediment sub-bottom profilers and two swath sounders. All systems were continuously operated in all working areas.
The hull mounted parasound system sediment echosounder (Atlas Hydrographics) represent a narrow beam sediment sub-bottom. Two frequencies (18 kHz and 22 kHz) are emitted from hull-mounted transducers. Due to the parametric effect, a 4 kHz signal is generated in the water column within an emitting cone of ca. 4°, which results in a foot print with a diameter of 7% of the water depth.

The signal penetration depth strongly depends on the lithology, grain size and gas load. The received data are digitised and stored in a SEG-Y like format. Data processing and visualisation has been carried out by means of the SESuit software package developed at the University of Bremen by Volkhard Spieß and co-workers. Processing mainly included frequency filtering and gain control.

Most of the profiles stroke (almost) perpendicular to the bathymetric contour in order to image water depth dependent deposition pattern or downslope sediment transport. On board processing and preliminary interpretation of the parasound data enabled us to carefully determine bottom sampling sites and OFOS tracks.
Bathymetric measurements have been carried out mainly with the hull mounted EM120 swath sounder. A swath of 256 preformed beams is emitted periodically with signal frequencies of 12 kHz. The usable foot print of a single emitted swath perpendicular to the ship's heading has a width of more than three times of the water depth.

5.3.2 EM120 Swath mapping

The EM120 was operated continuously in all working areas. In order to produce spatially extended bathymetric maps of particular working areas swath mapping has been carried out along parallel profiles with distances of twice the water depth. We used the on board NAUTILUS software for editing and removal of overlapping pings. Gridding and visualisation has been done by means of the Generic Mapping Tool software (GMT). Particular maps have been produced for the working areas fort he Mugia Canyon area, the Pagès Escarpment off northern Spain, the Cap Breton Canyon area, and the St. Nazaire Canyon area. (Fig. 4). The data further supported the selection of OFOS-tracks, TV-grab, lander deployment and core sites throughout the cruise.

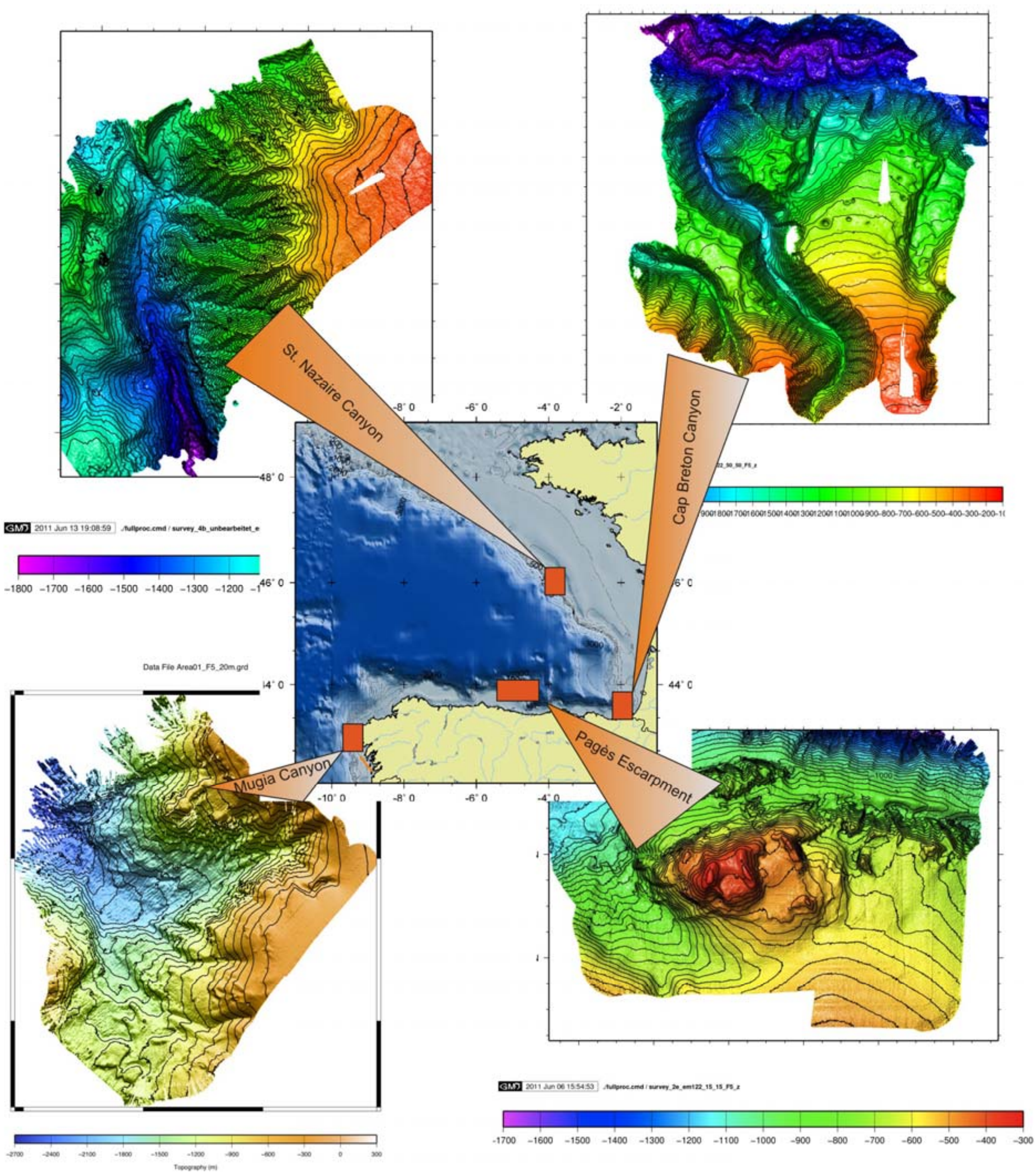

Fig. 4 Depicted are the multibeam maps for the four working areas: lower left – Mugia Canyon, lower right – Pagès Escarpment, upper right - Cap Breton Canyon, upper left - St. Nazaire Canyon.

5.4 Seafloor observations and measurements

5.4.1 OFOS observations (C. Orejas, M. Cunha, L. Génio, A. Gori, M. López Correa)

Introduction

The Ocean Floor Observatory System (OFOS) has been deployed in all working areas in order to have a first rough characterisation of the zones as well as a first description of the morphology, substrate and megabenthic communities inhabiting the study zones. For the four study areas, megafaunal occurrences were logged manually during real time observations using time-tags as a reference for further location in the video and geographic positioning records.

In the next paragraphs, a summary of the observations in each study area is given as well as an idealized schematic drawing from some dives. At the end of this chapter a preliminary semi-quantitative study of some transects is presented. These results are preliminary and all identifications must be taken as provisional until further verification using the digital photographs taken during the dives.

Table 6 (Appendix) presents the complete data for all OFOS surveys including graphical summaries of the respectice areas (Figures 16-19 (Appendix)).

Objectives

The main objectives of the visual sea floor observation were: 1) to conduct a ground thruthing survey to explore the selected research areas and to locate areas with presence of scleractinians, in order to determine subsequent sampling sites for box-core and TV-Grab (TVG) and 2) to have a first documentation of the megafaunal epibenthic biodiversity at the different study areas and to describe the benthic communities and their faunal zonation.

Methodology

The GEOMAR Ocean Floor Observation System (OFOS) is a TV-guided frame of 165x125x130 cm equipped with a black and white video camera, two Xenon lamps (Fa. Oktopus), an underwater still camera with flash (Fa. Benthos), two laser pointers (Fa. Oktopus) and a FSI memory CTD. For the seafloor observation procedure, OFOS is towed by the ship about 1-2 m above the sea floor with less than about 1 kn along a pre-defined track. The distance between the frame and the seafloor is controlled manually by the winch-operator. Still photos were taken manually during the deployment (maximum 800 frames). The video signal of the colour camera is permanently recorded onboard on video tapes (SHVS). The ship based recording of the OFOS data during our OFOS observations were also stored into a positioning protocol software (POSIDONIA) which automatically recorded UTC time, ship coordinates, depth of the OFOS and other data from a NMEA-link/DVS online string. The POSIDONIA program is in particular useful, because it allows the exact determination of the OFOS position independently from the ship position, which is pivotal for precise site identification and exact positioning of subsequent sampling with box cores and TVG.

Preliminary results

Detailed drawings of the habitats along the OFOS tracks are given in the Appendix (Figures 16-19).

<u>Area # 1 Mugia Canyon</u>

OFOS-1 Dive M84/5-561 OFOS Muxía canyon

A single OFOS track has been conducted in this area.

Depth range 1730-ca.1600 m: Numerous patches of cold-water coral framework and/or rubble with living scleractinian colonies were observed intercalated with areas of soft sediment showing various bioturbation traces (rows of circular burrows). Sponges, octocorals, including numerous *Stichopathes*-like corals (black corals), were observed in association with the cold-water coral patches.
Depth range 1600-ca.1500 m: At this depth the sea floor forms a sedimentary terrace. Coral patches become scarce and do no longer occur as there are vast areas of soft sediments with, ophiuroids, asteroids and a few *Stichopathes*-like corals and fish. There are an increasing number of rock blocks when approaching 1500 m depth.
Depth range: 1500-ca.1400 m: Slope becomes steeper, hard grounds are more frequent and the megafaunal assemblage is dominated by large sponges. Octocorals, actiniarians and occasionally fishes were also observed.
Depth range: 1400-ca.1300 m: Slope still steep (hard grounds often covered by soft sediments) but large sponges no longer occur. Megafaunal community is very poor.
Depth range: 1200-ca.1000 m: Steep slope with numerous brisingids and ophiuroids. Actiniarians or cerianthids (not possible to distinguish) and asteroids were also observed, as well as numerous bioturbation traces (small isolated or clustered circular burrows, mounds).
Depth range: 1000-ca.800 m: Very poor megafaunal assemblage with only occasional echinoids.
Depth range: 800-ca.650 m: The faunal assemblage is dominated by the occurrence of different species of echinoids including cidarids. Some bioturbation traces are also observed (small burrows and mounds).
Depth range 700-600m: Along the summit: Several aggregations of *Callogorgia*-like gorgonians are observed along the summit. Other megafaunal organisms include *Cidaris* and other echinoids, holothurians, asteroids, sea-pens and fishes. Some areas of the seafloor are densely bioturbated by burrows.
Depth range 600-300 m: Sedimentary floor with detritic component, rubble and occasionally some boulders. Fishes are more often observed in this area (including sharks probably *Scyliorhinus* sp.) together with a few *Nephrops* and *Sepia*. Soft bottom, bioturbated by burrows (probably from *Nephrops*?).
Anthropogenic impact along the transect: some glass bottles, several trawl marks, fishing line, garbage.

<u>Area # 2 Pagès Escarpment</u>

St. 579 OFOS#2, St. 613 OFOS#5 and St. 614 OFOS #6 surveyed a rocky outcrop north of Pagès Escarpment from approx. 1030 m at the northern base to the summit at approx. 680 m; St. 590 OFOS#3 surveyed the two summits of the Pagès Escarpment at approx. 260 m and then followed down-slope until approx. 700 m; St. 610 OFOS#4 surveyed the Pagès Canyon from approx. 1200 to 1700 m.
The logged observations of OFOS#2, 3 and 4 were organised into matrices using pooled segments of five minutes observations. In these cases it was possible to use multivariate analysis (namely multidimensional scaling, PRIMER software) to interpret the megafaunal zonation. A summary of these preliminary results is given at the end of this chapter. Five OFOS tracks were performed in this area.

- *OFOS-2 Dive M84/5-579 OFOS Pagès Escarpment*

Depth range ca. 1000-950 m: Soft bottom presenting strong bioturbation and high abundances of sea stars, some holothurians. Some fish.
Depth range ca. 950-800 m: Sandy to muddy bottoms highly bioturbated, in some places with parallel ripples which indicate strong currents. Burrows very abundant, probably made from

crustaceans. In some areas the biodetrital material appears distributed in patches. Sea stars are very abundant (with up 2 to 3 specimens/m^2), along with a presence of sea urchins and anemones. In areas where scattered boulders appear, the urchin *Cidaris* is present. At 900 m, a cliff occurs with some living coral (probably *Madrepora oculata*) and coral rubble at the cliff base. At 850 m, the floor gets coarser, but no rocks are present, in this area coral rubble is observed. Areas with sandy substrate are dominated by sea pens.
Depth range ca. 950-700 m: Patches of muddy and coarse sediment with a presence of scattered coral rubble. At this depth some rocky blocks appeared, but were not densely aggregated. The crustacean burrows continue to be abundant, however faunal presence is very scarce, some echinoids occurred, but in low numbers. Also scarce presence of fishes. By 700 m the substrate gets coarser, and *Phakellia* sponges comprise the dominant species. Up to this depth large bioturbation was observed as well as a higher presence of echinoids.
Anthropogenic impact along the transect: A fishing line, plastic bags.

- *OFOS-3 Dive M84/5-590 OFOS Pagès Escarpment*

Depth range: 260-ca.380 m: Sea floor mostly characterized by biodetrital substrate changing in some areas to fine sand and with a presence of rocky boulders. Soft bottom substrate dominates. Patches of coral rubble appear but are in general scarce. Megafauna in the areas characterised by detrital substrate or soft substrate is dominated by *Bonellia viridis*, bright sea urchins, holothurians and sponges; it is remarkable that large examples of *Asconema setubalensis* are present. Some isolated *Dendrophyllia*-like branches were observed. In the areas where rocky boulders occur, elongated gorgonians/sea pens (not possible to distinguish) grow on the top of the boulders. Fishes are very abundant, especially sharks.
Depth range: ca. 380-600 m: Steep cliff with few terraces, sponges dominated the megabenthic community within the cliff, occurrence of some fan-shaped gorgonians. At the terraces the floor is characterize by muddy sediment and *Callogorgia* sp. dominates. It is also to be poined out that the zooplankton occurrence observed in the benthic boundary layer was quite high. At 478 m depth, a dense *Callogorgia* forest has been recorded, with several large colonies orientated perpendicular to the slope parallel current. *Callogorgia* also grows in cliffs, where sponges are also quite abundant. However, the *Callogorgia* forest seems to be restricted to a sharply defined depth range. In deeper zons, holothurians, sea pens and some *Cidaris* are the dominant groups.
Depth range: 600-ca. 700 m: Muddy sand and biodetrital substrate, with coral rubble, sea pens and large sponges. A *Chimaera monstrosa* has been observed.
Anthropogenic impact along the transect: Lots of fishing lines, as well as lost weights of the long line fishing gear; This area seems to be a shark fishing zone. Some glass bottles.

- *OFOS-4 Dive M84/5-590 OFOS Pagès Canyon*

Depth range: 1100-1300 m: Substrate characterised by muddy sands with a biodetrital component, large burrows were observed. The megabenthic community is represented by diverse fauna: stalked sponges, sea pens, sea stars, *Cidaris*. *Keratoisis*-like corals were quite abundant, as well as some fan-shaped gorgonians. Fishes and sharks are also quite abundant. Below 1200 m depth some boulders start to appear, being dominated by octocorals, *Stichopathes*-like black corals and large sponges.
Depth range: 1300-1400 m: Muddy bottom dominated, but mixed with coarse sediment and in some places with the presence of rocky boulders. Lots of burrows are present in the area. The topography varies from plains to some cliffs and terraces. The dominant benthic megafauna comprises sponges, sea pens and stalked sponges, but in all cases with low abundances. Isolated occurrences of octocorals occur, as well as bamboo corals (some of them *Keratoisis*-like) and black corals. In areas with rocky boulders some scleractinian corals appear and also coral rubble.

Depth range: 1400-ca. 1610 m: Coarse sand and bedrock characterise this depth range. Fauna is in general very scarce, with some sea stars. Almost no presence of corals, octocorals and sponges, when present just isolated. In the outcropping rocks some scleractinians appear, also isolated. By 1500 meters depth loads of stalked crinoids dwell on hard substrates with high abundance and density. By 1600 scleractinian frame work occur.
Depth range: 1610-ca. 1670 m: Steep slope, mixed rocky and sedimentary substrate with presence of stalked crinoids, forming dense aggregates in some areas and also presence of scleractinian corals.
Along the whole transect only few fishes were observed
Anthropogenic impact along the transect: No rests of anthropogenic impact observed.

- *OFOS-5 Dive M84/5-613 OFOS northern Pagès Escarpment*

Depth range: ca. 700-800 m: Coarse sediment with some rocky blocks. On muddy bottoms some sponges, sea urchins and coral rubble occur. On the rocky blocks epifauna is present; *Cidaris*. Shark. Around 770 m depth hard grounds starts to appear, few fauna growing on it. Steep slope.
Depth range: 800-900 m: Hard ground in the slope covered by muddy sediment. *Cidaris*, indicating the presence of hard substrate (even if covered by muddy sediment). Some sea pens and sea stars, but in general very few animals.
Anthropogenic impact along the transect: Few fishing lines.

- *OFOS-6 Dive M84/5-614 OFOS northern Pagès Escarpment*

Depth range: ca. 750-800 m: Muddy-sandy bottom. Very few epifauna, some sea urchins occurred. Rocky blocks with increasing depth with muddy cover. *Cidaris*. Cliff is extending deeper. No fishes.
Depth range: ca. 800-ca. 920 m: Solitary corals (?). Cliff with some coral frame work and maybe living colonies. Corals may represent *Enallopsammia*. Fish (just one). At 910-920 m sandy areas with some *Echinus*.
Anthropogenic impact along the transect: Few fishing lines.

