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"No one ought to feel surprise at much remaining as yet unexplained in regard to the origin of species and varieties, if he make due allowance for our profound ignorance in regard to the mutual relations of the many beings which live around us. Who can explain why one species ranges widely and is very numerous, and why another allied species has a narrow range and is rare? Yet these relations are of the highest importance, for they determine the present welfare and, as I believe, the future success and modification of every inhabitant of this world."

Charles Darwin "The Origin of Species", 1859.

resumo

O conhecimento da fauna de crustáceos que habita os fundos marinhos, particularmente a dos ecossistemas existentes nos canhões é escasso. Esta tese investiga a abundância e diversidade de crustáceos dos canhões centrais de Portugal: Nazaré, Cascais e Setúbal e taludes adjacentes. Contribui para o conhecimento de padrões na estrutura da comunidade de crustáceos e pretende identificar diferenças entre as amostras recolhidas nos taludes e canhões e entre canhões, relacionando-as com o gradiente vertical de profundidade e gradiente vertical no sedimento, ao nível de espécie.

A amostragem decorreu em Agosto de 2005, com o cruzeiro RRSDiscovery (D297-NOCS), entre Abril e Maio de 2006, com o cruzeiro RRS Charles Darwin (CD179-NOCS) e em Setembro de 2006, com o cruzeiro RV Pelagia (64PE252-NIOZ). As amostras foram recolhidas usando USNEL-box corer (área=0.25m^2), UKORS megacorer (área=0,00785m^2) e NIOZ box corer (área=0.196m^2) respectivamente. Num total de 1260 indivíduos descritos e 157 taxa, 6 ordens, 9 sub-ordens e 47 famílias. Tanaidacea foi a ordem mais abundante seguida da ordem Isopoda (grupo com maior número de espécies, 61 taxa), Amphipoda, e finalmente Cumacea. Os decápodes e misídaceos foram os grupos com menor abundância. O padrão na distribuição vertical no sedimento indica que geralmente existe uma diminuição na densidade, de 0-1 até 5-10 cm. Estes animais revelam uma diversidade de estilos de vida e formas de se alimentar, ficando muitas vezes enterrados e alimentando-se de detritos, vivendo principalmente nas camadas superficiais ou sub-superficiais. A análise multivariavel das amostras revela diferenças significativas entre canhões e taludes; nos canhões e entre canhões e também entre amostradores/ano e profundidade. As comparações entre canhões indicam que existe uma maior similaridade entre as amostras dos canhões de Cascais e da Nazaré, do que entre estes canhões e o canhão da Nazaré. Sendo que o último exibe uma maior dominância de espécies, menor riqueza de taxa e maior abundância. As amostras de Cascais e de Setúbal apresentam maior equitatibilidade e maior diversidade. A 3400m todas as amostras recolhidas dos canhões apresentam uma maior abundância e riqueza de espécies, quando comparadas com as amostras recolhidas a 4300m. Estes padrões são discutidos tendo em atenção dados ambientais destes habitats, publicados recentemente.

Os resultados ilustram uma riqueza elevada de espécies e heterogeneidade nas amostras dos crustáceos peracarídeos dos canhões portugueses, sugerindo que a comunidade de crustáceos, das diferentes áreas analisadas, apresenta uma grande variabilidade na composição ao nível de espécie. Em conclusão, a conservação da biodiversidade dos canhões, nomeadamente dos portugueses, pode ser crucial para a sustentabilidade e o funcionamento do maior ecossistema da biosfera.

abstract

Knowledge of the deep-sea crustacean faunal composition, particularly on canyon ecosystems is scarce. This thesis investigates crustacean abundance and diversity from central Portuguese submarine canyons: Nazaré, Cascais and Setúbal and adjacent slopes. Contribute to the knowledge of crustacean assemblages patterns and aimed to identify differences between open slope and canyon, between canyons assemblages and related to the depth and sediment gradients at species level.

Sampling was performed in August 2005 during RRS Discovery cruise (D297-NOCS), between April and May 2006 during RRS Charles Darwin cruise (CD179-NOCS) and in September 2006 during RV Pelagia (64PE252-NIOZ) cruise. Samples were collected using: USNEL-pattern box corer (area=$0.25m^2$), UKORS megacorer (area=$0,00785m^2$) and NIOZ circular box corer (area=$0.196m^2$) respectively. A total of 1260 specimens were ascribed to 157 nominal taxa, 6 orders, 9 subOrders and 47 families. Tanaidacea was the most abundant followed by Isopoda (the most speciose group with 61 taxa), Amphipoda, and finally Cumacea. Decapods and mysids were the groups with lowest abundance. The trends in the vertical distribution within the sediment indicate generally that there is a decreasing in density from 0-1 to 5-10cm. These animals show a diversity of life styles and ways of feeding, they are burrowing detritivore peracarids species that live mainly in the surface or subsurface. Multivariate analyses of samples revealed significative differences between: canyons and open slopes; within and between canyons and also sampling gear/year and depths. The comparisons between canyons indicate higher similarities between the assemblages of Cascais and Setúbal than between these canyons and Nazaré. The latter exhibits greater dominance, lower taxa richness and higher abundance. The Cascais and Setúbal assemblages are more evenness and revel higher diversity. At 3400m all the canyons revel a higher abundance and diversity when compare to the 4300m assemblages. These patterns are discussed attending environmental conditions in these particular deep sea habitats.

The results illustrate the high taxa richness and heterogeneity of peracarida crustacean assemblages in Portuguese canyons, suggest that community structure of the different areas analyzed show a great variability in species composition. In conclusion, the conservation of deep-sea biodiversity of Portuguese canyons can be crucial for the sustainability of the functions of the largest ecosystem of biosphere.

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INTRODUCTION

1.1 Deep sea Biodiversity and Habitats

The oceans cover three quarters of the earth's surface and have a huge impact on the biosphere. The largest ecosystem on earth is not an environment with stable conditions; it is in fact very dynamic throughout time. However, the hydrologic, physical and chemical characteristics divide the oceans in four main ecological zones: one euphotic sublittoral or coastal zone (low water to 200m), and three deep-sea zones where sunlight penetration is to low to support primary production - bathyal (from 200 to 2000m), abyssal (2000 to 6000m), and hadal (more than 6000m) (Gage & Tyler 1991). The coastal waters occupy about 5% of the world's oceans, and the average depth of the oceans is approximately 3.8 kilometres with 88% are deeper than 1000m (Herring 2002). Up to now only 0.0001% of the deep sea floor has been investigated by biologists (UNEP 2007).

Our knowledge of the deep sea benthic boundary organisms and environmental conditions is intimately related to the evolution of the scientific methods. Qualitative and quantitative methods such as, box cores, multicores, epibenthic sledges, multibeam bathymetry, sidescan sonar; showed the outstanding heterogeneity of the deep sea habitats inhabited by a diversity of organisms with different shapes, sizes and life styles (Gage & Tyler 1991). In the last twenty to twenty - five years oceanographic research vessels with sophisticated sampling gear and research submersibles are being used to further explore this deep sea biodiversity in a variety of geological features, such as canyons, seamounts, hydrothermal vents and cold seeps (Gage & Tyler 1991; UNEP 2007) that is now acknowledged as playing a crucial role for the health and sustainability of all the ocean's ecosystems (Smith & Hughes 2008).

The tridimensional environment of the oceans exhibits several gradients of abiotic factors such as: pressure, temperature, salinity, oxygen, sediment type, organic matter,

seasonality, disturbance and bottom currents. Hydrostatic pressure is one of the most predictable gradients; 1 atmosphere increase per 10 m depth (Gage & Tyler 1991). The temperature at the deep seafloor usually varies from ca. -1° to 4°C, but in the Antarctic waters it may reach -1.9°C (Sverdrup *et al.* 1942). In most oceans the temperature reach ~ 0.8°C at 1300m, although in North Atlantic ocean the 4°C isotherm is located at about 4000m, owing to the influence of the Mediterranean outflow (Gage & Tyler 1991). At depths greater than 2000m the salinity is ca. 34.8psu ±0.3 reaching 34.65psu in deeper regions (Sverdrup *et al.* 1942). Oxygen concentration is usually near saturation but may reach minimum values at ca. 500 to 600m in certain geographical regions (Gage & Tyler 1991). The sediment type in the deep sea is predominantly characterized by very fine grain sizes but other sediments such as coarse sediments of terriginous origin, mud from submarine volcanoes, rocky outcrops at the oceanic ridges and seamounts, deposits around hydrothermal vents and others play an important role in creating heterogeneous habitats inhabited by different organisms.

Considering that deep-sea organisms live in the absence of sunlight, the biodiversity of the assemblages depends on factors other than the photosynthetic primary production, such as the input of material from the photic zone and localised sources of chemosynthetic production. According to Brunel (2006) benthic animals, seaweeds and protists account for 98% of marine species biodiversity, the remaining 2% being pelagic. The deep sea prevailing heterotrophic benthic assemblages depends on autotrophic production from the photic zone to obtain organic matter. The exceptions are the areas where chemoautotrophic bacteria on the base of the trophic chains in hydrothermal vents and cold seeps, biosynthesize organic carbon compounds from CO_2, using sulfide (H_2S) and methane(CH_4) as energy sources (Dubilier *et al.* 2008). Ecosystem functioning in the deep sea is related with production, consumption and transfer of organic matter from the basis of food chain to the higher throphic levels, decomposition of organic matter and nutrient regeneration are processes of utmost importance to understand benthic biodiversity (Danovaro *et al.* 2008). Microbial processes involved in nutrient regeneration, are essential to sustain primary and secondary production and are a major player in global nutrient cycles. The microbial assemblages can limit rates of

biological production and are therefore important structural drivers in these marine ecosystems (Gage &Tyler 1991; Arrigo 2005). Interactions between species, such as predation, competition (Gage & Tyler 1991; Gage 1995) and symbiosis (Dubilier *et al.* 2008) are other biological factors that influence biodiversity.

Blooms of phytoplankton, the falls of dead animals and plants contribute greatly to the input of organic matter in the deep sea. Particulate organic matter (POM) or dissolved organic matter (DOM), can reach the seabed as "marine snow" and "feed" the benthic assemblages. This main source of energy to the deep sea fauna can accumulate, can be redistributed by bottom currents or create patches with high concentrations of resources from drifting organic matter related to small-scale natural physical disturbances (Thistle 1981; Gage & Tyler 1991). According to Rowe (1991) the biomass (organic carbon) of benthic animals is more correlated to the particulate organic matter flux than directly to the depth gradient. Epifauna (mostly scavengers but also detritivores) can efficiently remove the food that reaches the deep sea floor (Smith 1986) and therefore most of the organic matter is consumed at the sediment surface.

Inputs of seasonal fluxes of material through the water column can reach the seabed as phytodetritus deposits inducing a temporal variability in the benthic community response. This is well-established for bacteria and protozoa but studies on metazoans (meio, macro or megafauna) are less common and confined to continental margins (Gooday 2002). Temporal variation at tidal rhythm scales may be induced by bottom currents that control sediment deposition and the concentration of organic matter; when currents exceed $7cm.s^{-1}$ the materials at the seafloor are resuspended (Row & Menzies 1969; Lampit *et al.* 1985) with important implications for the distribution of suspension feeders that can be favoured in some specific regions by the abundant suspend organic matter (Row & Menzies 1969).

At a high taxonomic level, biodiversity is much greater in the sea than in terrestrial and freshwater ecosystems (Brunel 2006). The depth gradient is probably the best known biodiversity pattern, where species diversity generally appears to show a peak at middle slope depths (Rex 1981; Paterson & Lambshead 1995; Levin *et al.* 2001). This unimodal

pattern, parabolic distribution with depth, has been explained by production, predation and competition based hypotheses (Rex 1981). However, regional deep sea diversity patterns are linked to several environmental factors and unimodal patterns do not appear to be universal (Levin *et al.* 2001). Boundary constrains and species ranges, sediment heterogeneity, productivity and food supply, bottom-water oxygen concentration, deep sea currents and catastrophic disturbance are processes and factors that can regulate species diversity and are subjected to a spatiotemporal variation in deep sea at local, regional and global scales. A conceptual model by Levin *et al.* (2001) shows the direct and indirect effects of various environmental factors on species richness of local communities (Fig. 1).
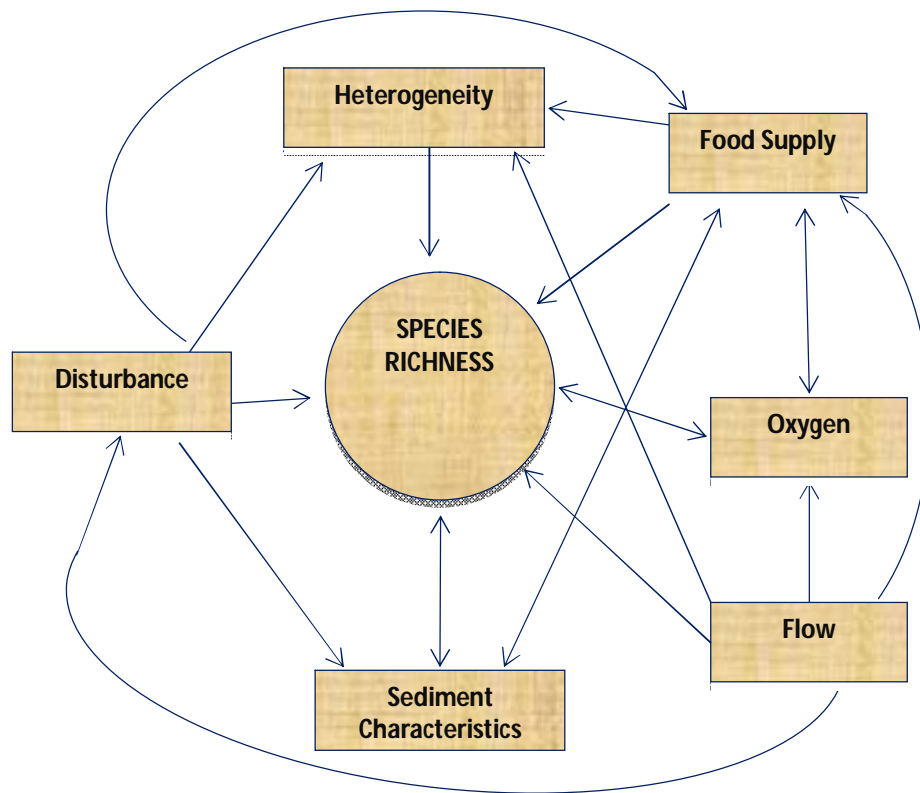
Figure 1: Conceptual model indicating direct and indirect effects of various environmental factors on species richness of local communities (adapted from Levin *et al.* 2001).

1.2 West Iberian Margin

The Iberian Peninsula is the south-westernmost region of the Eurasian Plate with an origin placed at the Cretaceous, Middle Cenomanian (late aptian, 117-94Ma.). It is an example of a rifted and non-volcanic continental margin (Arzola *et al.* 2008; Lastras *et al.* 2009).

The West Iberian Margin is characterized by a continental shelf with a gently sloping, thin shelf of 10 to 65km wide (Weaver & Canals 2003; Lastras 2009). This margin is incised, from north to south, by a number of submarine canyons, with a northeast–southwest trend (Arzola *et al.* 2008; Lastras *et al.* 2009). There are three large abyssal plains: Iberia, Tagus and Horseshoe, from north to south, and located at c.a. 4500m water depth. The first two abyssal plains are separated by Estremadura Spur (Lastras *et al.* 2009) and by the major canyons: Nazaré, Setubal and São Vincente into three distinct sections (Vanney & Mougenot 1981; Mougenot 1988).

1.2.1 North Atlantic Oceanography

The oceanography of west Iberian margin is complex. Analysing the depth variations, near the 50m and near the thermocline zone the salinity decreases from 35.8 or 36.0psu to a minimum of 35.6psu at 450-500m of depth. Here the North Atlantic Central Water is predominant (Van Aken 2000). From 500-800m to 1400m the salinity increases to 36.19psu due to the Mediterranean Water (MW) (McCave & Hall 2002). Beneath this lies the North Atlantic Deep Water Current (NADWC) that reaches ~2.5°C (Fiúza *et al.* 1998). The NADWC formed in the Norwegian Sea and traveling southwards, and the MW are of extreme importance for the faunal distributional patterns in the west Iberian marginrents (Gage & Tyler 1991).

Vitorino (2002) and Oliveira (2007) documented the influence of the seasonal upwelling in summer and the downwelling in winter as prevailing meteorological factors for the current patterns in the west Iberian margin.

1.2.2 Submarine Canyons

Canyons are common geological features along most ocean margins (Vetter & Dayton 1998; Weering & Stiger 2002; Stiger 2007), varying in shape and size from shallow systems to deeply incised sinuous valleys. In the past, when the sea level was lower, they were probably more active, but at the present time canyons are mostly sites of sedimentation (Weering & Stiger 2002). Canyons show a morphological similarity with erosional landforms (Stiger *et al.* 2007) and act as conduits of land and coastal materials to the deep sea floor. Canyons are preferential sinks for organic matter, and their biological activity indicate an input of fresh organic matter (Vetter & Dayton 1998; Duineveld *et al.* 1997). Due to this fact, these topographical features are thought to play an important role for the secondary production and may enhance benthic abundance and/or biodiversity in the deep sea (Vetter & Dayton 1998).

The main Portuguese canyons are *gouf* type with a deeply incised narrow, V-shaped thalweg flanked by small gullies and terraces, where landslides and rockfalls occur (Arzola *et al.* 2008). Morphologically canyons can be divided in three sections: the upper, middle and lower parts (Weering & Stiger 2002; Stiger *et al.* 2007; Arzola *et al.* 2008). Because they are complex systems in terms of hydrography, sedimentology, biogeochemistry and biology they present great variability within or between canyons. Turbidity currents are the dominant process of sediment transport, erosion and deposition in Nazaré and Setúbal canyons, due to the dominance of gravity flow deposits and erosive episodes. Probably the origin of terriginous sediments is the continental shelf. There are two types of turbidity currents: first, small volume, high frequency, carbonaceous and enriched in mica minerals, which deposit in shallower intra canyon terraces; second type, large volume, low frequency, canyon flushing turbidity currents that deposit mainly in the deeper parts of the canyon and in the abyssal plains (Arzola *et al.* 2008).

1.3 Crustacean Fauna

The crustaceans exhibit a huge diversity in morphology, adaptation, development and strategies of feeding. They live in all marine habitats, from supralitoral to the deeper parts of the oceans, but can also be found in terrestial habitats. Crustaceans range in size from less than 0.5mm to more than 1m. Their morphological diversity and all adaptative features make them a difficult phylum to define satisfactorily (Hayward & Ryland 1996). Above all, they have an important ecological role as they constitute a major food source to many marine invertebrates, vertebrates and mammals (Rehm 2007).