<u>Area # 3 Cap Breton Canyon</u>

Five OFOS tracks were performed in this study area – a shallower area (150-300 m) at the head of the canyon was surveyed during St. 630 OFOS#9. St. 628 OFOS#8, St. 627 OFOS#7, St. 681 OFOS#12 and St. 686 OFOS#13 surveyed several areas of the tributary canyons at depth ranges of approx. 420-950 m, 680-850 m, 950-1200 m and 1450-2050 m, respectively. Additionally, a large pockmark-like structure was also surveyed during St. 681 OFOS#12.
At the canyon head (St. 630 OFOS#9) the seafloor was characterized by coarse detrital sediments and larger rock boulders which were colonised by *Dendrophyllia cornigera,* sponges and other organisms hardly identifiable during the real-time observations. At depths greater than 200 m colonised boulders were sparser and some sedimentary areas were only inhabited by a few fishes (flatfishes and other). The tributary canyons were covered by a thick layer of muddy sediments. These bioturbated sediments (different types of burrows, isolated or in clusters and mound-like structures) showed a rather monotonous megafaunal assemblage dominated by cerianthids and different groups of echinoderms, frequently brisingiid sea stars.

From 400 to 500 m depth the assemblage was almost completely dominated by cerianthids, accompanied by crinoids (to be confirmed with the photographs) below 500 m. At approx. 600 m the assemblage was dominated by brisingiids and ophiuroids (St. 628 OFOS#8). In some areas these were accompanied by cerianthids and seapens (St. 627 OFOS#7). At greater

depth brisingiids were more sparse and the megafauna was practically absent between 1000 and 1200 m (St. 681 OFOS#12). From 1400 to 1500 m only a few fish were observed, followed by an assemblage dominated by sea-pens and tulip-like stalked hexactinellid sponges distributed down to approx. 1650 m and then again only a few fishes down to 1650 m. Approaching the *Talweg* edge, echinoids and holothurians increased in abundance and dominated the assemblage of the *Talweg* axis at approx. 2050 m (St. 686 OFOS#13). The megafaunal assemblage from the pockmark-like areas did not show any striking differences from the surrounding areas (St. 681 OFOS#12).
Anthropogenic impacts: Except for the numerous fishing lines at the head of the canyon, no other impacts were observed in this area.

In the following paragraphs a short description of each OFOS dive is given.

- *OFOS-7 Dive M84/5-627 OFOS Cap Breton Canyon*

Depth range: ca. 680-850 m: This transect started in a suspected pockmark structure. Substrate dominated by muddy bottom (highly bioturbated, burrows) with high abundance of brisingiid sea star and frequent presence of sea pens. Some holothurians, cerianthids and *Umbellula* were also registered. Several fishes occurred.
Anthropogenic impact along the transect: No anthropogenic impact recorded.

- *OFOS-8 Dive M84/5-628 OFOS Cap Breton Canyon*

Depth range: ca. 420-600 m: Muddy bottom with few small burrows, and little biodetrital stray. Ceriantaria were abundant, downslope from 450 m, sea urchins appeared and below 500 m also sea stars. Some fish, several sharks.
Depth range: 600-800 m: Below 600 m the muddy bottom (with burrows) continues and brisingiidae sea stars and other sea stars occur.
Depth range: 800-1000 m: Muddy bottom (with burrows). Brisingiidae continue to be dominant, along with the occurrence of *Echinus* and *Cerianthus*. Presence of sharks.
Anthropogenic impact along the transect: No anthropogenic impact recorded.

- *OFOS-9 Dive M84/5-630 OFOS Cap Breton Canyon: canyon-heads*

Depth range: ca. 150-200 m: Rocky boulders dominate, often colonized in high density by *Dendrophyllia cornigera. Cidaris* is present. Fishes were quite abundant and diverse. Around 200 m soft bottoms dominate with frequent presence of sea pens.
Depth range: ca. 200-ca. 300 m: Muddy sands (with burrows) are predominant below 200 m. Scarce presence of organisms. In some patchy areas with coarser sediment and small cobbles, *Dendrophyllia* corals appear again. Several fish observed, among them, *Chimaera monstrosa*. At 240 m depth the substrate changes again to muddy bottom, which is predominantely occupied by sea pens.
Anthropogenic impact along the transect: Fishing lines.

- *OFOS-12 Dive M84/5-681 OFOS Pockmark (two locations visited in this transect)*

First location
Depth range: ca. 830-890 m: Muddy bottom dominant (bioturbated: small burrows). Megafauna dominated by brisingiid seastars, with the presence of holothurians, other sea stars and cerianthids. Some fish, sharks.
Second location
Depth range: ca. 960-1000 m: Muddy bottom. Megafauna characterised by crinoids, anemones and brisingiid sea stars.
Depth range: 1000-ca. 1180 m: Muddy bottom with the presence of muddy cliffs of several meters in height. Megafauna was characterised by brisingiid sea stars and crinoids in low abundances. Fishes.
Anthropogenic impact along the transect: No anthropogenic impact was recorded.

- *OFOS-13 Dive M84/5-686 OFOS Deep canyon flank*

Depth range: ca. 1440-1600 m: Muddy bottom with bioturbation (burrows). Megafauna was present in low abundances, comprising holothurians, sea pens and tulip sponges. Fishes occurred.
Depth range: 1600-1800 m: Muddy bottom with bioturbation (burrows). Same as previous depth interval (1440-1660 m), but with the presence of brisingiid sea stars.
Depth range: 1800-1900 m: Muddy bottom. Megafauna: Sea urchins, sponges, ophiurids.
Depth range: 1900-2000 m: Muddy bottom (with bioturbation, burrows). Megafauna: holothurians and sea urchins.
Depth range: 2000-2100 m: Muddy bottom (with bioturbation, burrows). Megafauna: holothurians, *Echinus*. Fish.
Depth range: 2100-ca. 2180 Muddy bottom (with bioturbation, burrows). Megafauna: sea urchins, holothurians, cerianthids and sea stars.
Anthropogenic impact along the transect: No anthropogenic impact was recorded.

<u>Area # 4 Saint Nazaire Canyon</u>
Two OFOS tracks were performed in this study area – St. 641 OFOS#10 and St. 646 OFOS#11. These tracks mostly followed the ridges along the depth ranges of 380-1000 m and 700-1290 m, respectively. The observations showed first the occurrence of sediments and coral rubble with some patches of coral framework mostly covered by sediments occurring between 440 and 550 m and then consistently the presence of erected thickets and dense framework of scleractinian corals colonised by a diversity of other cnidarians (actiniarians, octocorals, anthipatharians, sea pens) and mostly echinoderms (cidarids and other echinoids, asteroids, crinoids). Living scleractinian colonies were mostly within the depth range of 700-850 m. A few meters away from the ridges the coral framework was often already covered by sediments. Approaching the *talweg* large sediment slumps were observed (approx. 1000 m) but isolated coral thickets continued to occur down to approx. 1100 m depths.

- *OFOS-10 Dive M84/5-641 OFOS St Nazaire canyon*

Way points of this transect: (1) 46°14.259’N, 4°18.096’W. 385 m (depth); (2) 46°13.915’N, 4°19.370’W, 746 m (depth); (3) 46°13.949’N; 4°19.650’W, 824 m (depth)
Depth range: ca. 380-500 m: Substrate dominated by sandy bottom; a dense coral rubble cover has been observed in several locations. Scattered appearance of rocky blocks. Coral framework preserved in some locations, all coral seems to be dead. The megafauna was characterised by sea stars, holothurians, sponges and *Cidaris*. By 467 m depth coral framework field. Several fish species, among others scorpionfish and *Helicolenus* sp.
Depth range: 500-600 m: Sandy bottom, coarse floor and coral framework. Mound-like topography in several areas. Cerianthids, sea urchins. Coral rubble patches. Sharks (probably cat sharks). Patchy distribution of coral framework.
Depth range: 600-700 m: Sandy bottom with presence of coral framework. In the sandy bottom, cerianthids dominated. The coral framework seems to present some living *Lophelia* thickets. Fish, among them cat shark.
Depth range: 700-800 m: Muddy sediment with some scattered coral colonies (seems to be dead with some alive thickets). Megafauna was dominated by sea stars, crinoids, cerianthids and sea urchins. Sharks.
Depth range: 800-900 m: Same kind of sea floor with scattered coral colonies. Mostly dead but also with living thickets. Presence of sea urchins and sea stars.
Depth range: 900-ca. 1000 m: Same kind of sea floor with scattered coral colonies dead but also living thickets. In the areas with sandy sediment, sea pens dominate. Rocky boulders also appear in a patchy distribution; presence of coral rubble.
Anthropogenic impact along the transect: Trawl marks. Lost fishing gears.

- *OFOS-11 Dive M84/5-646 OFOS St. Nazaire canyon*

Depth range: ca. 610-ca. 750 m: Sandy substrate covered to a large percentage by dead coral framework, with some living thickets on top, but most of the colonies appear to be dead. By 700 m it seems that more living corals occur. Fish.
Depth range: ca. 750-ca. 870 m: Sandy areas patched with coral framework. Some boulders and cobbles. Dense dead coral aggregations with living thickets. Presence also of sea urchins and *gorgonia* sp. Less corals below 800 m, where substrate is dominated by boulder patches and sandy bottom. On boulders some living corals and *Cidaris* occur.
Depth range: ca. 870-ca. 1060 m: Sandy bottom with patches of dead corals with some living exemplars. Megafauna: beside the corals, exemplars from *Echinus* and fan-shaped gorgonians. Fish. Hard sediment bottom below 1000 m depth.
Depth range: ca. 1060-ca. 1300 m: Patches with sandy bottom, with ripple fields. Sandy mounds with quite abundant living coral thickets and presence of some gorgonians. Fishes.
Anthropogenic impact along the transect: No anthropogenic impact was recorded.

Multivariate analyses of OFOS # 2, 3 and 4 (Pagès Escarpment. Area #2)
The logged observations of OFOS#2, 3 and 4 (Area #2 Pagès Escarpment) were organised into matrices using pooled segments of five minutes observations. In these cases it was possible to use multivariate analysis (namely multidimensional scaling, PRIMER software) to interpret the megafaunal zonation. A summary of these preliminary results is given below.
St. 579 OFOS#2 (Figure 5): fives zones were identified. Zone 1) Heavily bioturbated sediments with numerous ophiuroids; holothurians, echinoids and fishes were also frequently observed (1030-920 m); Zone 2) Large rock outcrop north of Pagès Escarpment; abundant coral rubble and boulders at the base of the steep northern rock wall, which was colonised by sparse colonies of octocorals and scleractinians; most of the outcrop was covered by a fine layer of sediments; scattered boulders were sometimes colonised by antipatharians, octocorals and scleractinians. Anthropogenic impacts (AI): Fishing lines (920-800 m); Zone 3) Channel between large outcrop and escarpment; bioturbated sediments with rubble; megafaunal assemblage dominated by echinoids; Litter: Plastic bag (830-800 m); Zone 4) Small rock outcrop at the base of Pagès Escarpment; megafaunal assemblage dominated by sponges, echinoids (including cidarids) and asteroids; Zone 5) Small channel between outcrop and escarpment; bioturbated sediments with rubble (approx. 700 m).

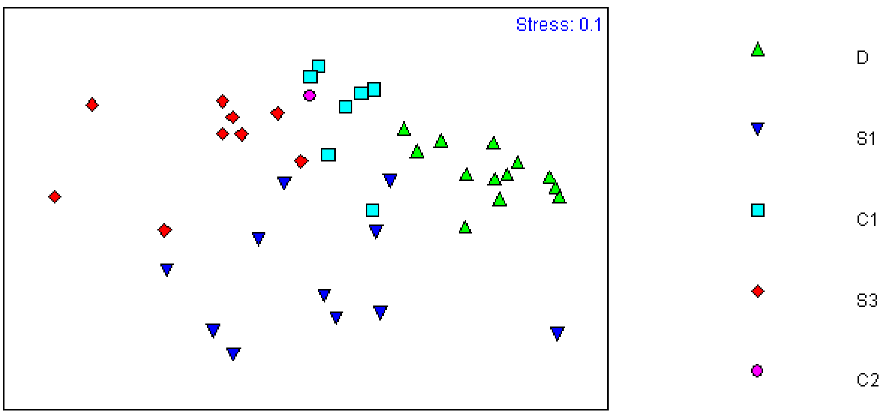

Fig. 5 MDS results for St. 579. Each symbol represents sequential 5-minute segments. D: zone 1; S1: Zone 2; C1: Zone 3; S3: zone 4; C2: zone 5. Note the faunal resemblance between the rocky outcrops (S1 and S3) segregated from the sedimentary areas (the channels C1 and C2 and the deeper area D north of the outcrops).

St. 590 OFOS#3: Five zones were identified. Zone 1) Summit of Pagès Escarpment, hardgrounds mostly covered by sediments, megafaunal assemblage dominated by a high diversity of fishes (including frequent observations of *Scyliorhinus* sp.) and echinoids; holothurians and sponges were also observed. Highly impacted by anthropogenic activities (AI; fishing lines and glass bottles (260-310 m); Zone 2) Slope, sediment with rubble; megafaunal assemblage dominated by echinoids and sponges and occasionally also octocorals; fishes were frequent especially *Scyliorhinus* sp. Heavily impacted (fishing lines and glass bottles) down to 375 m depth (285-410 m); 3) Cliff and base of the cliff; megafaunal assemblage dominated by *Callogorgia*-like octocorals and sponges with some fishes and very few echinoderms fishing lines frequently observed (450-515 m); 4). Bioturbated sediments (burrows) with a poor megafaunal community dominated by echinoids, as well as few holothurians and fishes. No AI (515-560 m); Zone 5) Heavily bioturbated sediments (small and large burrows, crab burrows and mounds, dominated by sea-feathers, echinoids, holothurians, also asteroids and a few sponges; few fishes, no AI (560-650 m).
St. 610 OFOS#3 (Figure 6): seven zones were identified. Zone 1) Terrace; bioturbated sediments with rubble: megafaunal assemblage dominated by stalked hexactinelid sponges (tulip-shaped) and sparse sea-pens, oter octocorals and fishes (1195-1185 m); Zone 2) Hardgrounds with boulders and sediments; sponges and high diversity of octocorals - "octoctocoral gardens" (1185-1270 m); Zone 3) Hardgrounds with boulders; sparse assemblage of black corals (*Stichopathes* like), octocorals and sponges (1270-1315 m); Zone 4) Track along the edge of escarpment; sediments with rubble and sparse rock blocks; megafaunal assemblage dominated by long sea-pens, *Acanella*-like octocorals and stalked hexactinellid (tulip-shaped) sponges; Fishes, ophiuroids, echinoids and other sponges and octocorals also frequently observed (1315-1330 m); Zone 5) Heterogeneous area; hardgrounds with patches of sediment and loose blocks and boulders; megafaunal assemblage dominated by octocorals, sponges and fishes; echinoderms (echinoids, asteroids and ophiuroids) occasionally observed (1330-1475 m); Zone 6) Hardgrounds, fields of crinoids with ophiuroids and occasionally large sponges and octocorals (1475-1815 m); Zone 7) Hardgrounds with scleractinians and octocorals (1615-1675 m).

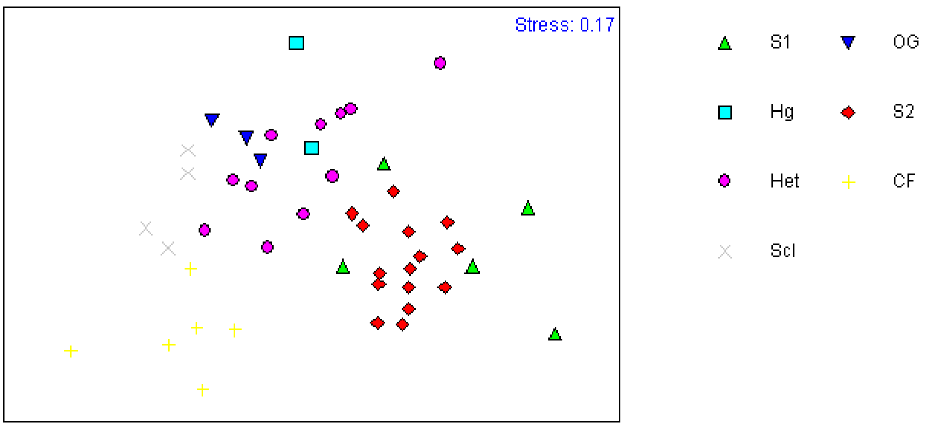

Fig. 6 MDS results for St 610. Each symbol represents sequential 5-minute segments. S1: Zone 1; OG: Zone 2; Hg: Zone 3; S2: Zone 4; Het: Zone 5 ; CF : Zone 6 ; Scl : Zone 7). Note the faunal resemblance between the sedimentary areas (S1 and S2) segregated from the hard-ground areas. The different hardground areas are also well segregated except for Zone 5 (Het; corresponding to a heterogeneous area of hardground and sediment patches.