1.3.1 Systematics and Morphology

Eucarids are malacostraceans that always have a carapace covering the entire thorax usually dorsally fused. The representatives of this group do not possess oostegites nor a brood pouch to incubate the eggs. The reproduction strategy consists in the dispersion of eggs directly to the environment. The eggs can also be maintained in the thoracic appendices, or adherent to the ventral part or to the abdomen. Juveniles hatch and have a larval stage before reaching the adult stage (Hessler & Watling 1999).

Peracarids are malacostracan crustaceans known from many habitats: land, freshwater, brackish and marine waters. They have a wide world distribution and exhibit all sorts of feeding strategies (Hessler & Watling 1999; Brusca & Brusca 2003). They are frequently detritus feeders with a free living epibenthic or bathypelagic lifestyle but may also burrow in the sediment or be tube dwellers (Gage & Tyler 1991). Peracarids range in size from a few millimetres to 500 mm in length and some are capable to live in hot springs, at 30-50°C. Morphologically they are characterized by the possession of a telson without rami; one or rarely 2-3 pairs of maxilipeds; mandibles with an articulated tooth (lacinia mobilis); carapace small and not fused with the posterior pereonites (once present); the gills are thoracic or abdominal; they possess oostegites, that form the marsupium (except in the Order Thermosbaenacea) (Fig. 2). Frequently juveniles hatch as mancas and do not have free living larval stages (Hessler & Watling 1999; Gutu & Sieg 1999; Brusca & Brusca 2003).
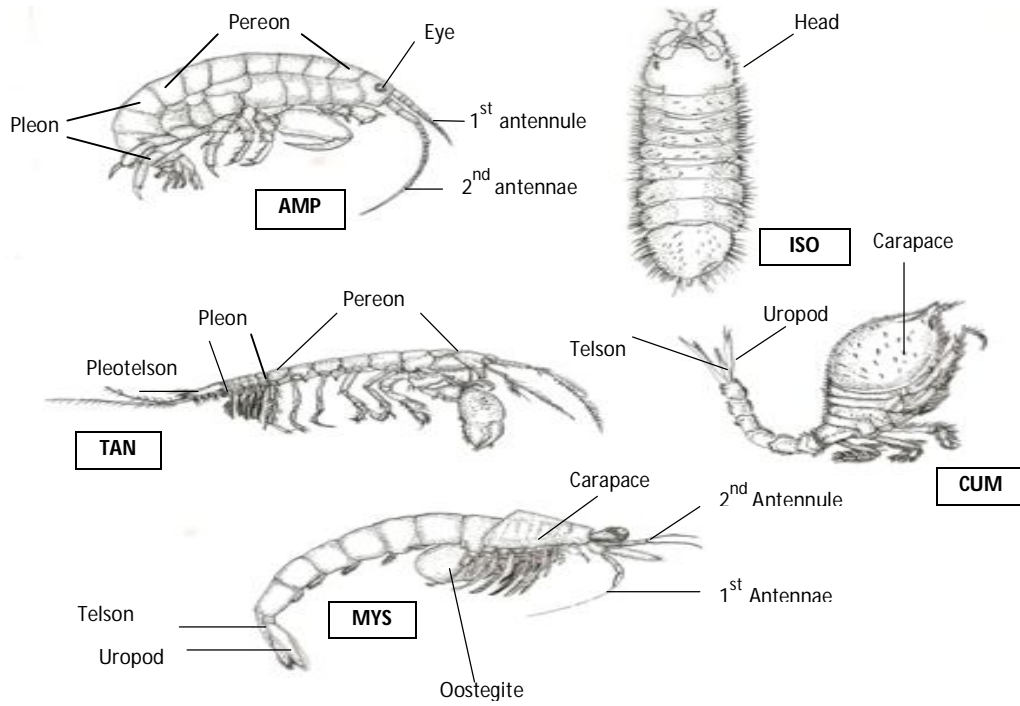
Figure 2: Anatomy and diversity in some peracarid crustaceans, AMP=amphipods, ISO=isopods, TAN=tanaids, CUM=cumaceans and MYS=mysids (adapted from Brusca & Brusca 2003).
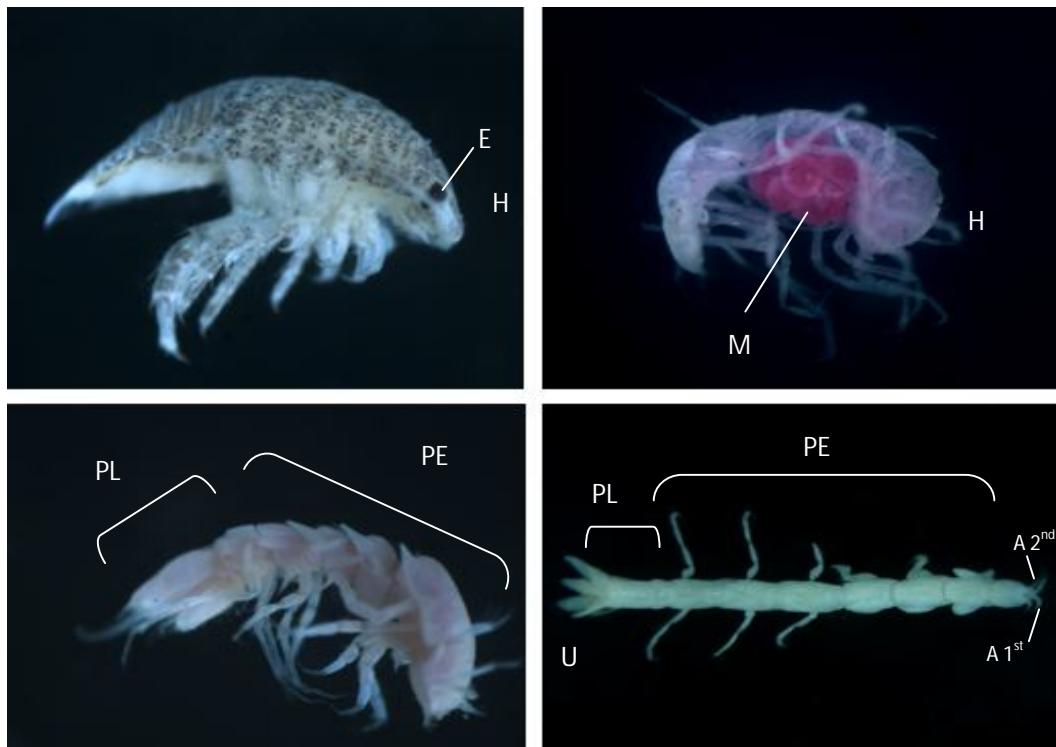
Figure 3: Anatomy and diversity in Isopoda. A 1st =first antennae; A 2nd =second antennule; E=eye; H=head; M=marsupium; PE=pereon; PL=pleon; T=telson and U=urosome.

Table 1 summarizes the principal morphological features of five peracaridan orders. In deep sea samples peracarida crustacean fauna represent between 31%-51% of all macrobenthic species (Gage & Tyler 1991).

Table 1: Main morphological features of five peracarida orders (adapted from: Shram 1983; Bacescu & Petrescu 1999; Gutu & Sieg 1999; Nouvel, Casanova & Lagardere, 1999; Roman & Dalens 1999 and Santinni 1999).

ORDER / MORPHOLOGY	AMPHIPODA	ISOPODA	CUMACEA	TANAIDACEA	MYSIDACEA
CARAPACE	absent	absent	present, fused with the first 3 (or up to 6) thoracomeres	present, fused to the first two thoracicomeres	present, covering the 1-3 thoracomeres
EYES	present, sessile compound or not	present, sessile compound or not	present , sessile compound or not	absent or present on lobes	stalked , compound
ANTENNAE (1ST)	5 segments, uniramous	4, 5 or 6 segments, uniramous	1-5 segments, a long flagellum on males	2 segmented protopod	3 segmented protopod
ANTENNULE (2ND)	3 segments, biramous	uniramous; 2, 3 or 4 segments	3 segments and two flagella in each	4 segments	3 segments and two well developed flagella
HEAD	fused with 1st thoracomere	fused with 1st thoracomere	pseudorostrum	Fused with the first two thoracomeres	rostrum small
MARSUPIUM	oostegites present	variable number of oostegites on 2-6 pereopods	oostegites present on maxillipedes 3 and pereopods 1-3	oostegites on 1-5 or 2-5 pereopods	oostegites present, in all or some pereopods
PEREON	7 pairs of pereopods (1-2 as subchelate gnathopods)	7 pairs of uniramous pereopods	5 pereopods	7 pairs of pereopods (1st pair as chelipedes)	pereopods biramous
PLEON	3 pairs of pleopods	5 pairs of pleopods biramous	5 pairs, one or few pleopods when present in males	absent, or 1-5 pairs of pleopods when present	5 pairs of pleopods
UROSOME	3 pairs of uropods	3 pairs of uropods	1 pair of uropods	1 pair of uropods	tail fan
TELSON	when present is free or bilobate	fused with 1-6 pleomeres	free or fused with the six pleomere (pleotelson)	pleotelson	with a variety of forms
STATOCYSTS	not present	sometimes present	not present	not present	present
LACINIA MOBILIS	present	present	present	present	present
SHAPE	latterally flattened	dorsoventrally flattened	comma shaped	subcylindrical and flattened	shrimp-like

1.4 Study Context

This work is integrated in the 6th Framework Programme and EU-funded project HERMES - Hotspot Ecosystem Research on the Margins of European Seas - that aims to provide scientific knowledge about the biodiversity and community structure, the deep sea floor geology, physical and chemical aspects, microbiology and biogeochemistry, in deep-sea ecosystems along the European margins (Atlantic Ocean, Mediterranean and Black Seas).

On the Portuguese margin, Nazaré, Cascais and Setúbal canyons were selected as target areas for the study of biodiversity and ecosystem functioning of submarine canyons as these geological features are amongst the most important in Europe and even worldwide.

1.4.1 Aims of the Study

The benthic assemblages in the upper, middle and lower sections of Nazaré, Cascais and Setúbal canyons and slopes were sampled during three main cruises carried out in 2005 and 2006. The present work focuses on the crustacean fauna and investigates the variability in the composition and structure of the assemblages. The specific objectives include the study of:

- the vertical distribution within the sediment (upper 20cm)

- the differences between canyon and open slopes;

- the changes along the depth gradient within canyons

- the variability between canyons

- the possible implications of using different sampling gears.

Methodology

2.1 Study Area

The study area compromises the section of the Portuguese Atlantic margin between 37°49.98′N to 39°35.02′N latitude and 9°06.00′W to 10°20.06′W longitude, where three major canyons are located: Nazaré, Cascais and Setúbal.

The Nazaré canyon is one of the largest submarine canyon of the world (Vitorino *et al.* 2005) and the northernmost of the central Portuguese canyons. Located at c.a. 39°45′N, it dissects the west Iberian margin, from east to west, starting at 50m water depth, and extending through almost 210km, to the Iberian abyssal plain at depths exceeding 4900 m (Arzola *et al.* 2008; Lastras *et al.* 2009). De Stiger *et al.* (2007) separate the canyon in upper, middle and lower sections: the first section ranges from 50 to 2700m, with a V shaped valley; the second from 2700 to 4000m, with a broad meandering valley, with terraces and V shaped valley axial channel and the last at depths greater than 4000m, with a flat valley. The Nazaré canyon is not connected to a major river, or drainage system on land. Despite this fact it still acts as a major conduit for sediment (Arzola *et al.* 2008; Lastras *et al.* 2009).

The Cascais canyon is the shortest, the steepest (›10°gradient) and the most central of the central Portuguese canyons. Located at latitudes of ca.38°25′N, it starts in the shelf at depths of ~175m and runs to the abyssal plain, at more than 4600m depth. This complex canyon in the vicinity the mouth of Tagus estuary and it sinuous (index=1.44) traject takes ca. 90km in an open U valley, and then continues 62km more as a single broader channel. Cascais canyon does probably receive its main input of organic matter from the Tagus River (Lastras *et al.* 2009).

The Setúbal Canyon is linked with Lisbon canyon, located at 37N°, is a more complex system and the southernmost of Central Portuguese Canyons. It also cuts the continental shelf starting at 150m water depth until the abyssal plain, to more than 4800m depths. The Setúbal branch starts in the mouth of Sado River and is 175km in length; Lisbon

branch is 167km long. Setúbal canyon is linked to Tagus and Sado rivers that are the two major source of organic matter (Lastras *et al.* 2009).

The open slopes of the West Portuguese margin are subjected to different environmental factors, such as landslides, current flow, sediment instability, constant flux and are considered in this study as control areas for the investigation on the canyon assemblages.

2.2 Sample Collection and Processing

The sampling of the benthic assemblages was carried out from 8th to 11th August 2005, on board of RRS Discovery (D297 cruise, NOCS); 21st April to 14th May 2006, on board RRS Charles Darwin (CD179 cruise, NOCS) and 6th 17th September 2006, on board RV Pelagia (64PE252 cruise, NIOZ) cruises, as we can sea in figure 2.1. A total of eleven stations, nine in the canyons and two in the open slopes were considered (Fig. 4).
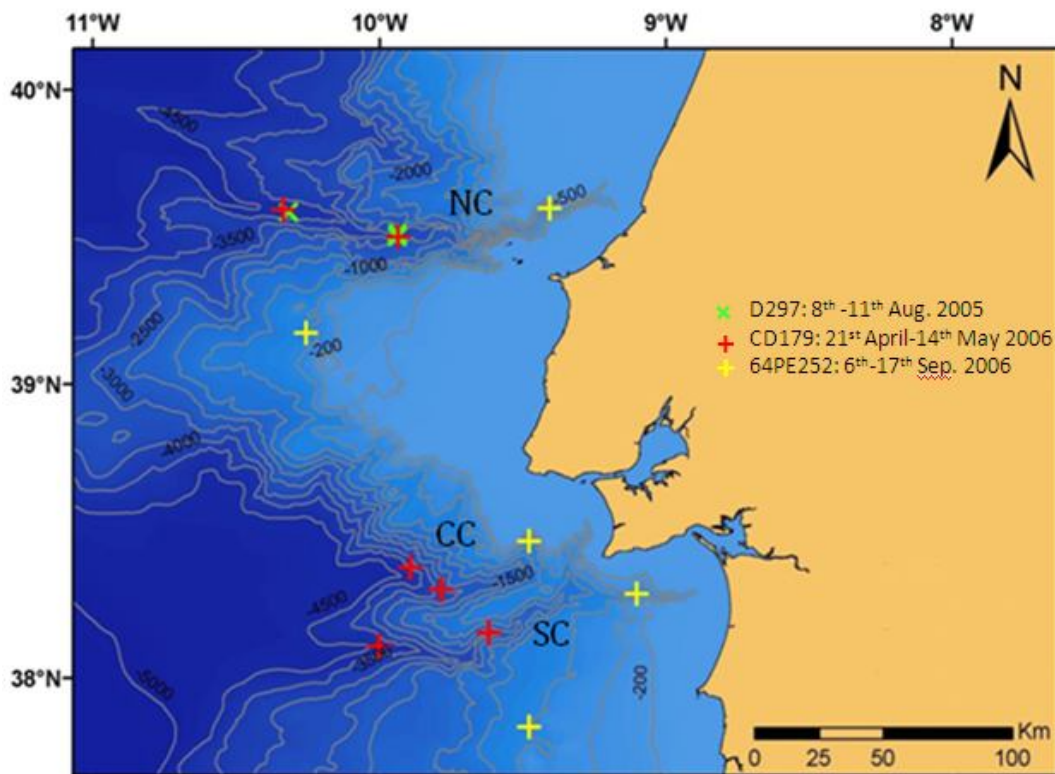
Figure 4: Bathymetric map of the 11 sampling stations, from central Portuguese canyons (NC-Nazaré Canyon, CC-Cascais Canyon and SC-Setúbal Canyon), during 2005 (D297) and 2006 (CD179 and 64PE252).

In 2005, (*D297)* only Nazaré canyon was sampled. Samples (three replicates each) were taken on the middle canyon terrace (ca. 3400m) and on the lower canyon floor adjacent to the thalweg (ca. 4300m), using a USNEL-box corer (area=0.25m^2) (Weaver 2005). In 2006, two cruises were carried out. During CD179, samples were taken from Nazaré, Setúbal and Cascais canyons, using a UKORS megacorer (multiple cylindrical cores of 0,00785m^2 internal area). In each canyon two depths (ca. 3400 and ca. 4300m) were sampled, with 4 to 5 replicates at each station (a total of 27 megacore replicates) (Billet 2006). During 64PE252 cruise, samples were taken from the three canyons and two open slope sites, one adjacent to Nazaré canyon (OS South) and one adjacent to Setúbal canyon (OS Sines) all at ca. 1000m. These 5 stations were sampled with the NIOZ circular box corer (Area=0.196m^2) (Stiger 2006).The metadata of the 45 samples considered in this study are presented in Table 2.

Table 2 - List of the samples taken for crustacean fauna in the Portuguese canyons during HERMES cruises: RSS Discovery (D297-2005), RSS Charles Darwin (CD179-2006) and RV Pelagia (64PE252-2006), using USNEL box core, UKORS megacore and NIOZ box core, respectively. Samples were taken in Nazaré (N), Cascais (C) and Setúbal (S) canyons and open slopes (OSO South of Nazaré, OSI off Sines).

Sites	Cruise	Date	Depth (m)		Sampled area (m^2)	Latitude	Longitude
15755#1	D297	8-Aug-05	3461	N	0.25	39° 30.62′N	09° 56.19′W
15758#2	D297	9-Aug-05	4364	N	0.25	39° 35.02′N	10° 18.95′W
15758#6	D297	10-Aug-05	4367	N	0.25	39° 34.99′N	10° 19.00′W
15760#1	D297	10-Aug-05	3465	N	0.25	39° 30.02′N	09° 56.17′W
15762#1	D297	11-Aug-05	3464	N	0.25	39° 30.02′N	09° 56.22′W
15765#2	D297	11-Aug-05	4336	N	0.25	39° 35.00′N	10° 19.04′W
56804#5	CD179	21-Apr-06	3275	S	0.063	38° 09.27′N	09° 36.93′W
56804#6	CD179	21-Apr-06	3275	S	0.063	38° 09.26′N	09° 36.94′W
56806#1	CD179	21-Apr-06	3275	S	0.063	38° 09.29′N	09° 36.96′W
56810#1	CD179	23-Apr-06	3224	S	0.063	38° 09.22′N	09° 37.02′W
56816#1	CD179	25-Apr-06	3275	S	0.063	38° 09.27′N	09° 36.94′W
56821#1	CD179	26-Apr-06	3219	C	0.063	38° 17.96′N	09° 46.87′W
56821#2	CD179	27-Apr-06	3214	C	0.063	38° 17.97′N	09° 46.89′W
56823#2	CD179	27-Apr-06	3218	C	0.055	38° 18.01′N	09° 47.02′W
56823#3	CD179	28-Apr-06	3219	C	0.055	38° 17.99′N	09° 47.07′W
56828#1	CD179	29-Apr-06	3199	C	0.063	38° 18.02′N	09° 46.98′W
56837#2	CD179	02-May-06	4245	C	0.063	38° 22.49′N	09° 53.40′W
56837#5	CD179	02-May-06	4241	C	0.063	38° 22.50′N	09° 53.48′W
56837#7	CD179	03-May-06	4243	C	0.063	38° 22.49′N	09° 53.52′W