5.4.2 POZ-Lander deployments (S. Flögel, C. Dullo)

Objectives

Cold-water corals are an ideal natural laboratory to study the impact of climate variability. The corals record short-term to decadal changes in the ambient hydrography such as temperature, salinity, oxygen availability, and current regime. For the past years, our group has investigated the dynamics of cold-water corals along the European continental margin. Our results showed that it is indispensable to measure present day oceanographic properties around sampling sites in high resolution and on various time scales of days to months to understand the high variability of geochemical parameters recorded in the calcareous coral skeletons. Until now we have used single CTD measurements and occasionally lander deployments to get a principle idea about the properties of water masses bathing cold-water coral habitats. The need for a specific observatory and advanced instrument package targeting on high-resolution data acquisition at the seafloor became evident. To promote this idea, we have designed and built a target-oriented lander system which was constructed by K.U.M. Umwelt- und Meerestechnik GmbH, Kiel (Figure 7).

On M84/5 we successfully deployed the lander system at the Pagès Escarpment and the St. Nazaire Canyon area.

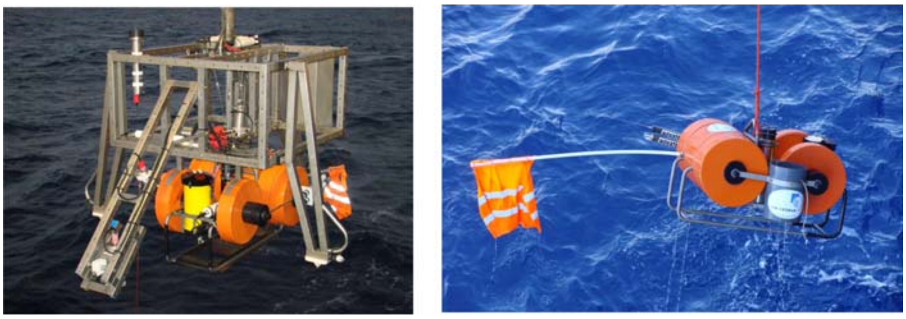

Fig. 7 Video-guided deployment and recovery of POZ-Lander system which is equipped with a CTD, an ADCP, and a high precision digiquartz for pressure/depth measurements.

Sampling and methods

The POZ-Lander system is equipped with a RBR XR-420CTm Conductivity-Temperature-Depth (CTD) profiler and a high precision Paroscientific and a high precision Paroscientific Intelligent pressure sensor with an accuracy of 0.015%. The system also carries a RDI Workhorse Sentinel 300 ADCP. To release the system we used a K/MT 562 Releaser from K.U.M. Umwelt- und Meerestechnik GmbH, Kiel. We deployed the system two times during the cruise for three and five days respectively, the Pagès Escarpment off northern Spain and the St. Nazaire Canyon area on the French slope.

Results

As an example we show pressure (depth), temperature, and salinity data from the second deployment in the St. Nazaire Canyon (station #642) where the system was at th ebottom for 144 hours. The bottom waters in the working area are characterized by a strong tidal signal which is expressed by a 12-hour cycle of depth which varies by about 300-350 cm between high- and low tide. This is accompanied by changes in temperature and salinity which obviously correlate to the pressure measurements. We are currently further investigating the physical prerequisites for CWC growth in the Bay of Biscay (Figure 8) by looking at ADCP measurements from the lander system and by comparing it to other sites such as the Pagès Escarpment.

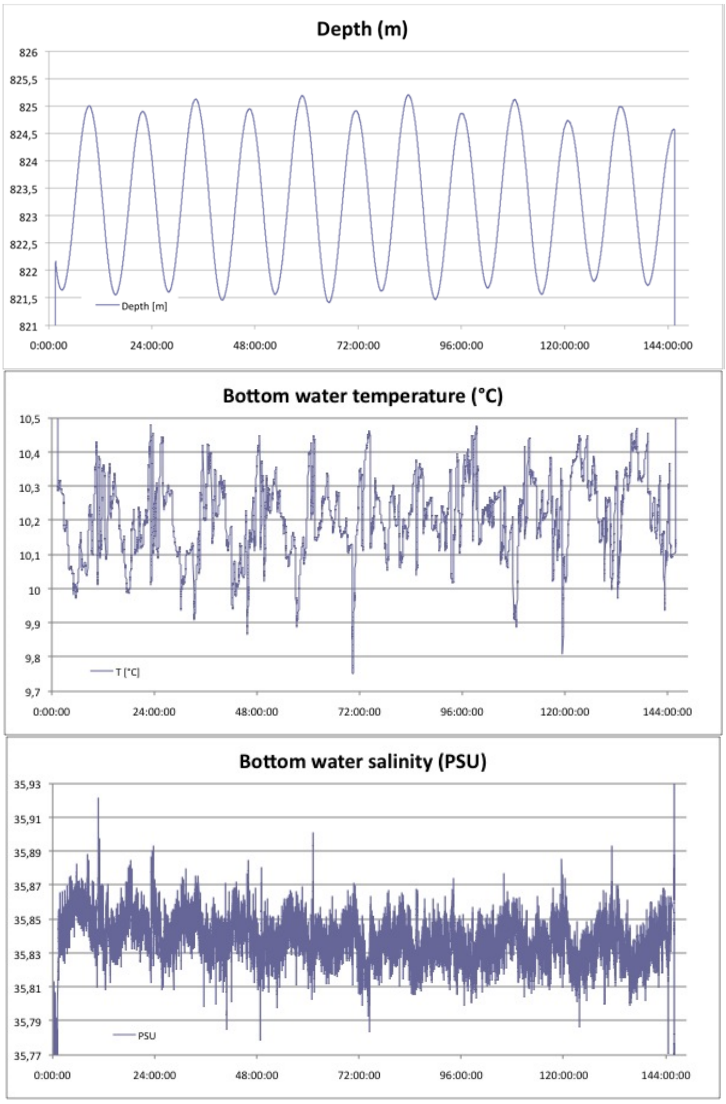

Fig. 8 Results of POZ-Lander deployment at station #642, St. Nazaire Canyon. Shown are pressure measurements, temperature, and salinity variation during the 144 hours of deployment. The upper panel nicely illustrates the strong correlation of pressure variation at station #642 being linked to tidal effects as recorded for La Rochelle (not shown).

5.5 Box coring (A. Rüggeberg)

5.5.1 Device and operations

The box corer was used at selected sites to recover undisturbed surface sediments from cold-water coral sites and surrounding environments. The sites were selected during OFOS surveys under consideration of slope angle, possible sediment penetration and the occurrence of corals. Dense living cold-water coral frameworks and mound parts were tried not to sample, however, they mainly occurred at steep slopes or cliff-like sites impossible to grab with the box corer.

We used a giant box corer with a sampling area of 50 x 50 cm and a maximal penetration of 50 cm. Depending on the sediment, the maximum recovery was 34 cm with an average of 23 cm. The box corer was equipped with a POSIDONIA transponder mounted 50 m above the gear on the cable to make positioning on the ground as precise as possible. Sampling occurred within ± 3–4 m of the coordinates selected during the OFOS video tracks, which were likewise logged with the POSIDONIA-system. When the box corer was back on board, the lids were opened for a first assessment of sample quality and decision for subsequent procedures.

The general procedure followed this scheme:

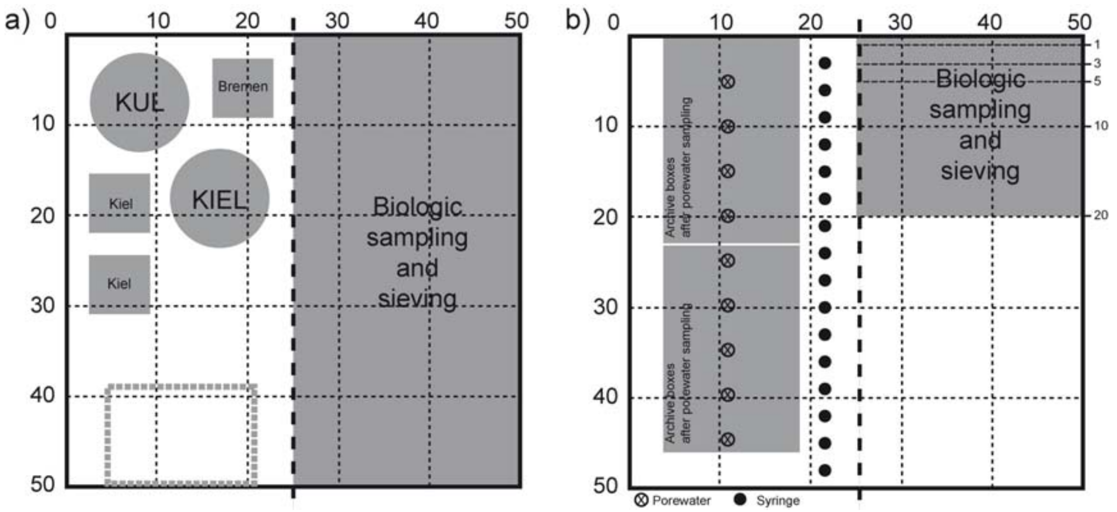

Fig. 9 Schematic sampling of a) sediment surfaces and b) vertical sections of box corer. All numbers correspond to centimeters.

Horizontal section of box corer (Figure 9a):
1. Filter surface water over a 63-µm sieve
2. Photo of sediment surface including label of station number and scale
3. Sketch of important features on sediment surface
4. Description of surface (sediment, sediment color, structure, morphology, living and dead organisms)
5. Sampling of living organisms
a. *Lophelia pertusa* for DNA analysis (Ifremer)
b. Corals (Santander, Barcelona)
c. Corals for geochemistry (Kiel/Erlangen)
d. All other fauna (Aveiro)
6. Sampling of dead organisms including corals for geochemistry (Aveiro, Kiel, Erlangen, Bremen)
7. Bulk surface sediment, 87.6 cm^3 – stained with rose bengal (Kiel)
8. Bulk surface sediment, 5 x 5 cm (Bremen)
9. Subcore ø 10 cm (Kiel) – stored cool at 4°C
10. Subcore ø 10 cm (KU Leuven) – stored frozen at –20°C
11. Pore waters in 5-cm interval (KU Leuven)

Vertical section of box corer (Figure 9b):

1. Clean surface and make photo with label and scale
2. Sketch of important features in the sediment profile
3. Description of the section (sediment, sediment color, structures, bioturbation, horizons, fossils, ...)
4. Sampling of vertical profile
a. Set of syringes in 3-cm interval (Kiel)
b. Biologic sieving of top 20 cm (Aveiro)
c. Fossil corals (Kiel, Erlangen, Bremen)
d. Archive boxes (Kiel)
e. Geologic sieving of the remaining sediment (Erlangen, Kiel)

The overlying water was carefully siphoned-off with a tygon-tube and rinsed over a < 63 µm sieve, and once the sediment surface was stable, the box was dismounted and moved to a sheltered place for surface sampling and description. Surface sediments for foraminiferal studies were collected using a frame of 87.6 cm^2 pushed into the sediment, and the uppermost cm was collected with a spoon. A 1-cm gauge on the inner side of the frame helped to keep the required depth level. The surface sample was immediately conserved and stained with a solution of 2 g Rose Bengal in 1 l ethanol (tech. qual., 98 %). When all surface samples and the biological fraction for sieving were taken, the side of the box corer was opened and the sediment profile was described. Archive boxes were placed from the side as reference, 10 cm^3 syringes were placed every 3 cm from top to bottom for foraminiferal studies, and at least one liner of 10 cm diameter were excavated for future studies (grain-size, foraminifera, etc.). On these liners pore water samples were taken afterwards in the geolab (Chapter 1.4.6.2). The remaining sediment and/or coral rubble were washed through a set of sieves with mesh size of 10, 0.5 and 0.25 mm to collect macrofossils.

In total, 18 box corer stations were performed, of which 12 successfully recovered surface sediments or some corals (Tables 7 and 8 (Appendix)). Maximum penetration of 34 cm could be reached for BC 649-1 in 1100 m water depth, while the rest reached ~20 cm or less in shallower water depths and along steeper seafloor morphologies. Detailed box corer descriptions and sample lists are given in 5.5.2 Biological facies.

5.5.2 Biological facies (M. da Cunha, C. Orejas)

Macrofaunal assemblages
The biological material collected from box cores will contribute to gain more information on the biodiversity and distributional ecology of macroinvertebrates associated to cold-water corals

Sampling
Box-core samples were taken in study areas #2 (Pagès Escarpment) and #4 (St.Nazaire Canyon). Half of the box-core surface (25 cm x 50 cm) was sub-sampled for macrofauna. After removal of any corals and rocks at the surface (washed separately), the material was sliced at 0-3, 3-5, 5-10 and 10-20 cm and the sediments were washed through 1, 0.5 and 0.25 mm mesh sieves. In some cases the presence of corals prevented the slicing of the sample and therefore only two samples were considered: surface (approx. 0-5 cm) and deeper sediments (from approx. 5 cm up to 15 cm deep). The fauna removed from the surface and the different fractions of the washed sediments were kept in 95% ethanol to be sorted later. Biological

specimens will be curated and deposited in the Biological Research Collection of the University of Aveiro for further ecologic, taxonomic, morphologic and genetic studies

Preliminary results

The results on the macrofaunal assemblages obtained during the cruise consist on preliminary lists of macroinvertebrate organisms compiled in Table 8 (Appendix). A preliminary description of the samples based on the material partially processed on board is given below. These lists will be further detailed after a thorough taxonomic and molecular study of the samples.

Area #2 - the Pagès Escarpment: five box-core samples were taken from the SW flank of the Pagès Escarpment at the base of a steep cliff where *Callogorgia*-like colonies were observed during OFOS operations (Sts. 602 and 603; depth: approx. 600 m) and slightly deeper in a sedimentary area dominated by sea-feathers (Sts. 600, 601 and 604; depth: 630-670 m). Some crustaceans (euphausids and amphipods) were recovered from the filtering of the water covering the sediments and a few ophiuroids were picked from the surface of the sample. Other fauna observed during the sieving of the sediments consisted mostly of polychaetes and a few small bivalves.

Area #4 – St. Nazaire Canyon: macrofaunal samples were taken from a series of four box-cores (Sts. 649 and 651-653) collected along a depth gradient from 750 to 1100 m. Most samples yielded a large amount of dead scleractinian coral framework. Sessile fauna recovered mainly from the dead corals consisted sponges (mainly encrusting forms), hydrozoans, a variety of anthozoans including different species of actiniarians, anthipatharians and soft corals, cirripeds, bivalves, crinoids and abundant bryozoans. Mobile fauna included numerous ophiuroids (several species), and polychaetes (*Eunicidae* and others), polyplacophorans, gastropods, squat lobsters (*Munida* sp.) and various shrimps (*Alpheidae* and others).

5.5.3 DNA sampling (R. Becheler)

Context and objectives

Lophelia pertusa and *Madrepora oculata* are the two main cold-water corals in the Gulf of Biscay, and structuring key marine ecosystems, with high level of species diversity and abundance, in particular for species of commercial interest. The bottom trawling is the current major cause of destruction of these habitats, potentially leading to a genetic impoverishment (genetic drift, shift in gene flow...), and thus a decreased adaptive capacity of populations facing environmental variations.

Assessing the genetic impacts of human activities on cold-water coral populations is one of the five objectives of the "populations genetics" workpackage of the Coralfish project, and constitutes a central question of my phD.

The two species on which we are focusing are *Lophelia pertusa* and *Madrepora oculata*.

The objectives for this cruise were:

- evaluating the presence/absence of these species in the areas surveyed during the cruise M84/5.

- sampling *Madrepora oculata* individuals from different locations to: 1. test the microsatellite bank developed by Morrison et al. (Leetown Science Center, United States). 2. evaluate the level genetic diversity and connectivity among populations.
- sampling *Lophelia pertusa* individuals from different locations to complete an existing database (microstallites are already available), in order to assess genetic diversity of populations and their level of connectivity.
- Sampling *Eunice norvegica*, the CWC-associated polychaete worm, for which microsatellite primers were recently designed (Arnaud-Haond, personal communication).
- Sampling different scleractinian species, for the project "Tree of Life" on one hand, and in order to constitute a collection of samples for future phylogenetic studies on the other hand.

Sampling areas

The four explored areas are located along the iberic west coast, and in the Gulf of Biscay (Figure 1). This corresponds to the MOW, constituting the potential way of connectivity between mediterranean and Atlantic cold-water coral populations. Topographic features of each area were studied using Multibeam Sounder, allowing scientists to determine the zones potentially supporting coral reefs. The second step was the video survey of these zones, using the OFOS-system. Along a previously determined transect, each interesting point was georeferenced for future sampling.

Sampling strategy

Once potentially suitable zone were determined, sampling equipment was operated. Living sampling units of cold-water corals were taken using: the TV-grab and the box-core, recovering the upper layer of the sediment, including organisms of the surface. Several replicates were carried out, in order to collect a satisfying number of sampling units, for genetic analyses -for statistical relevance. For each replicate, geographical coordinates were noticed, allowing to estimate the distance between each sampling point. These distances are important data, aiming to study the spatial genetic structure, at the scale of the reef. On these points, all scleractinian colonies were recovered for population genetics studies (*Lophelia pertusa, Madrepora oculata*), or for barcoding (other scleractinian species, project Tree of Life).

Processing of samples on board

On board, each sample was immediatly proceed, for DNA extraction (CTAB method). For each colony, one or two polyps were cut, and put on a clean plate, to recover living tissue containing DNA, avoiding contamination. Using forceps, the skeleton was gently broken, and fresh tissue put in an Eppendorf tube, in which 480 µL of CTAB-Buffer and 20 µL of proteinase K were added. This extraction-mix was placed on a heating bath (58°C, correspond to the activation temperature of the proteinase) overnigth. The remaining of the sample was stored in ethanol (80%) and frozen at -80°C.

An overview on the collection of samples for DNA analysis is given in Table 9 (Appendix):

Report per species

Madrepora oculata: the collected samples will allow testing the microsatellite bank, in order to visualize the genetic variability of these markers. This is the preliminary step before classical populations genetic studies. When suitable markers identified, these samples will be included for study of the large-scale connectivity.

Lophelia pertusa: these samples will be added to the current Ifremer collection, in order to perform genetic analyses required by the fourth objective of the genetic workpackage of Coralfish

Other scleractinian species: the DNA was extracted for barcoding, using the relevant genetic marker (CO1 or ITS).

Data acquisition and valorization
Three main panels will be explored with these data:

- The genetic structure and connectivity among CWC populations (microsatellites)
- The genetic impact of bottom trawling on genetic and clonal composition of corals populations (microsatellites)
- The past connectivity between Mediterranean and atlantic populations, for *Lophelia pertusa, Madrepora oculata and Eunice norvegica* (ITS and CO1)

Microsatellite data
This kind of markers is highly variable, both in space and time, due to a high mutation rate. Microsatellites are very usefull and used in population genetic because this high variability leads to a spatio-temporal resolution, allowing the discrimination of clonal lineages for partially clonal species (such as CWC), which is the first step before classical genetic analyses. After DNA extraction, PCR are carried out, using nine pairs of primers for *Lophelia* and *Eunice*, to amplificate nine loci PCR products were visualized using an ABI-3100 FNVR automated sequencer (Applied Biosystems) and scored using STRand software (http://www.vgl.ucdavis.edu/informatics/strand.php). A double blind reading was made by two different users and gels were re-scored when discrepancies were recorded.

The genetic structure of populations (assessed with the fixation index Fst) allows inferring the gene flow among populations, and identifying source and sink reefs. This is crucial information to design marine protected areas.

The genetic diversity (assessed with two main metrics, heterozygosity Ho and allelic richness Â) is another key information, as this level of biodiversity is potentially reflecting the level of adaptability of populations facing environmental fluctuations.
This thematic are largely included in the need of informations for the conservations of these deep ecosystems

ITS and CO1 data
Theses markers are from far less variable than microsatellites, but are also usefull for phylogenetic and phylogeographic studies. As a hypothesis, De Mol et al (2005) have proposed the Mediterranean Sea as the origin of Atlantic CWC populations. Using these markers on our sample collection –including the three co-occuring species, *L. pertusa*, *M. oculata* and *E. norvegica*), we aim to test this hypothesis. We are currently amplifying ITS (1200 base-pairs for corals and 1000 bp for *Eunice*) and CO1 for *Eunice* only (800 bp), as

mitochondrial DNA of coral totally unvariable. PCR products are sequenced and haplotypic distinction performed using Geneious (Drummond A.J. et al., 2011).

Fig. 10 Mugia Canyon. This shows the TV-grab sample, containing colonies of *Solenosmilia sp.* (for barcoding) and bamboo coral.

Fig. 11 Cap Breton Canyon. This area was the shallower one explored during the cruise. Here is a beautiful colony of *Dendrophyllia cornigera*, a scleractinian species with big polyps (for barcoding).

Fig. 12 Canyon of Saint-Nazaire. Important colonies of *Madrepora oculata* were sampled (here using the Box-corer). In this area, some little samples of *Lophelia pertusa* and small young recruits of *Desmophyllum* sp. were found.

Fig. 13 Details of a beautiful colony of *Madrepora oculata*. Skeleton outgrowth could be seen, revealing the presence of the associated polychaete worm *Eunice norvegica*.

5.6 Sediment coring

5.6.1 Coring devices and operations (A. Rüggeberg)

We used a conventional gravity corer with tube lengths of 3 and 6 m and a head-weight of 1.5 tons to retrieve longer sediment sequences, to reconstruct cold-water coral reef development and growth at the Pagès Escarpment and in the St. Nazaire Canyon system. Eleven gravity cores with a total length of 27.13 m were recovered from 12 stations with only one failed station (Tab. 1). At the Pagès Escarpment two cores with 227 and 282 cm were recovered at ~970 m water depth. The nine other cores could be retrieved along a depth transect between 500 and 1100 m at selected sites in the St. Nazaire Canyon (Table 1). We followed the same procedure as for the box corers to select possible target sites during previous OFOS tracks. The gravity corer was also equipped with a POSIDONIA transponder mounted 50 m above the weight on the cable to make positioning on the ground as precise as possible. Sampling occurred within ±3-4 m of the coordinates selected during the OFOS video tracks, which were likewise logged with the POSIDONIA-system. Once the gravity corer was on deck, the core catcher was removed and sampled, and the PVC-liner was cut into 1-metre sections, labeled and stored under cool (4°C) conditions.

Table 1: Gravity Corer (GC) stations during cruise M84/5.

M84/5-	Location	Latitude [N]	Longitude [W]	Depth [m]	Core [m]	Recovery (cm)
621-1	Pagès Escarpment	44° 01.79'	005° 40.96'	969	3	227
622-1	Pagès Escarpment	44° 01.77'	005° 40.87'	947	3	–
623-1	Pagès Escarpment	44° 01.81'	005° 40.95'	979	3	282
668-1	St. Nazaire Canyon	46° 14.24'	004° 18.63'	539	3	266
669-1	St. Nazaire Canyon	46° 14.13'	004° 19.27'	670	3	285
670-1	St. Nazaire Canyon	46° 14.24'	004° 19.60'	747	3	78.5
671-1	St. Nazaire Canyon	46° 14.24'	004° 19.60'	752	3	50.5
672-1	St. Nazaire Canyon	46° 14.10'	004° 20.28'	979	3	291
673-1	St. Nazaire Canyon	46° 14.01'	004° 20.55'	1118	3	289
674-1	St. Nazaire Canyon	46° 14.29'	004° 18.39'	515	3	199
675-1	St. Nazaire Canyon	46° 14.25'	004° 18.62'	538	6	346.5
676-1	St. Nazaire Canyon	46° 14.11'	004° 20.28'	980	6	398.5

5.6.2 Pore water analysis (A. De Cleyn, H. Hamaekers, A. Foubert)

Pore water analysis has been carried out to reveal the influence of early diagenetic processes on cold-water carbonate mounds. $O_{2\,diss}$, salinity, pH, TA measurements have been carried out on board. SO_4^{2-}, Cl^-, H_2S, Ca^{2+}, Mg^{2+}, Sr^{2+}, Fe_{diss}, Mn_{diss} and DIC will be measured afterwards in the lab of the Earth & Environmental Sciences Department of the KU Leuven.

Pore water sampling occurred immediately when the cores were on board (Fig. 5.4.6.2a).

4 mm holes were drilled in the PVC core liners with a sample resolution of 5, 10 or 20 cm, with a higher resolution at the upper 1 to 2 m sections and a lower resolution in the deeper sections. Rhizon CSS-F 5cm (2,5 ∅, pore size 0,15 µm, PE/PVC tubing 12 cm, Rhizosphere Research Products (RRP)) and Rhizon SMS 10 cm (2,5 ∅, pore size 0,15 µm, SS wire, PE/PVC tubing 12 cm, RRP) have been used for sampling, in combination with sterile, plastic 10 ml Luer Lock syringes (RRP). Approximately 8 – 10 ml was collected in the syringes and they were stored at 4°C until splitting. Four splits were made of every sample (Figure 14).

Fig. 14 Pore water sampling from 1 m cores using Rhizon 5 cm samplers connected to 10 ml Luer Lock syringes.

Table 2: Overview of splits. Only split D was measured on board of the vessel.

Split	Volume (ml)	Fixation	Storage	To be measured
A	1 – 1,5 ml	ZnAc (2% w/v)	Frozen	SO_4^{2-}, Cl^-, H_2S
B	2 – 4 ml	1 – 2% HNO_3	4°C	Ca^{2+}, Mg^{2+}, Sr^{2+}, Fe_{diss}, Mn_{diss}
C	1,5 ml	$HgCl_2$	4°C	DIC
D	1,5 – 4 ml	/	4°C	$O_{2\,diss}$, salinity, pH, TA

During the cruise, pore water samples were taken from:

- 2 video Grabs: M84/5 -563 and -619
- 6 box Cores: M84/5 -600, -601, -602, -603, -604 and -649
- 5 gravity Cores: M84/5 -621, -668, -670, -673 and -676

Dissolved O_2 was measured with an oxygen electrode (BNC, 182623, Eijkelkamp) and multi-parameter analyzer (18.28, Eijkelkamp). During calibration to air and a zero oxygen solution, approximate salinity (g/L) and air pressure (hPa) values were entered and both the concentration of dissolved O_2 and degree of O_2 saturation were measured. Temperature was recorded as well.

Salinity was also measured with a conductivity electrode. KCl 0,01M was used for calibration and TDS, salinity (g/L) and conductivity (S/cm) were measured. Due to problems with the calibration of the electrode, measuring of the salinity of the samples of gravity cores # 668, # 670, # 673, # 676 was not possible on board.

The seawater alkalinity is determined by pH titration. After calibration of the pH electrode, the pH was measured (initial pH). 100 µl HCl 0,01M was added to the sample and the pH was measured again. This step is repeated until a final pH value between 3.5 and 3.9 is reached. The closer to the titration point, the smaller the volumes of HCl added in each step become. The initial and final pH values and the added volume of HCl 0,01M are necessary to calculate the alkalinity through the following formula (Grasshoff et al., 1983, Kolling et al., 2000).

The results of these measurements can be found in the appendix. pH values vary between 6.6 and 7.5. The difference between the minimum and maximum values is about 0.2 in the smaller cores and 0.6 in the largest cores. Although in BC #649 (35 cm), the difference is 0.8. In #670 two zones with lower pH values found (17,5 – 32,5 cm, 42,5 – 67,5 cm). In #673, the values increase slowly from 7.2 to 7.4, but there is a peak of 7.1 around 27,5 cm. The upper 130 cm of #676 fluctuate around 7.4 and from 130 cm onwards, they jump to 7.6.

The alkalinity of the shorter cores is between 1,7 – 3,3 mmol/L. The alkalinity of #670, #673 and #668 increases with depth from ± 2 – 5,5 mmol/L and in #676 from 2 – 12 mmol/L. The O_2 saturation percentages range for the shorter cores between 30 – 60 % and for the longer gravity cores between 40 – 85%. Core #676 has one low value of 26,5% at a depth of 62,5 cm. The salinity ranges between 5 – 25 mg/L.

5.6.3 Description and planned activities (A. Rüggeberg, C. Stalder)

Opening, description and sampling on board was dismissed, as Computer Tomography (CT) imaging and core logging will be done onshore in home laboratories prior to core opening. First, CT scans will be performed at UZ Leuven campus Gasthuisberg (university hospital) in Leuven (Belgium) in September 2011 to provide further insight into the abundance and orientation of coral fragments, the quantification of coral carbonate, and the glacial-interglacial transition below the coral cover. The core sampling party is planned for October 2011 in the laboratories at IFM-GEOMAR, Kiel. Here, the cores will be frozen at –20°C, cut with a saw into a working and an archive half. The archive half will be used for core description, core photography, color and XRF scanning. The work half will be sampled with 10 cm^3 syringes at 5 cm intervals for paleoclimatic and -oceanographic studies, benthic and planktonic foraminiferal assemblages, including grain size analysis.

The sediment cores fill an important gap between studied cold-water coral mounds in the Porcupine Seabight and in the Gulf of Cadiz. Under the auspice of the EU project HERMIONE and several national projects, an international group leading cold-water coral and carbonate mound research in Europe will work on the recovered sediment cores. ***KU Leuven (Belgium)*** will focus on the early diagenesis in cold-water coral settings, the geochemistry on pore water, and carbonate budget calculations using the 3-D computed tomography scan. ***Université Fribourg (Switzerland)*** will perform ^{14}C dates using mono-specific samples of foraminifera to refine the chronostratigraphy. Furthermore, the benthic (and planktonic) foraminiferal assemblages will be investigated to interpret the paleoecology. ***Ghent University (Belgium)*** is interested to do palaeocurrent analysis on the gravity cores focussing on sedimentary canyon processes with respect to better define oyster and coral habitats. The geochemistry on cold-water corals comprises a wide field with different analytical methods and as well as isotopic or elemental systems. Here, existing collaborations between ***IFM-GEOMAR Kiel***, ***GZN Erlangen***, ***Ghent Univerity*** and ***MARUM Bremen*** will share the same sample material (bamboo and stone corals, deep-sea oysters, sediments) to determine Nd-isotopes, Mg-isotopes, stable Sr-, O-, C-isotopes, clumped isotopes, B-isotopes, and trace-element concentrations using LA-ICP-MS, Microprobe, and solution-MC-ICP-MS. Dating of corals using Th/U isotope systematics will be conducted by ***IFM-GEOMAR Kiel***, and subsequent ^{14}C-dating is intended in collaboration with ***GZN Erlangen***. First results of this cruise and gravity cores were presented at the 5th International Symposium on Deep-Sea Corals April 2012 in Amsterdam.

5.7 TV grab

5.7.1 Device and operation (V. Liebetrau)

During various OFOS tracks different types of cold-water coral settings were observed and potential sites defined for the recovery of large samples with a video guided hydraulic grab (VGHG).

This kind of grab (Figure 15), made out of approx. 2 t of steel, was originally designed to dig into soft sediments and very successful used for the recovery of Fe-Mn-concretions and gas hydrates from the seafloor. This tool is characterized by a penetration depth of 0.5 to 1 m, a sample volume of around 1 m^3 and a deployment depth of up to 6000 m.

The integrated online video system allows a detailed search for suitable targets and sampling documentation by a straight vertical seafloor observation through the open jaws of the grab. Due to the fact of a closing pressure of around 5 t of the actual system hosted by GEOMAR, provided by the integrated battery-driven hydraulic system, the claws could hold and recover samples even larger than the volume of the closed grab. The new design of a less vertical extension at a wider foot print supports sampling on slope positions, even tolerating slight tilt. The successful deployment on large rock samples or reef fragments depends strongly on the coordination of ship positioning, winch control and the timing of jaw closure.

A final challenge is getting the recovered sample on deck when its weight is almost doubled by leaving the water column. Often several tries are necessary for successful sampling of hard ground sites.

Nevertheless, this technique provides well documented, unique large samples for detailed profile studies through the uppermost sediments and reef structures, often including the hard-substrate of primary cold water coral settlement underneath.

Based on this material ex-situ vertical profiles enable the high resolution sub-sampling and reconstruction of latest reef formation sequences and detailed insights into growth structures and calcification processes in one sample. Therefore, this approach provides an important extension of gravity coring towards undestroyed surface sampling.

Furthermore, the recovery of big bolder and blocks includes quiet often the sampling of whole habitats and supports biological studies by retrieving typical seafloor faunal communities. The sampling is not as undisturbed as provided by box-coring, but an important additional option for sedimentologists and biologists by being more selective and targeted due to the video control and documentation. Already by the potential sample size and weight the video guided grab provides an important addition and due to the video control partially an alternative to ROV (remote operating vehicle) and submersible sampling approaches.

However, as shown by the example in Figure 16 the VGHG-system was deployed successfully on cruise M84/5. The list of deployments is implemented in the station list and the recovered samples are still under investigation for biology, geochemistry, isotope geochemistry and chronology. On this cruise all VGHG recovered sediments have been sieved and washed for their paleontological inventory.

Fig. 15 The GEOMAR video guided hydraulic grab (VGHG) deployed from RV METEOR during cruise M84/5

Fig. 16 Example for precise, video controlled and well documented sampling of cold-water coral sites by recovery of complete and representative habitat fragments, often providing combined ex-situ subsampling of the sediment-hardground-carbonate-biology systematics.

5.7.2 Biological samples (M. da Cunha, L. Génio)

Macrofaunal assemblages

The biological material collected from TV-grabs will contribute to attain the following specific objectives:

1) to gain more information on the biodiversity and distributional ecology of macroinvertebrates associated to cold-water corals

2) to determine the trophic status of abundant species using stable isotope analyses ($\delta^{13}C$, $\delta^{15}N$)

3) to determine the site-specific elemental signatures of bivalve shells (e.g. ^{48}Ca, ^{55}Mn, ^{59}Co, ^{88}Sr, ^{138}Ba, ^{208}Pb, and ^{238}U) using LA-ICPMS (inductively coupled plasma-mass spectrometry with laser ablation).

Sampling

TV- grab samples were taken in four study areas (Mugia Canyon, Pagès Escarpment; Cap Breton Canyon and St. Nazaire Canyon). Whenever possible an area of approx. 30 cm x 4 0cm was sub-sampled for macrofauna and two layers were considered: surface (approx. 0-5 cm) and deeper sediments (from approx. 5 cm up to 15 cm deep). The corals, rocks and sediments were washed through 1, 0.5 and 0.25 mm mesh sieves. The fauna removed from the surface and the two ractions of the washed sediments were kept in 95% ethanol to be sorted later. Biological specimens will be curated and deposited in the Biological Research Collection of the University of Aveiro (Department of Biology) for further ecologic, taxonomic, morphologic and genetic studies.