Sites	CRUISE	Date	Depth (m)		Sampled area (m^2)	Latitude	Longitude
56837#8	CD179	03-May-06	4244	C	0.063	38° 22.49′N	09° 53.52′W
56838#2	CD179	03-May-06	4482	S	0.063	38° 06.50′N	09° 59.98′W
56838#3	CD179	04-May-06	4482	S	0.063	38° 06.49′N	09° 59.94′W
56838#4	CD179	04-May-06	4485	S	0.055	38° 06.52′N	09° 59.99′W
56842#1	CD179	05-May-06	4482	S	0.063	38° 06.45′N	09° 59.94′W
56842#2	CD179	05-May-06	4485	S	0.063	38° 06.49′N	09° 59.97′W
56851#1	CD179	09-May-06	3517	N	0.063	39° 29.99′N	09° 55.97′W
56851#2	CD179	09-May-06	3517	N	0.063	39° 29.99′N	09° 56.01′W
56856#1	CD179	11-May-06	3519	N	0.039	39° 29.95′N	09° 56.00′W
56856#2	CD179	11-May-06	3522	N	0.055	39° 30.00′N	09° 55.98′W
56847#6	CD179	08-May-06	4403	N	0.063	39° 35.57′N	10° 19.99′W
56847#7	CD179	08-May-06	4404	N	0.055	39° 35.55′N	10° 20.06′W
56859#1	CD179	12-May-06	4418	N	0.055	39° 35.58′N	10° 20.00′W
56861#1	CD179	14-May-06	4404	N	0.047	39° 35.57′N	10° 20.02′W
27BC1	64PE252	06-Sep-06	1030	OSSO	0.196	39° 10.36′N	10° 15.23′W
27BC2	64PE252	06-Sep-06	1030	OSSO	0.196	39° 10.36′N	10° 15.23′W
36BC2	64PE252	18-Sep-06	935	C	0.196	38° 27.89′N	09° 28.51′W
36BC3	64PE252	18-Sep-06	1014	C	0.196	38° 27.86′N	09° 28.49′W
36BC4	64PE252	18-Sep-06	1020	C	0.196	38° 27.90′N	09° 28.50′W
43BC1	64PE252	11-Sep-06	897	N	0.196	39° 35.80′N	09° 24.25′W
43BC3	64PE252	11-Sep-06	897	N	0.196	39° 35.80′N	09° 24.24′W
56BC1	64PE252	16-Sep-06	1001	OSSI	0.196	37° 49.99′N	09° 28.50′W
56BC2	64PE252	16-Sep-06	1001	OSSI	0.196	37° 49.95′N	09° 28.49′W
56BC3	64PE252	16-Sep-06	1001	OSSI	0.196	37° 49.98′N	09° 28.49′W
61BC1	64PE252	17-Sep-06	970	S	0.196	38° 17.10′N	09° 05.98′W
61BC2	64PE252	17-Sep-06	970	S	0.196	38° 17.10′N	09° 06.01′W
61BC3	64PE252	17-Sep-06	970	S	0.196	38° 17.10′N	09° 06.00′W

For the biological analyses, the upper 20cm of the sediment cores were sliced in to six different layers, whenever possible: A: 0-1cm; B: 1-3cm; C: 3-5cm; D: 5-10cm; E: 10-15cm and F: 15-20cm (Fig. 4). This methodology follows the standard techniques discussed in the Census of Marine Life workshop on the study of "Biodiversity of Deep-sea Sediments" and adopted as general practice in HERMES. In some sites, only the 10cm of the sediment were sampled, and the sediments with more than 10cm, that were not sieved, were only examined for larger fauna. Prior to sieving, the sediment layers 0-1 and 1-3cm where placed at once in formalin. All material from the six layers including the overlying water in the 0-1cm sample, were carefully washed with seawater through 500μm and 300μm sieves. The sieved material was fixed in 10% buffered formalin in

seawater, or in 96% ethanol (in the case of the cruise 64PE252). Than the material was stored and brought to the laboratory on land where the material was sieved.
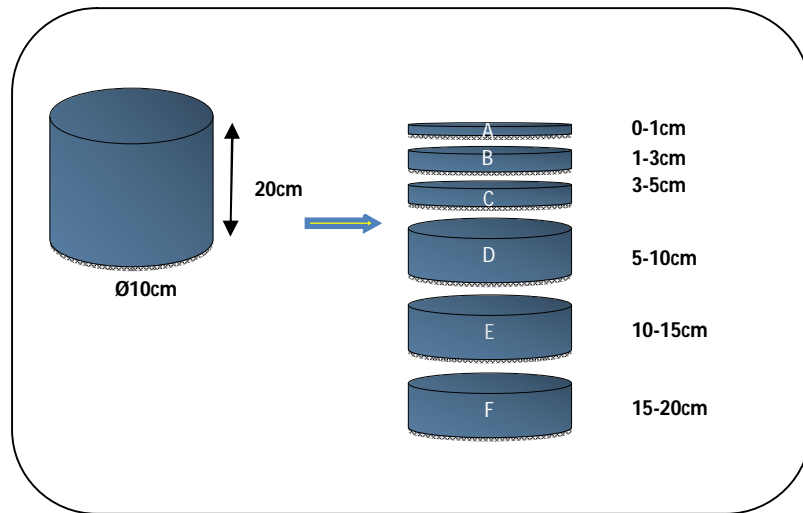
Figure 5: Procedure adopted on the three cruises, resulting: A=0-1cm, B=1-3cm, C=3-5cm, D=5-10cm, E=10-15cm and F=15-20cm sediment layers.

Crustacean specimens were identified to the lowest possible taxonomic level and counted under a stereoscope microscope. All Amphipoda and Isopoda species were photographed using Nikon NIS-Elements digital system and software. The taxonomic list of the collected species is in the Appendix 1 and the Amphipoda and Isopoda species photos are in the Appendix 2 and Appendix 3 respectively. As many species could not match the descriptions found in the available literatures many of them were identified by a unique code (eg. AMPSP077).

2.3 Data Analysis

2.3.1 Univariate and Distributional Analyses

The data were built in a species vs station abundance matrix integrating all sediment layers, in order to investigate the variability of the crustacean assemblages from the Portuguese canyons.

Univariate measures such as: Shannon-Wiener diversity index (H') and Pielou's evenness index (J') were estimated using the software PRIMER v6 (Clarke & Warwick 1994) Distributional analysis was carried out using K-dominance curves. K-dominance curves consist of plotting the cumulative ranked abundances (y-axis) against species (x-axis) that are ordered by decreasing abundances, in a logarithmic scale. The shape of the curve and the Y intersection allow some interpretation of community structure. Communities dominated by a small number of species have a high value of y-axis intersection point. Curves with a long "tail" indicate a large quantity of rare species in the community.

2.3.2 Multivariate Analysis

Multivariate analysis was performed using the statistical package PRIMER v6. Non-metric MDS ordination was performed using the Bray-Curtis similarity measure, after fourth root transformation of the data. An analysis of similarities by permutation tests (ANOSIM) was performed on each MDS results.

Because different sampling gears were used in different cruises the data were analyzed according to the following objectives and test designs:

- One-way ANOSIM was performed to assess the significance of differences between canyons and open slopes using the data (obtained in two open slope sites and three canyon sites at ca. 1000m depth during 64PE252.

- A two-way crossed layout ANOSIM was performed to assess the significance of differences between depths (3400m vs 4300m) and between canyons (Nazaré, Cascais and Setúbal) using the data obtained during CD179.

- A two-way crossed layout ANOSIM was performed to assess dissimilarities between different samplers (box core vs megacore) and between different depths (3400m vs 4300m) using the data obtained for Nazaré canyon during D297 and CD179.

Results

A total of 1260 specimens were counted and ascribed to 157 nominal taxa, in 47 families and six crustacean orders in the material gathered from Nazaré, Cascais and Setúbal Canyons and Open slopes of central West Iberian margin, between 2005 and 2006. The Tanaidacea were represented by 619 specimens in 40 nominal taxa and were the most abundant group, followed by the most speciose group, the Isopoda with 376 specimens in 61 nominal taxa, and then the Amphipoda with 183 specimens in 32 nominal taxa, Cumacea with 80 specimens with 22 nominal taxa and finally Decapoda and Mysidacea with only one specimen in one taxa each (Fig. 6).
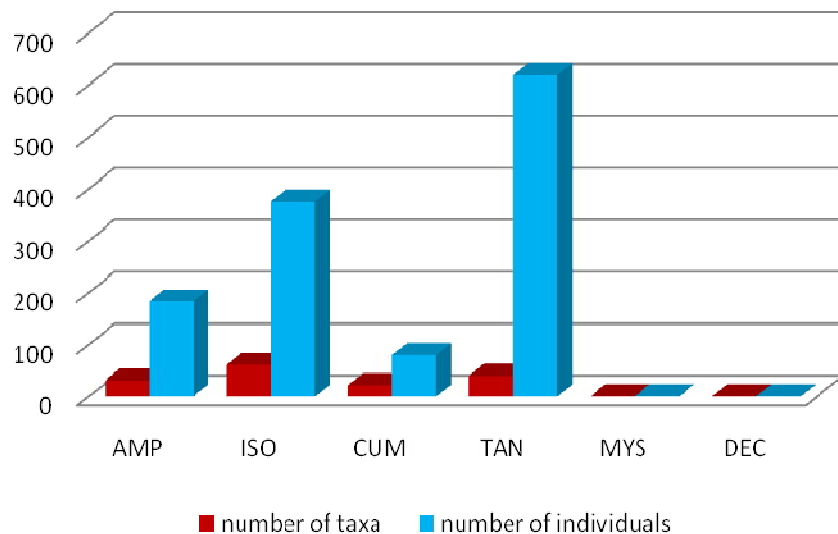
Figure 6: Crustacean specimen examined showing a total of 1260 individuals, data collected during D297, CD179 and 64PE252 cruises, between 2005 and 2006. AMP (Amphipoda), ISO (Isopoda), CUM (Cumacea), TAN (Tanaidacea), MYS (Mysidacea) and DEC (Decapoda).

The lowest species richness (Fig. 7) was observed in Nazaré at 3400m in 2006 (20 taxa) and the highest in Setúbal canyon at 3400m in 2006 (47 taxa). Globally the taxa richness was consistently higher in Cascais and Setúbal than in Nazaré canyon at all depths. Amphipoda and Cumacea showed the highest diversity at lower depths, while Isopoda and Tanaidacea revealed the opposite trend.
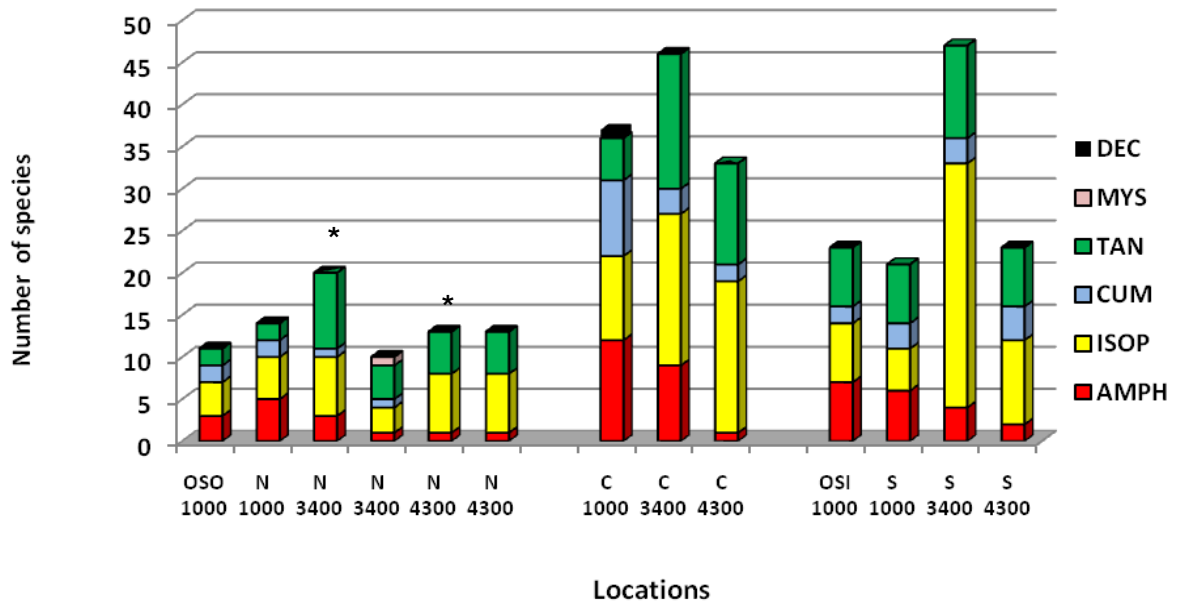
Figure 7: Species richness in the different sampling station from the Portuguese Canyons. The values are pooled from all replicates in one site. Samples taken in the same site at consecutive years (Nazaré 3400m and 4300m) were kept separate. *Samples taken during D297 in 2005.

The crustacean abundance (Fig. 8) showed the lowest values in open slopes (OSO: 36ind.m $^{-2}$, OSI: 93ind.m $^{-2}$) and high variability within and between canyons although the highest values were found consistently at 3400m in all canyons (Nazaré: 537 ind.m $^{-2}$; Cascais Canyon: 624 ind.m $^{-2}$; Setúbal Canyon: 477 ind.m $^{-2}$).

The composition and structure of the assemblages also showed important differences either within and between canyons or between open slopes and canyons (Fig. 9). Some crustacean groups were dominant (eg. Gammaridea and Cumacea) and sometimes almost restricted to the shallower depths (eg. Apseudomorpha, Cymothoida and Corophiidea) while others were dominant at greater depths (eg. Tanaidomorpha); Asellota was the most speciose group and could be found at all locations and depths, nervetheless with high consistently higher abundance at greater depths.

The estimated indices of diversity and evenness (Table 3) reflect some of the features in the structure of the assemblages such as the high dominance (low evenness and diversity) in Nazaré canyon at 3400m and the consistently highly diverse crustacean assemblage at Cascais canyons.
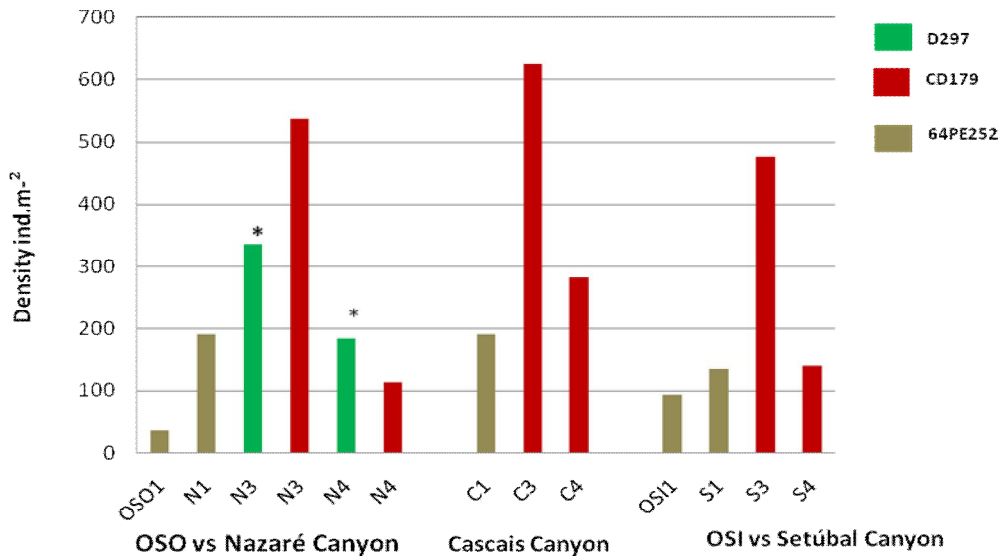
Figure 8: Crustacean abundance in the different studied sites, during D297, CD179 and 64PE252 cruises. The values are averages from the replicates taken in each site expressed as ind.m-². Samples taken in the same site at consecutive years (Nazaré 3400m and 4300m) were kept separate. *Samples taken during D297 in 2005.

Table 3: Univariate biodiversity indices for each station sampled during D297, CD179 and 64PE252 cruises. Values are average from replicates in each station: n= number of replicates; S: number of species; N: densities (ind.m-²); J': Pielou's evenness index and H' (log e) Shannon-Wiener diversity index.