Analyses of the natural, stable isotopic composition ($\delta^{13}C$, $\delta^{15}N$) of the sediment and tissues of selected species will be carried out in the specimens collected from several stations. Some bivalve specimens will also be used for elemental fingerprinting studies of the larval shell. Specimens for stable isotope analysis and elemental fingerprinting were selected, carefully washed in cold seawater and deep-frozen (-80ºC).

Preliminary results

The results on the macrofaunal assemblages obtained during the cruise consist on preliminary lists of macroinvertebrate organisms compiled in Table A2 (Appendix). A preliminary description of the samples based on the material partially processed on board is given below. These lists will be further detailed after a thorough taxonomic and molecular study of the samples.

Area #1 – the Mugia Canyon: macrofaunal samples were taken from St.562-TVG#1 and St. 563-TVG#2. The samples were collected from an area with scleractinean corals observed during OFOS observations (approx. 1830-1890 2<m depth). The samples yielded both live and dead scleractinean framework (*Solenosmillia* sp. and *Elanopsammia* sp.). Sessile fauna recovered mainly from the dead corals consisted of sponges (mainly incrusting forms), hydrozoans, actiniarians, cirripeds and bryozoans. Mobile fauna included numerous ophiuroids (several species), but also a few specimens of Eunice (possibly *E. norvegica*) and other polychaetes, squat lobsters (*Munida* sp.) and gastropods.
Some specimens of ophiuroids, actiniarians, cirripeds, *Munida* sp. and *Eunice* sp. were prepared for stable isotope analysis

Area #2 - the Pagès Escarpment: A TV-grab sample (St. 617; depth: 1238 m) collected from the northern flank of the Pagès Canyon in an area of octocoral gardens observed during OFOS#4 yielded only a small rock with a few sponges, anthozoans, bryozoans, polychaetes and ophiuroids. Another TV-grab sample (St. 619; depth: 965 m) was collected from the base of a rocky outcrop north of Pagès Escarpment. The sandy sediments contained abundant coral rubble and brachiopod shells. The organisms observed during sieving included mostly ophiuroids, polychaetes and small crustaceans (isopods and amphiods), a few molluscs and one echinoid (*Brissopsis* sp.).

Area #3 – Cap Breton Canyon: macrofaunal samples were taken from five TV-grab samples (Sts.632-633, and 677-679). The samples were collected at the head of the Canyon from an area with *Dendrophyllia cornigera* colonies attached to rock boulders (approx. 1830-1890 m depth). Most samples yielded live scleractinian colonies (*D. cornigera*) and a high diversity of macrofaunal organisms. Sessile fauna recovered consisted of various species of sponges (incrusting and others), hydrozoans, actiniarian and stoloniferan anthozoans, bivalves, brachiopods and bryozoans. Mobile fauna included numerous ophiuroids (several species), a variety of crabs, hermit crabs and shrimps, and also polychaetes, polyplacophorans, and gastropods.
An additional TV-grab taken down-slope at about 2360 m (St. 636 TVG#10) did not yield any conspicuous organisms.
Some specimens of sponges, hermit crabs and brachiopods were prepared for stable isotope analysis

Area #4 – St. Nazaire Canyon: macrofaunal samples were taken from a series of six TV-grab samples (Sts. 643-644 and 697-690) collected along a depth gradient from 570 to 850 m. Most samples yielded a large amount of dead scleractinian coral framework but living colonies of *Madrepora oculata* and *Lophelia pertusa* were also collected mostly within the depth range of 700-850 m. Sessile fauna recovered mainly from the dead corals consisted of sponges (mainly incrusting forms), hydrozoans, a variety of anthozoans including different species of actiniarians, anthipatharians and soft corals, cirripeds, bivalves, crinoids and abundant bryozoans. Mobile fauna included numerous ophiuroids (several species), and polychaetes (Eunicidae and others), polyplacophorans, gastropods, squat lobsters (*Munida* sp.) and various shrimps (Alpheidae and others).

Some specimens of *Munida* sp., alpheid shrimps, Arcidae bivalves and brachiopods were prepared for stable isotope analysis. The shells of the bivalves will also be used for elemental fingerprinting analysis.

5.8 Onboard analyses

5.8.1 Seawater oxygen analysis (Thorsten Garlichs)

The measurements of the CTD oxygen sensors were validated on board with water samples by iodometric WINKLER-Titration after Graßhoff (1983). The measurements were performed on 11 of 49 CTD casts. Water samples were taken on upcast only. When a designated sampler bottle was released, the oxygen sensor readings were noted and later compared to the titration results. Immediately after collection, the water samples were filled into volume-calibrated WINKLER-bottles. Two parallel samples were taken, and we paid particular attention of not having any air in the WINKLER -bottles. The oxygen was fixed with 0.5 cm^3 manganese-II-chloride and 0.5 cm^3 alkaline iodide. Then the bottles were shaken and stored cool for several hours. Before titration, the manganese hydroxide was solved with 1 cm^3 H_2SO_4 (9M) and the bottles were shaken again. The samples were each transferred into a 250 ml beaker, where they were titrated with 0.02 M sodium thiosulfate until the solution turned into yellow. After adding 1 cm^3 of zinc iodide solution, the titration was continued until the blue colour of the sample disappeared. The factor of the thiosulfate solution was determined with a standard, which was performed after every CTD station. The oxygen content was calculated from the thiosulfate consumption by using the following standard formula:

$$O_2 = (a * f * 0.112 * 103) / (b-1) \text{ [ml/l]}$$

where a is the consumption of thiosulfate solution [ml], b is the volume of the WINKLER bottle [ml], and f is the factor of the thiosulfate solution.

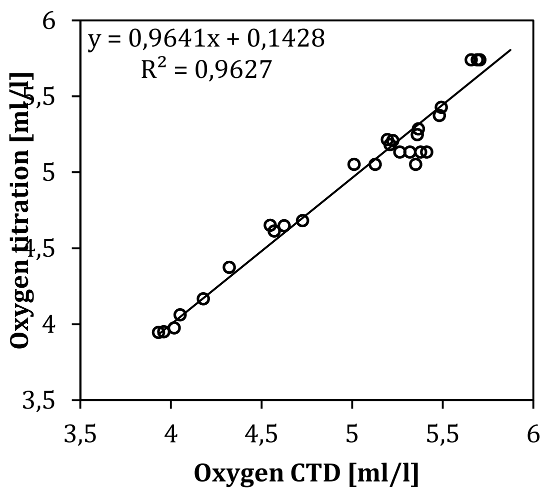

Fig. 15 Comparison between dissolved oxygen of CTD measurements and Winkler-Titration for all measurements during cruise M 84/5. The regression equation was used to calibrate the CTD data.

A total number of 56 titrations were performed. The oxygen contents range from 3.93 to 5.87 ml/l. The differences between parallel measurements range from 0.0003 to 0.108 ml/l, on average 0.12 ml/l. The accuracy of our titrations is considered as 0.5%, which is in the range of values reported in the literature (0.06 to 0.89 %; Furuya and Harada, 1995). The oxygen sensors of the CTD transmitted slightly different oxygen contents at depth. The comparison of sensor readings and WINKLER-titration results revealed that the sensor indicated different oxygen contents with a range from 0.01 ml/l to 0.30 ml/l, on average 0.09. Therefore, we considered sensor as reliable and corrected the measured values according to the regression equation (Fig. 15).

6 Ship's meteorological station (A. Raecke)

RV METEOR left the port of Vigo on the 31th of May at 07 UTC. The weather was cloudy with a northerly wind of strength 3 Beaufort.
The focus of the expedition between Vigo and Brest (France) was to investigate the occurrence and distribution of living and fossil cold-water corals and their biological, chemical and hydrographic control factors.

An Azoric high to the northwest of the cruising area was extending a ridge to the west of the Iberian Peninsula while a low was located over the Iberian Peninsula. From the very beginning of the cruise these pattern caused stormy conditions and a high sea state.
During the first night close to Vigo on the open sea a sea of 4 m and winds of 8 Beaufort were experienced.

Due to the persistent strong pressure gradient around Cape Finisterre, the wind slowed only slightly to 6 to 7 Beaufort. However, at first the swell was strong and abated slowly. So until the 4th of June, METEOR experienced a wind sea of 2 to 3 m within sunny weather.
Since METEOR left this area of work to the southern Bay of Biscay the previously difficult working conditions improved. However, fog banks disturbed the mainly good visibility.
Within the harbor area of La Coruna on the 04th a land / sea breeze set in with sometimes winds freshening to force 7 Beaufort. However, within the shelter of the land only winds of strength 5 were experienced. Warm continental air brought a temperature increase to about 24 degree with the highest temperature during the cruise.

In the second working area from the 05th low pressure on the Iberian Peninsula deepened while a ridge of the Azorean high retreated. The pressure gradient weakened causing the seastate to drop to about 2 m with at first northerly winds then westerly winds. From the 06th occasional rainfall was experienced. From the 10th another ridge extended into the cruising area while a weak low pressure system caused overcast conditions with a just a little precipitation.

Off the coast of the Basque region (third working area) winds of 3 Beaufort were experienced with a sea about 1 m having no impact on the scientific work.
For the final working area one week ahead a storm low was likely to develop. Therefore the area was reached earlier to avoid any hassles from the expected storm. The Basque area was left on the 12th accompanied by showers and thunderstorms.

From the 13th to the 16th METEOR benefitted from the achieved time gap between two low pressure systems. Seas of about 2 m within mostly SW'ly winds about 4 to 5 Beaufort were experienced causing no worries on the working conditions. To avoid the expected storm

METEOR cruised again into the working area off the Basque coast. In this area further scientific work was conducted under better weather conditions.

On the 17th, the sea reached only 2 to 2.5 m with a wind shifting from the SE to the NW with a strength of 4 Beaufort. On the 18th the swell of the forecasted storm low about 4 m reached the working area with winds of 5 to 6 Beaufort. The use of the working gear was adjusted according the weather conditions. Later the Azorean ridge strengthened again in the southern Bay of Biscay.

The transit back to the area close to Brest was adjusted according to the weather not bringing any hassles to the work. Within a swell / sea about 2.5 m and wind speeds 5 to 6 Beaufort the scientific work has been completed successfully on the 20th. Within a SW wind around 5 Beaufort and a sea of 2m the RV METEOR reached the harbor of Brest on the 21th of June.

7 Station list M84/5 (Moritz Zieringer)

Table 3: Station list

station M84/5	working area	gear	date	time (UTC)	depth (m)	latitude (N)	longitude (W)
M556	Cabo Corubedo	sound velocity	5/31/11	11:34	97	43.059	9.200
M557	Mugia Canyon	sound velocity	5/31/11	21:30	1603	43.919	9.687
M558	Mugia Canyon	MB/Parasound	6/1/11	16:02	812	43.907	9.615
M559	Mugia Canyon	CTD-Ro	6/2/11	6:22	2344	43.010	9.719
M560	Mugia Canyon	CTD-Ro	6/2/11	9:27	2350	43.010	9.718
M561	Mugia Canyon	OFOS	6/2/11	11:02	1835	43.979	9.670
M562	Mugia Canyon	TVG	6/3/11	5:40	1835	43.980	9.670
M563	Mugia Canyon	TVG	6/3/11	8:40	1902	43.968	9.676
M564	Mugia Canyon	Box Coring	6/3/11	14:30	1792	43.981	9.670
M565	Mugia Canyon	Box Coring	6/3/11	16:40	1788	43.981	9.670
M566	Mugia Canyon	Plankton Net	6/3/11	18:44	1853	43.979	9.675
M567	Mugia Canyon	Plankton Net	6/3/11	19:10	1852	43.979	9.675
M568	Mugia Canyon	CTD-Ro	6/3/11	19:56	1846	43.979	9.675
M569	Mugia Canyon	CTD-Ro	6/3/11	22:14	1851	43.979	9.675
M570	Mugia Canyon	CTD-Ro	6/3/11	23:12	1851	43.979	9.675
M571	Mugia Canyon	CTD-Ro	6/4/11	0:06	1854	43.979	9.675
M572	Mugia Canyon	CTD-Ro	6/4/11	0:59	1851	43.979	9.675
M573	Mugia Canyon	CTD-Ro	6/4/11	1:54	1852	43.979	9.675
M574	Mugia Canyon	CTD-Ro	6/4/11	2:49	1845	43.979	9.675
M575	Mugia Canyon	CTD-Ro	6/4/11	3:47	1849	43.979	9.675
M576	Pagès Escarpment	CTD-Ro	6/5/11	1:01	3295	44.264	6.001
M577	Pagès Escarpment	CTD-Ro	6/5/11	4:45	3326	44.264	6.001
M578	Pagès Escarpment	MB/Parasound	6/5/11	6:06	2837	44.226	5.991
M579	Pagès Escarpment	OFOS	6/5/11	13:46	1069	44.075	5.680
M580	Pagès Escarpment	POZ Lander	6/5/11	19:52	762	44.044	5.707
M581	Pagès Escarpment	MB/Parasound	6/5/11	22:13	1320	44.083	5.753
M582	Pagès Escarpment	CTD-Ro	6/6/11	7:18	763	44.047	5.703
M583	Pagès Escarpment	CTD-Ro	6/6/11	8:20	763	44.047	5.703
M584	Pagès Escarpment	CTD-Ro	6/6/11	9:05	763	44.047	5.703
M585	Pagès Escarpment	CTD-Ro	6/6/11	9:58	764	44.047	5.703
M586	Pagès Escarpment	CTD-Ro	6/6/11	10:42	764	44.047	5.703
M587	Pagès Escarpment	CTD-Ro	6/6/11	11:42	763	44.047	5.703
M588	Pagès Escarpment	CTD-Ro	6/6/11	12:25	763	44.047	5.703
M589	Pagès Escarpment	CTD-Ro	6/6/11	13:11	764	44.047	5.703
M590	Pagès Escarpment	OFOS	6/6/11	14:43	354	44.998	5.693
M591	Pagès Escarpment	CTD-Ro	6/7/11	0:07	762	44.046	5.703
M592	Pagès Escarpment	CTD-Ro	6/7/11	0:53	761	44.047	5.703
M593	Pagès Escarpment	CTD-Ro	6/7/11	1:39	763	44.047	5.703

M594	Pagès Escarpment	CTD-Ro	6/7/11	2:19	761	44.046	5.703
M595	Pagès Escarpment	CTD-Ro	6/7/11	3:04	761	44.046	5.703
M596	Pagès Escarpment	CTD-Ro	6/7/11	3:55	764	44.047	5.703
M597	Pagès Escarpment	CTD-Ro	6/7/11	4:49	763	44.047	5.703
M598	Pagès Escarpment	CTD-Ro	6/7/11	5:41	764	44.047	5.703
M599	Pagès Escarpment	Plankton Net	6/7/11	7:57	667	44.970	5.725
M600	Pagès Escarpment	Box Coring	6/7/11	8:15	666	44.970	5.725
M601	Pagès Escarpment	Box Coring	6/7/11	9:47	668	44.970	5.725
M602	Pagès Escarpment	Box Coring	6/7/11	11:05	594	44.972	5.721
M603	Pagès Escarpment	Box Coring	6/7/11	12:25	582	44.972	5.720
M604	Pagès Escarpment	Box Coring	6/7/11	13:40	634	44.977	5.727
M605	Pagès Escarpment	Box Coring	6/7/11	14:59	348	44.977	5.711
M606	Pagès Escarpment	Box Coring	6/7/11	15:45	350	44.977	5.711
M607	Pagès Escarpment	Box Coring	6/7/11	16:50	353	44.998	5.693
M608	Pagès Escarpment	MB/Parasound	6/7/11	19:29	2257	44.125	5.617
M609	Pagès Escarpment	Plankton Net	6/8/11	5:37	565	44.915	5.769
M610	Pagès Escarpment	OFOS	6/8/11	8:40	1251	44.043	5.837
M611	Pagès Escarpment	CTD-Ro	6/8/11	15:58	1996	44.996	5.902
M612	Pagès Escarpment	CTD-Ro	6/8/11	19:04	1252	44.043	5.837
M613	Pagès Escarpment	OFOS	6/8/11	21:33	767	44.048	5.707
M614	Pagès Escarpment	OFOS	6/9/11	0:04	813	44.052	5.704
M615	Pagès Escarpment	CTD-Ro	6/9/11	2:14	620	44.977	5.726
M616	Pagès Escarpment	MB/Parasound	6/9/11	4:18	922	44.880	6.008
M617	Pagès Escarpment	TVG	6/9/11	6:15	1234	44.041	5.840
M618	Pagès Escarpment	TVG	6/9/11	9:30	811	44.055	5.680
M619	Pagès Escarpment	TVG	6/9/11	11:17	813	44.055	5.683
M620	Pagès Escarpment	POZ Lander	6/9/11	13:55	780	44.047	5.707
M621	Pagès Escarpment	Gravity Coring	6/9/11	16:43	899	44.060	5.683
M622	Pagès Escarpment	Gravity Coring	6/9/11	18:30	898	44.059	5.681
M623	Pagès Escarpment	Gravity Coring	6/9/11	19:43	899	44.060	5.682
M624	Cap Breton	CTD-Ro	6/10/11	10:54	2384	44.467	2.616
M625	Cap Breton	CTD-Ro	6/10/11	13:40	2365	44.467	2.616
M626	Cap Breton	MB/Parasound	6/10/11	15:16	2061	44.470	2.650
M627	Cap Breton	OFOS	6/11/11	9:07	717	44.281	2.633
M628	Cap Breton	OFOS	6/11/11	12:42	476	44.242	2.705
M629	Cap Breton	MB/Parasound	6/11/11	17:09	306	44.168	2.767
M630	Cap Breton						
M631	Cap Breton	TVG	6/12/11	10:19	238	43.529	2.758
M632	Cap Breton	TVG	6/12/11	10:52	240	43.529	2.758
M633	Cap Breton	TVG	6/12/11	11:41	221	43.529	2.760
M634	Cap Breton	TVG	6/12/11	13:01	238	43.529	2.759
M635	Cap Breton	CTD-Ro	6/12/11	13:43	230	43.528	2.756
M636	Cap Breton	TVG	6/12/11	15:30	2366	43.733	2.616
M637	Cap Breton	Plankton Net	6/12/11	18:03	2366	43.733	2.616
M638	St. Nazaire Canyon	CTD-Ro	6/13/11	10:34	2057	46.167	4.467
M639	St. Nazaire Canyon	CTD-Ro	6/13/11	12:48	2060	46.167	4.467
M640	St. Nazaire Canyon	MB/Parasound	6/13/11	13:50	2070	46.167	4.467
M641	St. Nazaire Canyon	OFOS	6/13/11	22:02	440	46.238	4.301
M642	St. Nazaire Canyon	POZ Lander	6/14/11	5:25	814	46.232	4.325
M643	St. Nazaire Canyon	TVG	6/14/11	7:50	825	46.232	4.326
M644	St. Nazaire Canyon	TVG	6/14/11	10:25	820	46.233	4.327
M645	St. Nazaire Canyon	MB/Parasound	6/14/11	15:41	1510	46.217	4.510
M646	St. Nazaire Canyon	OFOS	6/15/11	2:39	660	46.233	4.320
M647	St. Nazaire Canyon	Plankton Net	6/15/11	7:39	1348	46.230	4.352
M648	St. Nazaire Canyon	Box Coring	6/15/11	9:35	1099	46.233	4.342
M649	St. Nazaire Canyon	Box Coring	6/15/11	10:56	1105	46.233	4.342
M650	St. Nazaire Canyon	Box Coring	6/15/11	12:22	990	46.234	4.338
M651	St. Nazaire Canyon	Box Coring	6/15/11	13:40	982	46.235	4.338
M652	St. Nazaire Canyon	Box Coring	6/15/11	14:55	781	46.237	4.326
M653	St. Nazaire Canyon	Box Coring	6/15/11	16:00	753	46.237	4.326
M654	St. Nazaire Canyon	Box Coring	6/15/11	17:10	669	46.235	4.321
M655	St. Nazaire Canyon	Box Coring	6/15/11	18:40	530	46.237	4.310