	n	S	N	J'	H'(loge)
OSO	2	11	35.7	0.961	2.30
N1	2	14	191.3	0.689	1.82
N3D	3	20	336.0	0.289	0.87
N4D	3	20	185.3	0.743	2.22
N3C	4	10	533.5	0.392	0.90
N4C	4	13	112.7	0.914	2.34
C1	3	37	192.2	0.872	3.15
C3	5	46	510.7	0.898	3.44
C4	4	33	281.7	0.940	3.29
OSI	3	23	93.5	0.883	2.77
S1	2	21	135.2	0.896	2.73
S3	5	47	476.2	0.881	3.39
S4	5	23	139.3	0.950	2.98
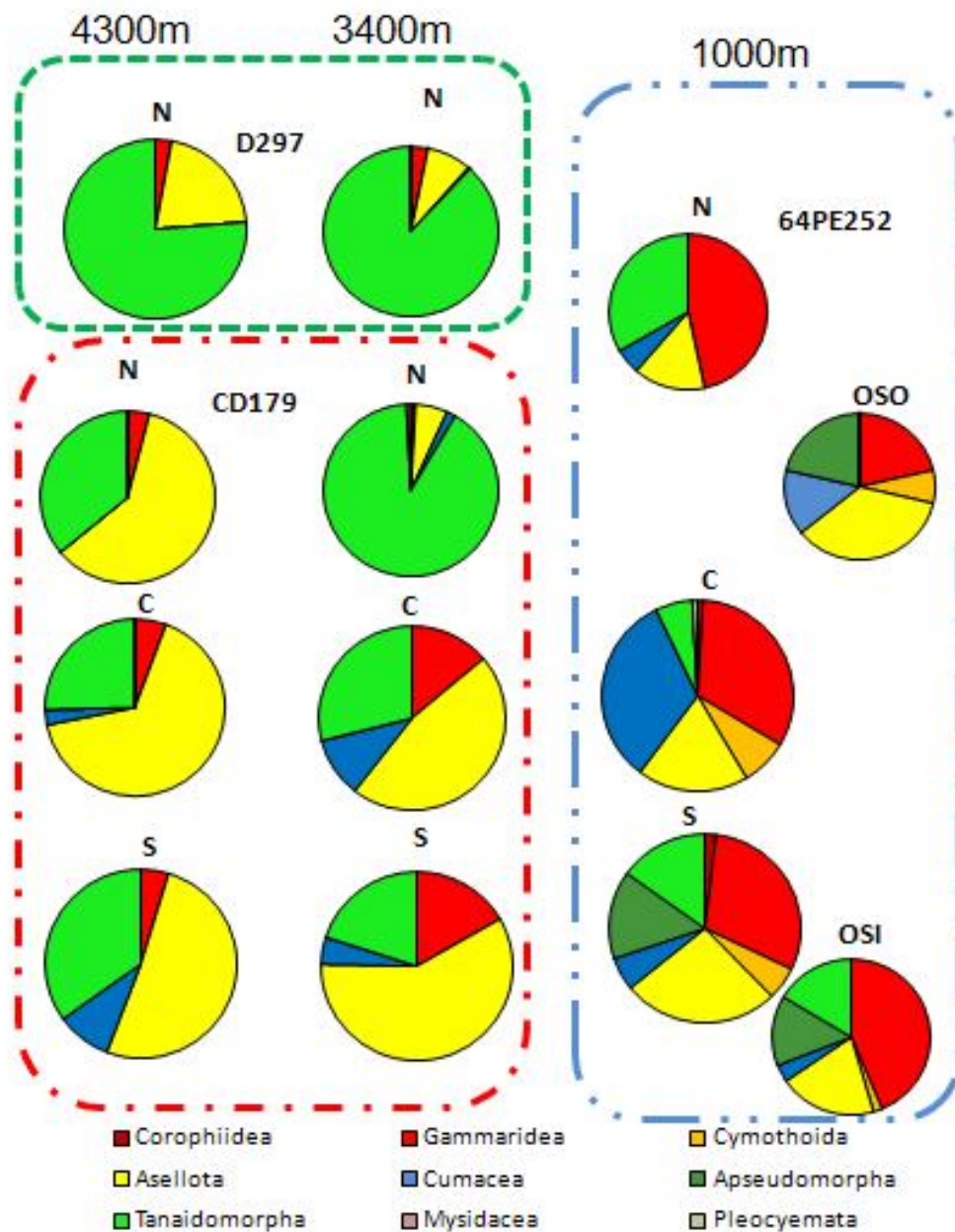
Figure 9: Composition and structure of the crustacean assemblages from the study sites in the Portuguese canyons: Nazaré (N), Cascais (C), and Setúbal (S) and Open slope South Nazaré (OSO) and Open slope Sines (OSO) at 1000, 3400 and 4300m of depth, until subOrder taxonomic level.

The variability in the composition and structure of the crustacean assemblages will be further discussed in relation to the results of the multivariate analyses.

3.1 Vertical Distribution Within the Sediment

The results on the vertical distribution of the crustacean fauna within the sediment layers (first 20 cm) are presented in figures 10 (cruise D297), 11 (cruise CD179), and 12 (cruise 64PE252).

The assemblages sampled during 2005 in Nazaré canyon (2005) at 3400m and 4300m (Fig.10) reveal similar trends with crustacean densities decreasing with sediment layer although at 3400m the maximum density is observed at subsurface (1-3cm).
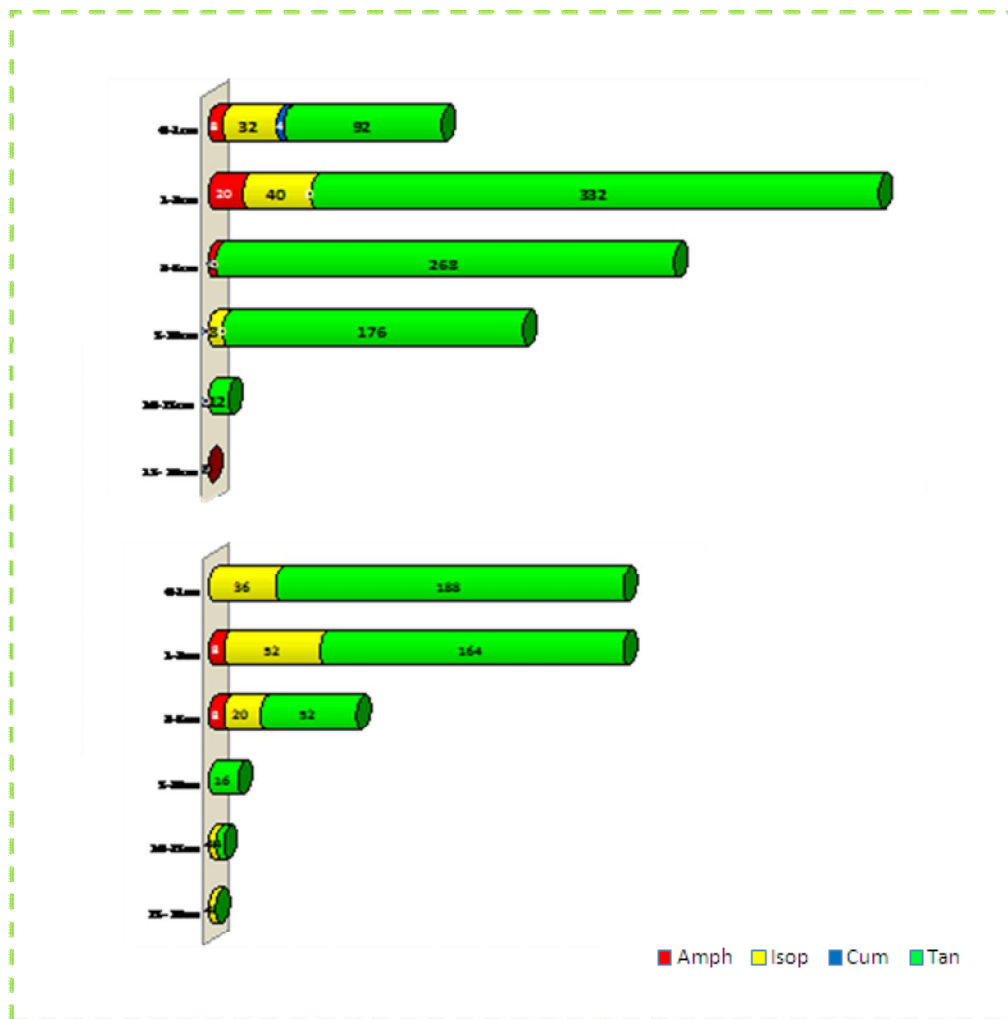
Figure 10: Vertical distribution of crustacean fauna within the sediment (ind.m^{-2}). Data from Nazaré canyon at 3400m and 4300m depths, obtained during D297 cruise, in 2005.
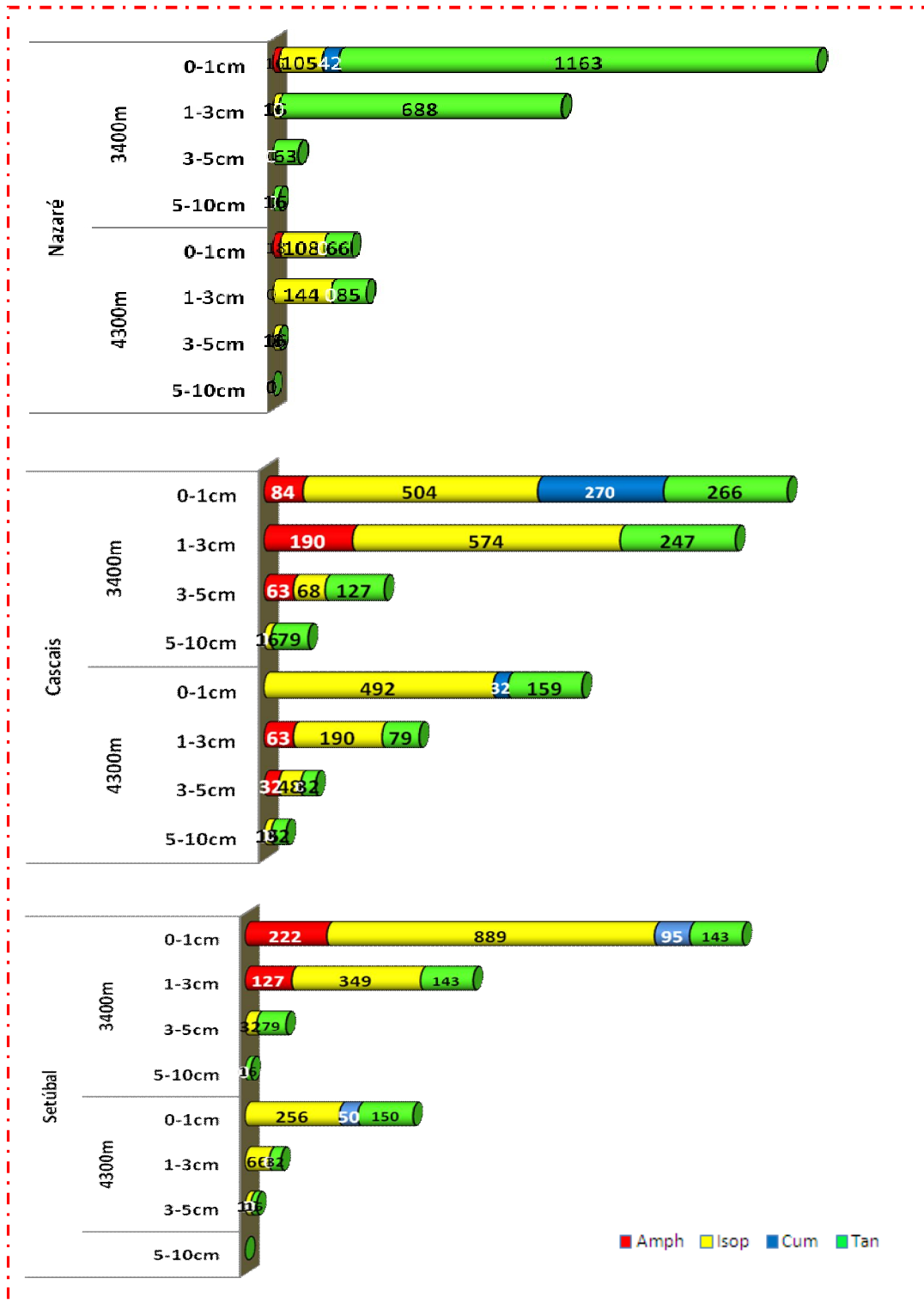
Figure 11: Vertical distribution of crustacean fauna within the sediment (ind.m^{-2}). Data from Nazaré, Cascais and Setúbal canyons at 3400m and 4300m depths, obtained during CD179 cruise, in 2006.