M656	St. Nazaire Canyon	CTD-Ro	6/15/11	20:00	1357	46.230	4.353
M657	St. Nazaire Canyon	CTD-Ro	6/15/11	21:31	1121	46.233	4.343
M658	St. Nazaire Canyon	CTD-Ro	6/15/11	22:54	837	46.239	4.336
M659	St. Nazaire Canyon	CTD-Ro	6/15/11	23:55	650	46.236	4.319
M660	St. Nazaire Canyon	CTD-Ro	6/16/11	0:46	486	46.238	4.306
M661	St. Nazaire Canyon	CTD-Ro	6/16/11	1:37	355	46.241	4.287
M662	St. Nazaire Canyon	CTD-Ro	6/16/11	2:24	1132	46.233	4.342
M663	St. Nazaire Canyon	CTD-Ro	6/16/11	3:35	837	46.239	4.336
M664	St. Nazaire Canyon	CTD-Ro	6/16/11	4:40	646	46.235	4.319
M665	St. Nazaire Canyon	CTD-Ro	6/16/11	5:35	483	46.238	4.305
M666	St. Nazaire Canyon	CTD-Ro	6/16/11	6:20	808	46.233	4.325
M667	St. Nazaire Canyon	Plankton Net	6/16/11	7:11	845	46.231	4.326
M668	St. Nazaire Canyon	Gravity Coring	6/16/11	7:43	535	46.237	4.310
M669	St. Nazaire Canyon	Gravity Coring	6/16/11	8:44	674	46.235	4.321
M670	St. Nazaire Canyon	Gravity Coring	6/16/11	9:35	750	46.237	4.326
M671	St. Nazaire Canyon	Gravity Coring	6/16/11	10:30	752	46.237	4.327
M672	St. Nazaire Canyon	Gravity Coring	6/16/11	11:27	980	46.235	4.338
M673	St. Nazaire Canyon	Gravity Coring	6/16/11	12:37	1098	46.234	4.342
M674	St. Nazaire Canyon	Gravity Coring	6/16/11	14:03	499	46.238	4.306
M675	St. Nazaire Canyon	Gravity Coring	6/16/11	15:15	530	46.237	4.310
M676	St. Nazaire Canyon	Gravity Coring	6/16/11	16:40	988	46.235	4.338
M677	Cap Breton	TVG	6/17/11	10:30	214	43.528	2.758
M678	Cap Breton	TVG	6/17/11	11:35	215	43.528	2.758
M679	Cap Breton	TVG	6/17/11	13:21	216	43.528	2.758
M680	Cap Breton	TVG	6/17/11	15:08	173	43.530	2.763
M681	Cap Breton	OFOS	6/17/11	16:56	880	43.666	2.728
M682	Cap Breton	MB/Parasound	6/17/11	22:18	1137	43.667	2.750
M683	Cap Breton	Plankton Net	6/18/11	5:56	912	43.662	2.725
M684	Cap Breton	CTD-Ro	6/18/11	6:24	909	43.662	2.725
M685	Cap Breton	CTD-Ro	6/18/11	7:36	911	43.662	2.725
M686	Cap Breton	OFOS	6/18/11	10:02	1491	43.730	2.868
M687	St. Nazaire Canyon	TVG	6/19/11	11:25	537	46.238	4.310
M688	St. Nazaire Canyon	TVG	6/19/11	12:58	667	46.236	4.321
M689	St. Nazaire Canyon	TVG	6/19/11	14:55	752	46.237	4.326
M690	St. Nazaire Canyon	TVG	6/19/11	16:46	755	46.237	4.326
M691	St. Nazaire Canyon	MB/Parasound	6/19/11	19:16	313	46.229	4.278
M692	St. Nazaire Canyon	POZ Lander	6/20/11	6:55	760	46.234	4.322

8 Data and sample storage and access

Station list, cruise track and bathymetric data obtained during R/V METEOR cruise M84/5 are archived at the German Oceanographic Data Centre, Bundesamt fur Seeschiffahrt und Hydrographie (BSH), Hamburg (http://www.seadata.bsh.de). They are available to the public. Hydroacoustic subsurface profiling data are curated at GEOMAR (Sascha Flögel). Swath mapping bathymetric data are archived at German Oceanographic Data Centre, BSH. They are available to the public upon request by July 2016. The hydrographic data obtained by CTD casts as well as chlorophyll data measured with the Fluorometer are archived at the PANGAEA database (http://www.pangaea.de). The seawater oxygen analyses are documented in PANGAEA. The descriptions of sediment cores are archived at the GEOMAR datacenter. Copies of the station list, cruise track and bathymetric data recorded in the Exclusive Economic Zones of Spain and France were given to the scientific observers from Instituto Español de Oceanografía (IEO)/Santander and Ifremer/Brest.

The samples taken on R/V METEOR cruise M84/5 were distributed to the following principle investigators for initial analyses. Seawater samples are analysed by Christian Dullo and Sascha Flögel at IFM-GEOMAR. They will characterize the trace metal inventory describe the Orinoco river plume by εNd distribution. Zooplankton samples are analysed by Joachim Schönfeld at GEOMAR. Plankton net samples are analysed by Ralf Schiebel at the Université de Angers, France. Video recordings and seabed images taken during OFOS deployments are examined by Covadonga Orejas Saco del Valle. Sediment surface samples are analysed by Andres Rüggeberg, Ghent University, Belgium. Sediment cores are analysed by Andres Rüggeberg, Sascha Flögel, and Volker Liebetrau. Sediment cores and archive cores from box cores are archived at Lithothek Core Repository, GEOMAR, Kiel. Subsample as are available to the public upon request by July 2016. The cruise participants will archive all raw data collected during the cruise. This is the responsibility of the chief scientist. The GEOMAR data management team provides a data archival system where metadata collected onboard by the DSHIP-System will be archived. This GEOMAR internal data management system is accessible for all project participants and can be used to share metadata and real data as they become available.

The bathymetric and hydro-acoustic raw data as well as processed data will be archived on a dedicated server at GEOMAR, which is daily backed up and which holds all data since the founding days of GEOMAR. The sediment cores will be stored in the Lithothek. Other data generated in laboratory work, e.g. from sedimentological and geotechnical analyses, will be stored in the GEOMAR data management system until publication.
The collected macrofauna is curated at the the Univerity of Aveiro and at GEOMAR.

9 Acknowledgements

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Appendix

Table 4: Nd/Hf-water sampling stations during M84/5.

station no. M84/5-	Date	Latitude	Longitude	Depth	Elements	Volume
subsurface samples		(N)	(W)	(m)		(l)
559	02.06.11	43°0.25	9°43.11	2300	Hf/Nd	80
559	02.06.11	43°0.25	9°43.11	1700	Nd	20
559	02.06.11	43°0.25	9°43.11	1500	Hf/Nd	80
559	02.06.11	43°0.25	9°43.11	1300	Nd	20
560	02.06.11	43°0.30	9°43.10	1100	Hf/Nd	80
560	02.06.11	43°0.30	9°43.10	800	Nd	20
560	02.06.11	43°0.30	9°43.10	480	Hf/Nd	80
560	02.06.11	43°0.30	9°43.10	250	Nd	20
568	03.06.11	42°59.37	9°40.52	1869	Hf/Nd	80
576	05.06.11	44°7.92	6°0.08	3250	Hf/Nd	80
576	05.06.11	44°7.92	6°0.08	2500	Nd	20
576	05.06.11	44°7.92	6°0.08	1800	Hf/Nd	80
576	05.06.11	44°7.92	6°0.08	1400	Nd	20
577	05.06.11	44°7.92	6°0.08	1000	Hf/Nd	80
577	05.06.11	44°7.92	6°0.08	700	Nd	20
577	05.06.11	44°7.92	6°0.08	450	Hf/Nd	70
577	05.06.11	44°7.92	6°0.08	200	Nd	20
589	06.06.11	44°1.40	5°42.16	760	Nd	20
611	08.06.11	43°59.890	5°54.106	1993	Hf/Nd	80
611	08.06.11	43°59.890	5°54.106	1893	Hf/Nd	80
612	08.06.11	44°1.285	5°50.225	1248	Hf/Nd	80
612	08.06.11	44°1.285	5°50.225	1148	Hf/Nd	80
615	09.06.11	43°59.317	5°43.575	609	Hf/Nd	80
615	09.06.11	43°59.317	5°43.575	511	Hf/Nd	80
624	10.06.11	43°43.995	2°36.988	2300	Hf/Nd	80
624	10.06.11	43°43.995	2°36.988	1800	Nd	20
624	10.06.11	43°43.995	2°36.988	1500	Hf/Nd	80
624	10.06.11	43°43.995	2°36.988	1200	Nd	20
625	10.06.11	43°43.995	2°36.988	900	Hf/Nd	80
625	10.06.11	43°43.995	2°36.988	700	Nd	20
625	10.06.11	43°43.995	2°36.988	450	Hf/Nd	80
625	10.06.11	43°43.995	2°36.988	200	Nd	20
635	12.06.11	43°31.695	2°45.377	223	Hf/Nd	80
635	12.06.11	43°31.695	2°45.377	124	Hf/Nd	80
638	13.06.11	46°10.005	4°28.006	2013	Hf/Nd	80
638	13.06.11	46°10.005	4°28.006	1650	Nd	20
638	13.06.11	46°10.005	4°28.006	1300	Nd	20
638	13.06.11	46°10.005	4°28.006	900	Hf/Nd	70
639	13.06.11	46°9.993	4°28.006	750	Nd	20
639	13.06.11	46°9.993	4°28.006	550	Hf/Nd	80
639	13.06.11	46°9.993	4°28.006	200	Hf/Nd	80

666	16.06.11	46°13.950	4°19.492	798	Hf/Nd	80
sample ID						
surface samples						
SW01	02.06.11	42°59.493	9°40.101	3	Hf/Nd	140
SW02	04.06.11	43°50.776	7°53.824	3	Nd	20
SW03	05.06.11	44°4.474	5°59.439	3	Hf/Nd	140
SW04	10.06.11	43°42.421	2°45.761	3	Hf/Nd	140
SW05	13.06.11	46°11.629	4°24.252	3	Hf/Nd	140
SW06	17.06.11	43°58.409	3°0.728	3	Hf/Nd	140

Table 5: Plankton net samples and number of planktic foraminifers (Plf) analysed from each sample.

date (2011)	station M84/5-	depth (m)	latitude (N)	longitude (W)	sampling area	number of analysed Plf
03/06	566	0 - 50	42°59.38'	9°40.52'	Mugia Canyon	31
03/06	567	0 - 100	42°59.37'	9°40.52'	Mugia Canyon	50
07/06	599	0 - 100	43°59.09'	5°43.50'	Pagès Escarpment	50
08/06	609	0 - 50	43°57.44'	5°46.14'	Pagès Escarpment	50
12/06	637	0 - 100	43°43.99'	2°36.95'	Cap Breton Canyon	50
15/06	647	0 - 100	46°13.79'	4°21.10'	Cap Breton Canyon	50
16/06	667	0 - 100	46°13.89'	4°19.56'	St. Nazaire Canyon	50
18/06	683	0 - 100	43°39.74'	2°43.48'	St. Nazaire Canyon	32

Table 6: OFOS stations carried out during the METEOR M84/5 cruise. Station number, working area, date, time, depth and positions at start and end of each station are displayed. MC = Mugia Canyon, WDB = West of Le Danois Bank, PE= Pagès Escarpment; CB = Cap Breton Canyon, NC= St. Nazaire Canyon.

		start					**end**				
station M84/5-	**area**	**date**	**time (UTC)**	**bottom depth (m)**	**lat. (N)**	**long (W)**	**date**	**time (UTC)**	**bottom depth (m)**	**lat. (N)**	**long (W)**
561	MC	02/06/2011	11:02	1835	42º 59.37	9º 40.20	03/06/2011	4:34	198	43° 4.83	9º 32.66
579	WDB	05/06/2011	13:46	1069	44º 2.253	5º 40.78	05/06/2011	19:29	699	44° 0.63	5º 41.51
590	WDB / PE	06/06/2011	14:43	354	43º 59.94	5º 41.57	06/06/2011	23:01	771	43° 59.03	5º 43.71
610	PE	08/06/2011	8:40	1251	44º 1.29	5º 50.23	08/06/2011	15:45	1776	44° 0.33	5º 52.73
613	PE	08/06/2011	21:33	767	44º 1.45	5º 42.41	08/06/2011	23:18	960	44° 1.66	5º 42.69
614	PE	09/06/2011	0:04	813	44º 1.55	5º 42.22	09/06/2011	1:45	980	44° 1.78	5º 42.50
627	CB	11/06/2011	9:07	717	43º 38.44	2º 37.96	11/06/2011	12:03	901	43° 38.46	2º 38.84
628	CB	11/06/2011	12:42	476	43º 37.26	2º 42.31	11/06/2011	16:47	1132	43° 37.06	2º 44.06
641	NC	13/06/2011	22:02	440	46º 14.28	4º 18.09	14/06/2011	3:46	1077	46° 13.79	4º 20.10
646	NC	15/06/2011	2:39	660	46º 14.00	4º 19.21	15/06/2011	7:30	1348	46° 13.79	4º 21.10
681	CB	17/06/2011	16:56	880	43º 39.98	2º 43.66	17/06/2011	22:00	1245	43° 39.80	2º 45.24
686	CB	18/06/2011	10:02	1491	43º 43.78	2º 52.07	18/06/2011	15:19	2251	43° 43.70	2º 54.20

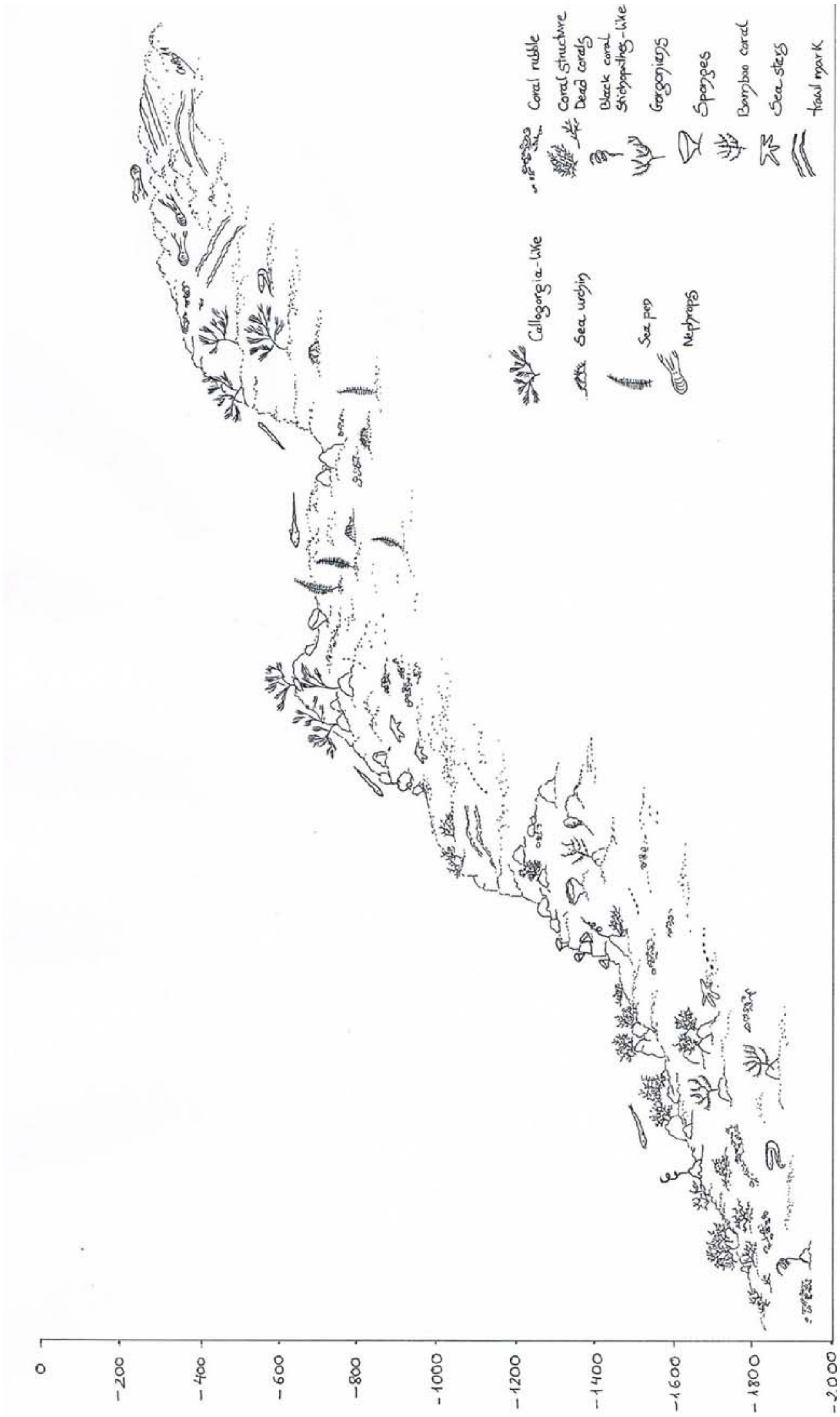

Fig. 16 Idealised representation of the OFOS transect M84/5-561 in the Muxía canyon. Y-axis displays depth in meters. Please note that horizontal distance along the transect (X-axis) has not been scaled.

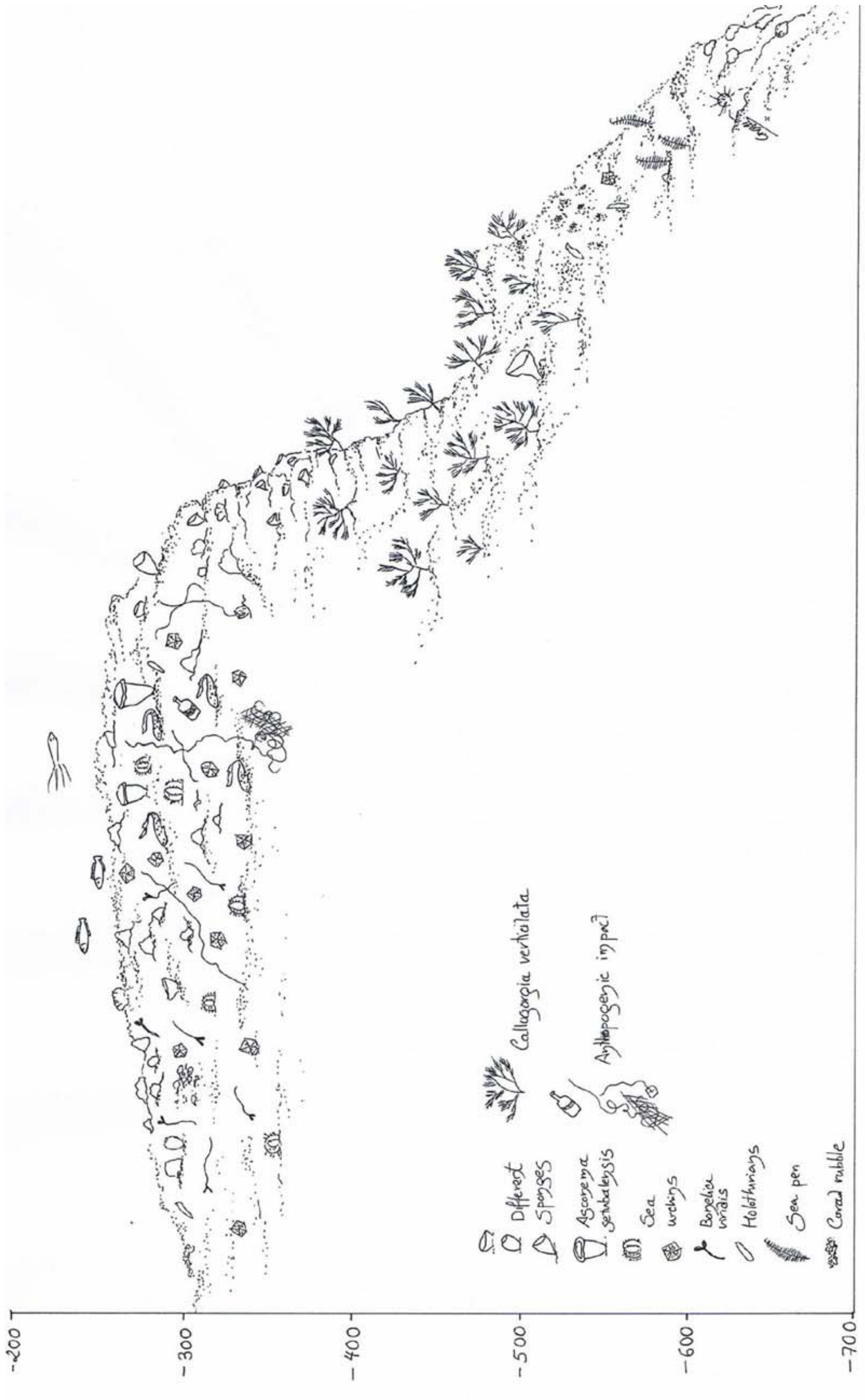

Fig. 17 Idealised representation of the OFOS transect M84/5-590 in the Pagès Escarpment. Y-axis displays depth in meters. Please note that horizontal distance along the transect (X-axis) has not been scaled.

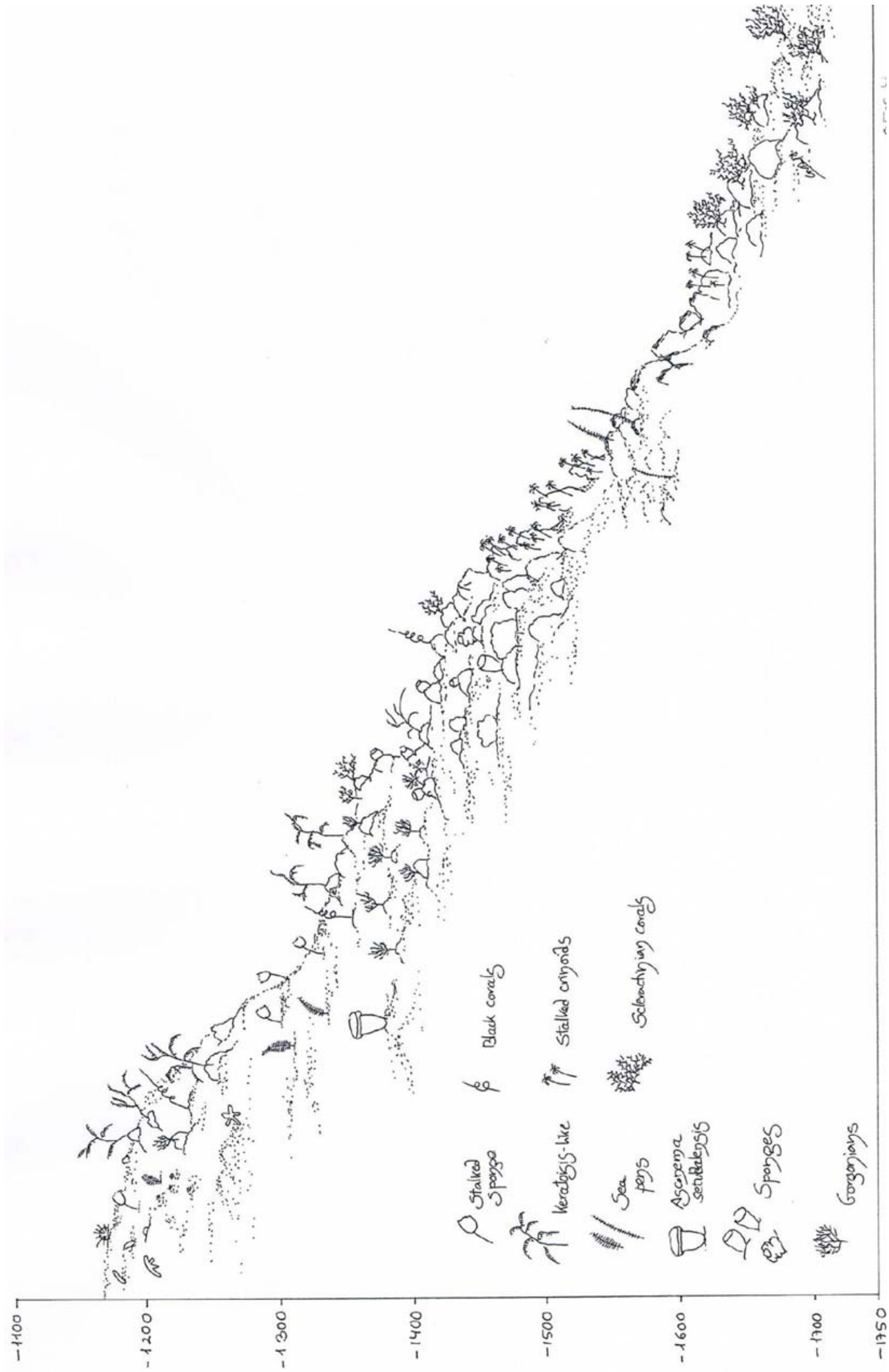

Fig. 18 Idealised representation of the OFOS transect M84/5-590 in the Pagès canyon (NW from Pagès **Escarpment**). Y-axis displays depth in meters. Please note that horizontal distance along the transect (X-axis) has not been scaled.

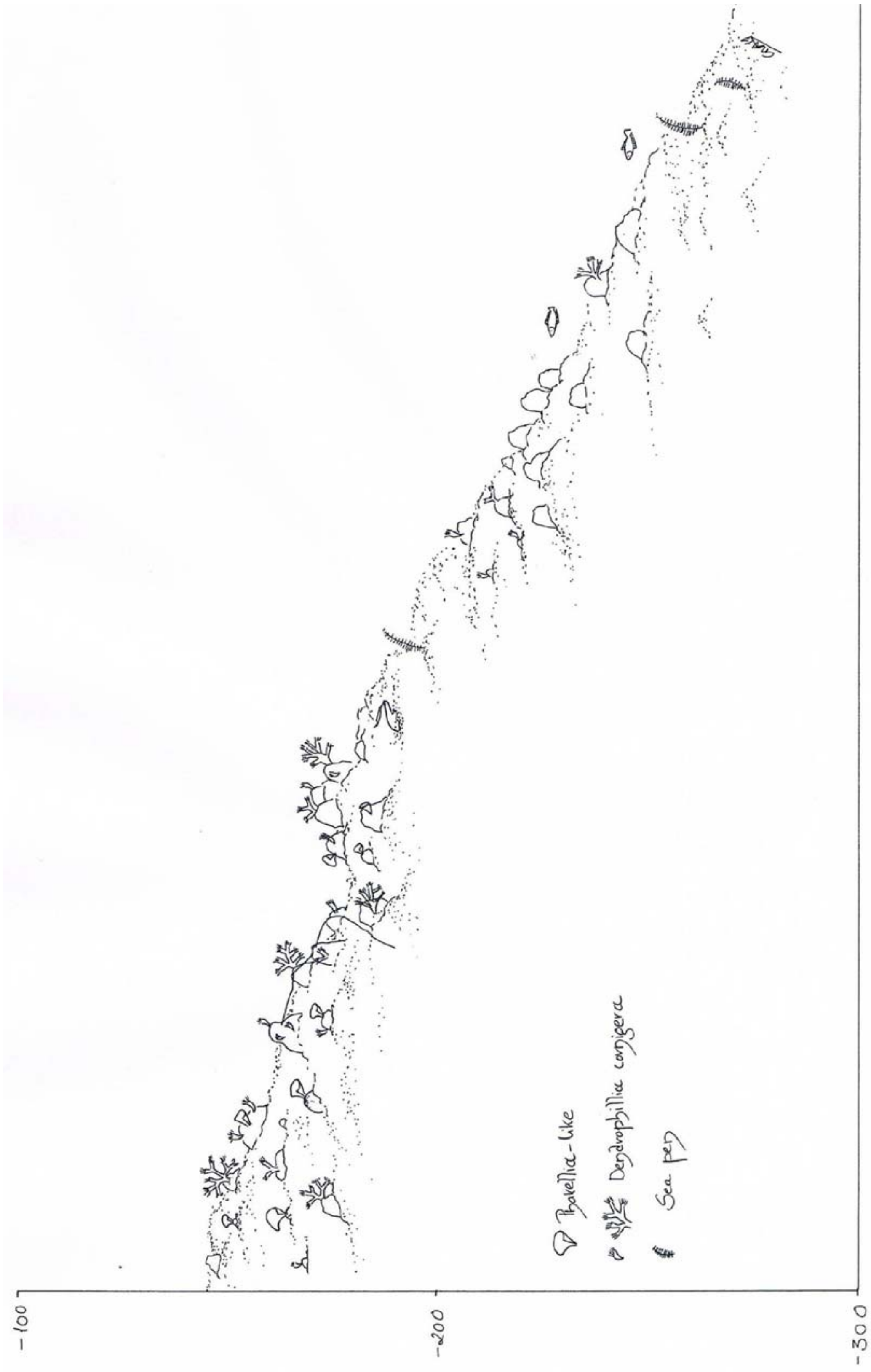

Fig. 19 Idealised representation of the OFOS transect M84/5-630 in the Cap Breton canyon head. Y-axis displays depth in meters. Please note that horizontal distance along the transect (X-axis) has not been scaled.

Table 7: Box corer (BC) stations during cruise M84/5.

M84/5-	location	latitude (N)	longitude (W)	depth (m)	recovery (cm)	sediments
564-1	Mugia Canyon	42° 59.42'	009° 40.18'	1848	0	silty–fine sand
565-1	Mugia Canyon	42° 59.41'	009° 40.18'	1848	0	–
600-1	Pagès Escarpment	43° 59.09'	005° 43.50'	671	21	silty–fine sand
601-1	Pagès Escarpment	43° 59.09'	005° 43.50'	671	27	silty–fine sand
602-1	Pagès Escarpment	43° 59.16'	005° 43.29'	592	20	medium sand
603-1	Pagès Escarpment	43° 59.16'	005° 43.21'	589	21	fine–coarse sand
604-1	Pagès Escarpment	43° 59.32'	005° 43.66'	644	22	muddy silt
605-1	Pagès Escarpment	43° 59.32'	005° 42.66'	357	0	–
606-1	Pagès Escarpment	43° 59.32'	005° 42.66'	356	0	–
607-1	Pagès Escarpment	43° 59.94'	005° 41.58'	364	0	–
648-1	St. Nazaire Canyon	46° 13.97'	004° 20.53'	1109	0	–
649-1	St. Nazaire Canyon	46° 13.99'	004° 20.54'	1110	34	corals
650-1	St. Nazaire Canyon	46° 14.06'	004° 20.29'	986	0	sand, dead coral
651-1	St. Nazaire Canyon	46° 14.10'	004° 20.27'	977	20	silty sand, corals
652-1	St. Nazaire Canyon	46° 14.19'	004° 19.58'	780	0	living, dead corals
653-1	St. Nazaire Canyon	46° 14.23'	004° 19.59'	749	22	living, dead corals
654-1	St. Nazaire Canyon	46° 14.12'	004° 19.27'	671	0	sand, dead corals
655-1	St. Nazaire Canyon	46° 14.24'	004° 18.62'	531	0	–

Phylum	POR	CNIDARIA					MOLLUSCA			ANN	ARTHROPODA						ECHINOD			BRY	BRA
Class		Hyd	Anthozoa										Malacostraca								
			Act	Sto	Ant	Scl	Polp	Gas	Biv	Polc	Pyc	Cir	Eup	Dec	Amp	Tan	Ast	Oph	Cri		
St 600										+			+		+	+		+			
St 601									+	+					+			+			
St 602									+	+			+		+			+			
St 603									+	+	+				+			+			
St 604									+	+					+			+			
St 649	+	+	+	+	+			+	+	+				+				+	+	+	+
St 651	+	+	+						+	+								+			+
St 652	+	+	+				+		+	+								+	+		
St 653	+	+	+	+	+	+	+	+	+	+		+		+			+	+	+	+	+

Biological debris				
	Scl	Bra	Pte	Biv/Gas
St 600				+
St 601				+
St 602				+
St 603				+
St 604				+
St 649	+	+	+	+
St 651	+	+	+	+
St 652	+	+	+	+
St 653	+++	+	+	+

Table 8: Preliminary list of the main macrofaunal taxa present in the box core samples. POR: *Porifera*; ANN: *Annelida*; ECHINOD: *Echinodermata*; BRY: *Bryozoa*; BRA: *Brachiopoda*; Hyd: *Hydrozoa*; Polp: *Polyplacophora*; Gas: *Gastropoda*; Biv: *Bivalvia*; Polc: *Polychaeta*; Ast: *Asteroidea*; Oph: *Ophiuroidea*; Cri: *Crinoidea*; Act: *Actiniaria*; Sto: *Stolonifera*; Ant: *Antipatharia*; Scl: *Scleractinia*; Pyc: *Pycnogonida*; Cir: *Cirripedia*; Eup: *Euphausiacea*; Dec: *Decapoda*; Amp: *Amphipoda*; Tan: *Tanaidacea*; Pte: *Pteropoda*.

Table 9: Collection of samples for DNA analysis.

location	**station**	**latitude (N)**	**longitude (W)**	**depth (m)**	**sampling method**	**species**
Mugia Canyon	562	42°59.46'	09°40.15'	1822	TV grab	*Eunice* sp. + 1 coral?
Mugia Canyon	563	42°59.13'	09°40.50'	1890	TV grab	5 *Eunice* sp.
Pagès Escarpment	600	43°59.09'	5°43.50'	na	box core	-
	601	43°59.0'	5°43.50'	na	box core	-
Cap Breton Canyon	634	43°31.74'	2°45.52'	150-200m	TV grab	11 *Dendrophyllia*
	678	43°31.70'	2°45.50'	215	TV grab	7 *Dendrophyllia*
	679	43°31.70'	2°45.50'	215	TV grab	10 *Dendrophyllia*
St. Nazaire Canyon	644	46°13.99'	4°19.59'	820	TV grab	11 samples *Lophelia* + 1 *Madrepora*
	646	46°14.11'	4°19.21'	660	OFOS	7 *Madrepora*
	652	46°14.20'	4°19.58'	781	box core	9 *Madrepora*
	653	46°14.20'	4°19.58'		box core	2 *Madrepora* + 1 *Lophelia pertusa* ?
	687	46°14.24'	4°18.59'	523	TV grab	dead corals
	688	46°14.14'	4°19.26'	670	TV grab	7 *Eunice*, 5 *Madrepora*, 17 *Lophelia* (3 colonies and 14 young recruits)
	689	46°14.22'	4°19.56'	751	TV grab	3 *Lophelia*, 2 *Madrepora*, 6 *Eunice*
	690	46°14.22'	4°19.56'	758	TV grab	4 *Lophelia*, 2 *Madrepora*, 4 *Eunice*

Phylum	POR	CNIDARIA						MOLLUSCA			ANN	ARTHROPODA						ECHINOD				BRY	BRA	OTH
Class		Hyd	Anthozoa					Polp	Gas	Biv	Polc		Malacostraca					Ast	Oph	Echi	Cri			
			Act	Sto	Oct	Ant	Scl					Cir	Eup	Dec	Amp	Iso	Tan							
St 562					+		+				+	+		+					+			+		
St 563	+	+	+				+		+		+	+							+		+	+	+	+
St 617	+				+						+								+			+		
St 619									+	+	+				+	+			+	+				
St 632											+		+											
St 633	+	+	+	+			+	+	+	+	+		+	+					+			+	+	+
St 636																								
St 643	+	+	+	+	+		+		+	+	+			+					+			+	+	
St 644	+	+	+	+			+		+	+	+			+				+	+		+	+	+	
St 677											+													
St 678	+	+	+	+			+	+	+	+	+			+					+				+	
St 679	+	+	+	+			+	+	+	+	+			+	+				+				+	+
St 687	+	+								+	+			+					+			+		
St 688	+	+	+				+		+	+	+			+	+		+		+		+	+	+	
St 689	+	+	+		+	+	+	+	+	+	+			+					+		+	+	+	
St 690	+	+	+			+	+		+	+	+			+					+		+	+	+	

	Biological debris			
	Scl	Bra	Pte	Biv/Gas
St 562	++			+
St 563	+++	+	++	+
St 617				
St 619	+++	+++		+
St 632				+
St 633	+	+		+
St 636				+
St 643	+			
St 644	+++	+	+	+
St 677	+			+
St 678	+			+
St 679	+			+
St 687	++			+
St 688	+++			+
St 689	+++	+		+
St 690	+++	+		+

Table 10: Preliminary list of the main macrofaunal taxa present in the TV-grab samples. POR: *Porifera*; ANN: *Annelida*; ECHINOD: *Echinodermata*; BRY: *Bryozoa*; BRA: *Brachiopoda*; OTH: Other (*Sipuncula*, *Priapulida*); Hyd: *Hydrozoa*; Polp: *Polyplacophora*; Gas: *Gastropoda*; Biv: *Bivalvia*; Polc: *Polychaeta*; Ast: *Asteroidea*; Oph: *Ophiuroidea*; Echi: *Echinoidea*; Cri: *Crinoidea*; Act: *Actiniaria*; Sto: *Stolonifera*; Oct: *Octocorallia*; Ant: *Antipatharia*; Scl: *Scleractinia*; Cir: *Cirripedia*; Eup: *Euphausiacea*; Dec: *Decapoda*; Amp: *Amphipoda*; Iso: *Isopoda*; Tan: *Tanaidacea*; Pte: *Pteropoda*.

Photo plate 1: Macrofauna collected during M84/5 (M. da Cunha, L. Matos, C. Orejas)

Fig. 20 Macrofauna from Mugia Canyon (St. 563 TVG). a. Priapulid worm b. Sipunculid worms. c. Crinoid. d. Eunicid polychaetes. e. Ophiuroids. Scale bars 1 cm.

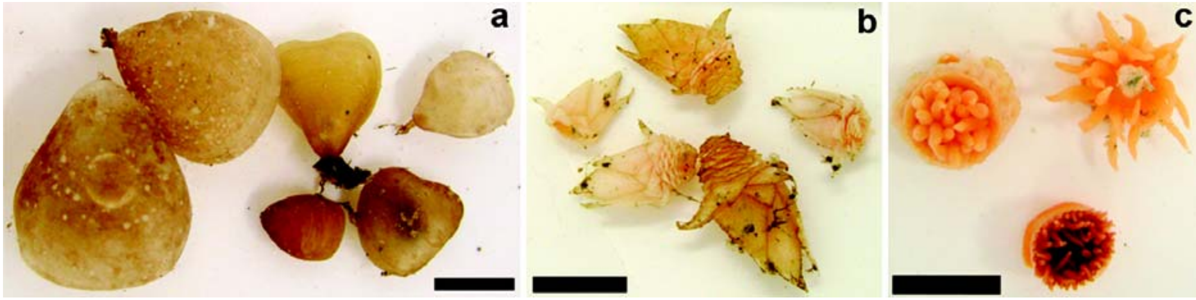

Fig. 21 Macrofauna from Mugia Canyon (St. 563 TVG). a. Brachiopods (*Gryphus vitreus* and others). b. Cirripeds c. Actiniarians. Scale bars 1 cm.

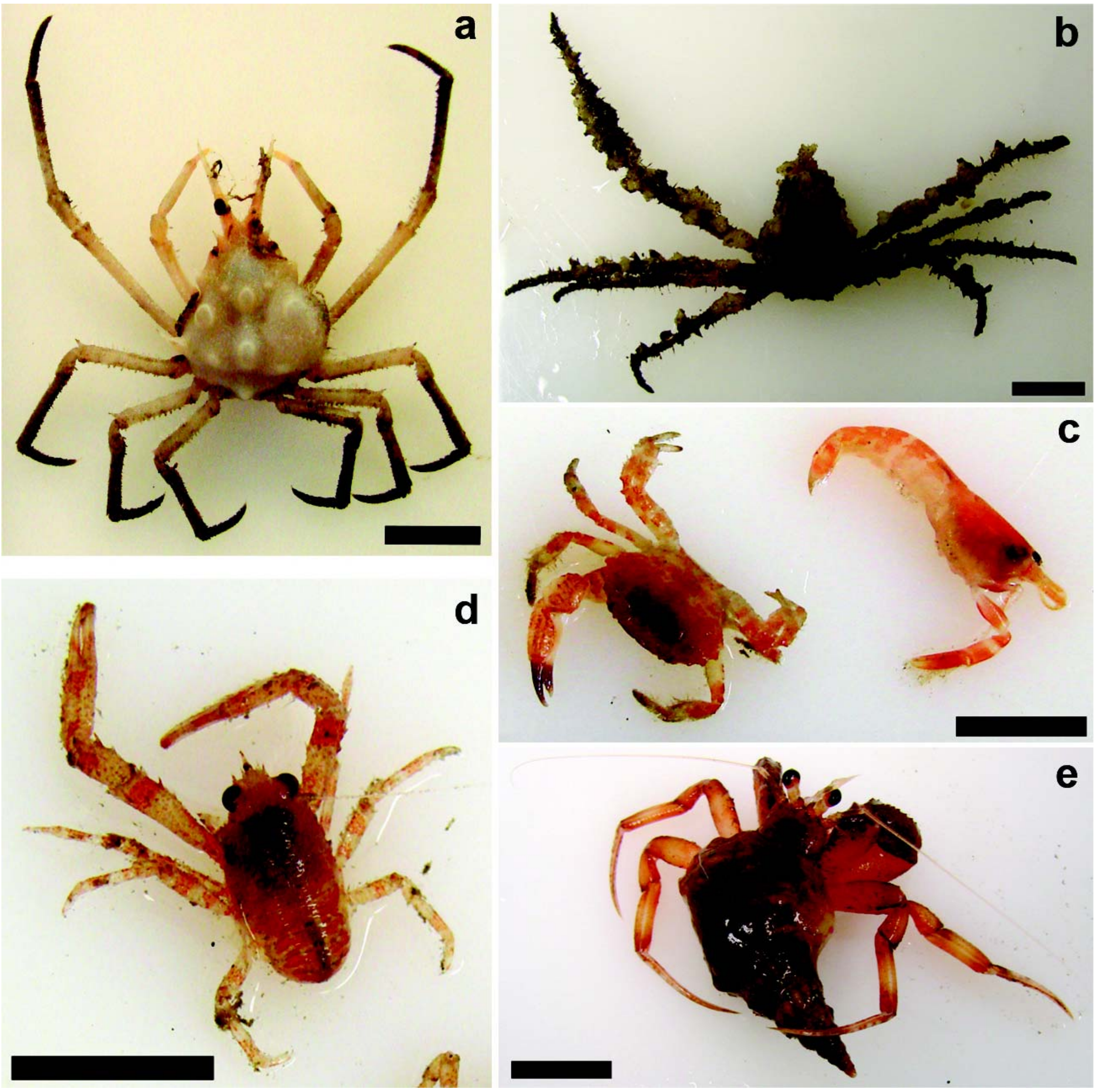

Fig. 22 Decapods collected from Cap Breton Canyon. a. Spider crab (St. 627 OFOS). b. Spider crab covered by incrusting sponges (St. 633 TVG). b. Xanthid crab and Alpheid shrimp (St. 678 TVG). d. Squat lobster (*Munida* sp.) (St. 679 TVG). e. Hermit crab (St. 679 TVG). Scale bars 1cm.

Fig 23 Brachiopods from Cap Breton Canyon with different kinds of incrusting epifauna (St. 633 TVG). Scale bar 1 cm.

Fig. 24 Sponges collected from Cap Breton Canyon.

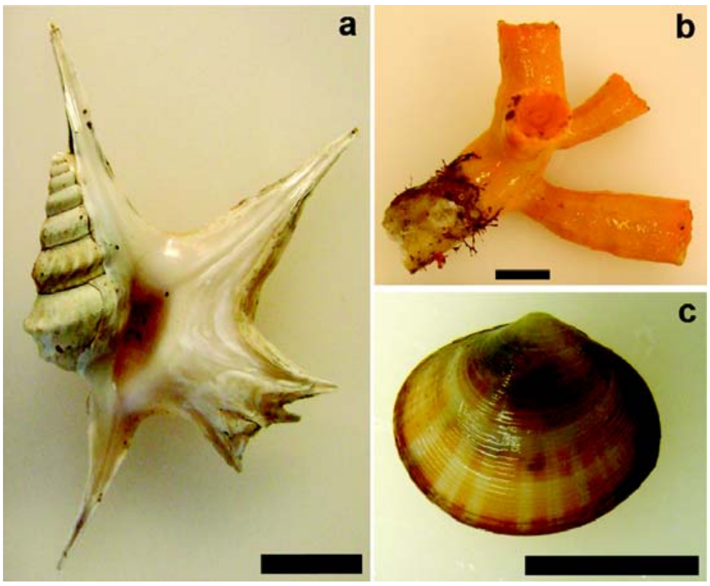

Fig. 25 Macrofauna from Cap Breton. a. Aphorraid gastropod (St. 627 OFOS). b. *Dendrophillia cornigera* (St. 679 TVG). c. Bivalve (St. 679 TVG). Scale bars 1 cm.

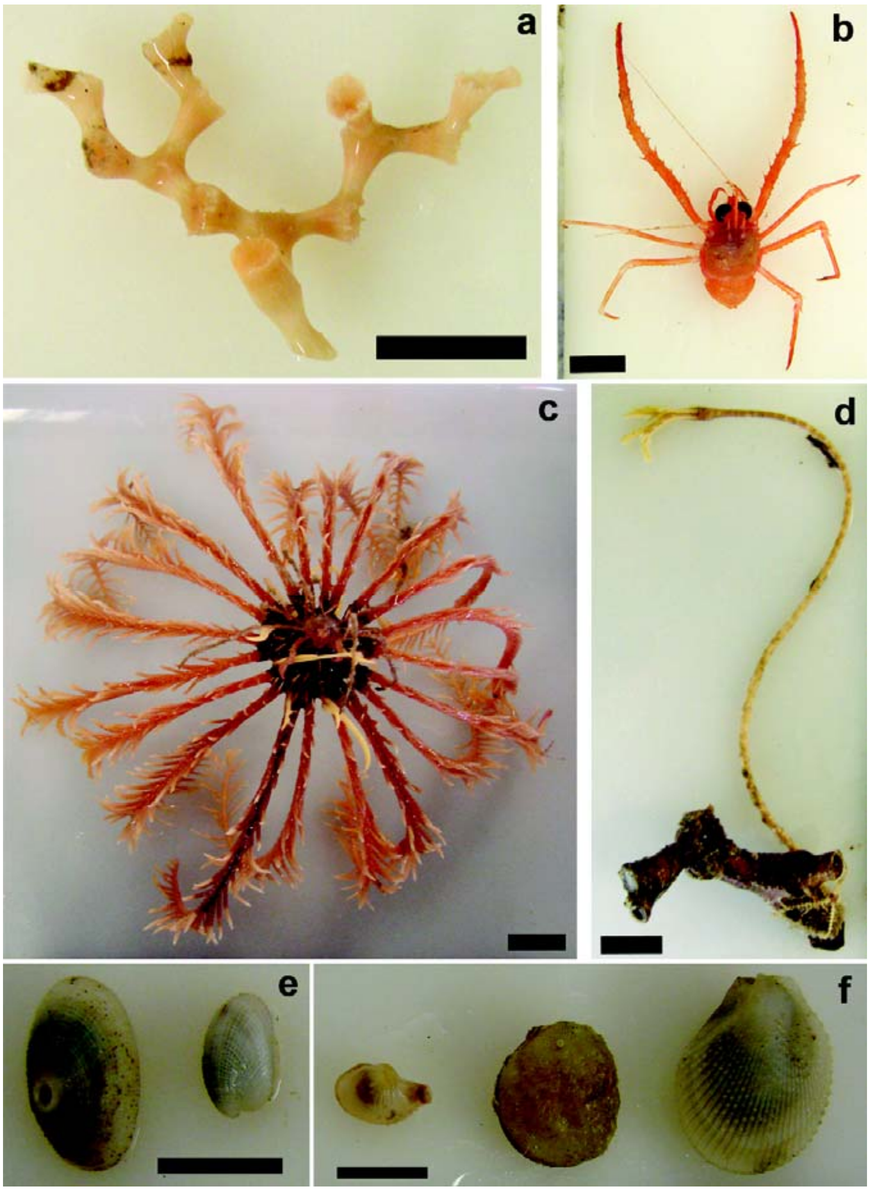

Fig. 26 Macrofauna from St. Nazaire Canyon. a. *Lophelia pertusa* (St. 643 TVG). b. Squat lobster (*Munida* sp.) (St. 643 TVG). c, d. Crinoids (St. 649 GKS). e. Gastropods (St. 643 TVG). f. Bivalves (St. 643 TVG). Scale bars 1cm.