The trends in the vertical distribution observed in the samples collected during the cruise CD179 (2006) indicate generally that there is a decrease in density, from 0-1 to 5-10cm (Fig. 11). The only exception is Nazaré canyon at 4300m where a slight increase at the subsurface (1-3cm) is recorded. Cumaceans are only recorded at the surface of the sediments while Isopoda and Tanaidacea usually also reach high densities deeper in the sediment.
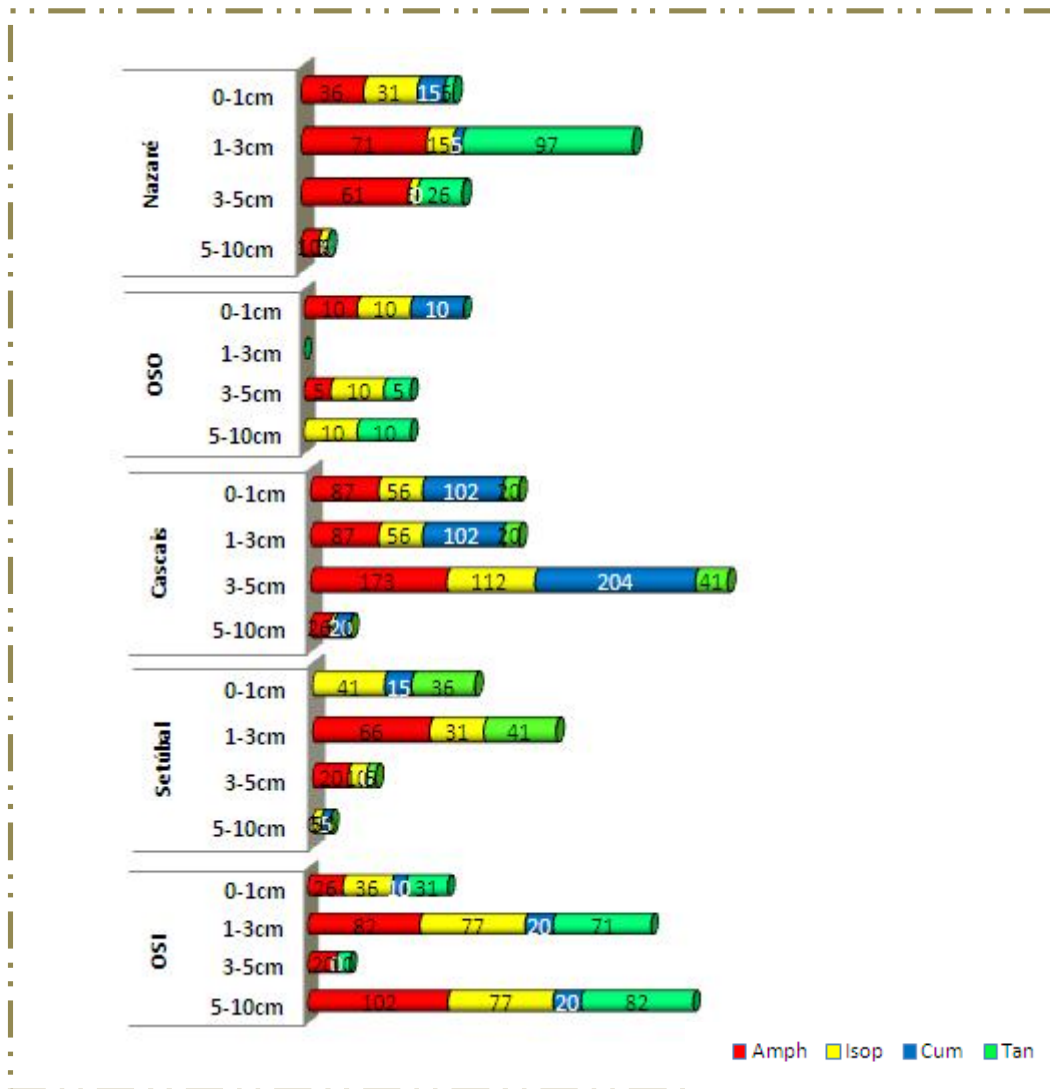
Figure 12: Vertical distribution of crustacean fauna within the sediment (ind.m^{-2}). Data from Nazaré, Cascais and Setúbal canyons and Slopes (OSO; OSI) at 1000m depth, obtained during 64PE252 cruise, in 2006.

The analysis of the data from 64PE252 cruise at 1000m depths in canyons and slopes shows heterogeneous results. Nazaré and Setúbal show an increase in the density of crustaceans at the subsurface (1-3cm). The maximum density is reached at 3-5cm sediment layer In Cascais and at 5-10 cm in OSI. A decreasing trend in the vertical distribution of crustaceans at the stations located at 1000m is only observed in OSO (Fig. 12). At 1000m depths the amphipods and cumaceans are found burrowing deeper in the sediment than in the stations sampled at greater depths.

3.2   Canyons vs Open Slopes (cruise 64PE252)

A total of 310 specimens were sampled in Pelagia cruise, from the five stations sample at 1000m depth. Amphipoda was the most abundant order (117 ind.) followed by Isopoda (76 ind.) and then Tanaidacea and Cumacea (69 and 48 ind., respectively). The Decapoda order is represent only by one specimen. To assess differences between canyons and slopes the data was subjected to multivariate analysis. The MDS plot (Fig. 13) shows a clear segregation of the two groups of samples. The one way ANOSIM results confirm the significance of differences between canyons and slopes (R: 0.473; significance level: 0.1%)

Except for the lower densities observed in the open slopes (Fig. 8) there is no clear trend in the composition and structure of the crustacean assemblages at 1000m. The assemblages are very heterogeneous: the species richness in OSO and OSI (Fig. 7) were similar to the adjacent canyons (Nazaré and Cascais, respectively). Cumacea show a high species richness and density in Cascais canyon but also occur in the other stations; Apseudomorpha are abundant in the open slopes but also in Setúbal while Cymothoidae occur in Cascais and Setúbal canyons but are also present in OSO (Figs 8 and 9).
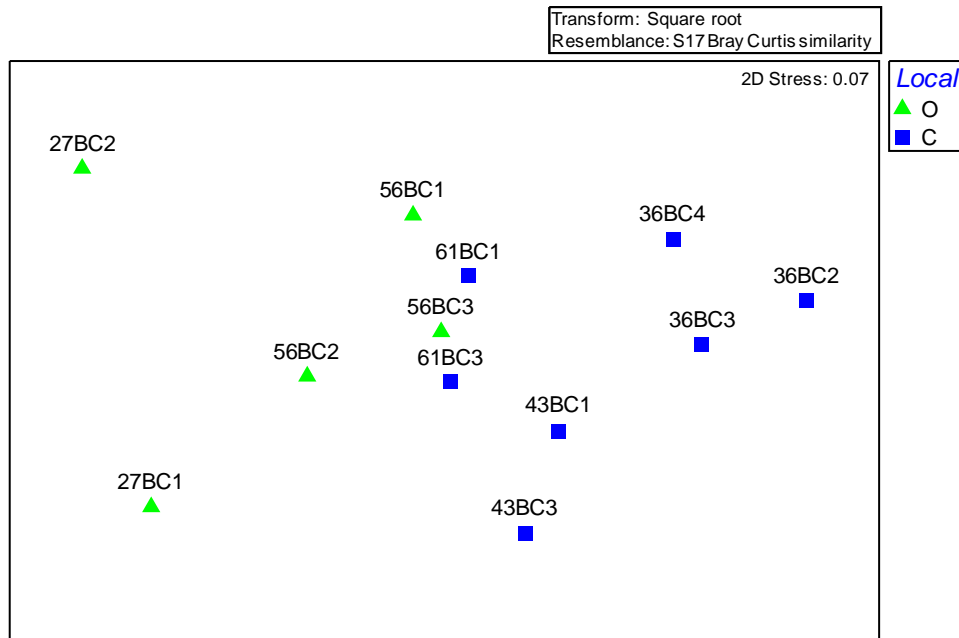
Figure 13: MDS plot of the analysis performed on the crustacean data from samples collected during 64PE252 cruise. Labels of sampling station as in Table 2.

The k-dominance curves (Fig. 14) show that the assemblages of Cascais and Setúbal canyons are slightly less dominated than the open slope assemblages but the lowest diversity and evenness occurs in Nazaré canyon (Fig. 14 and Table 4). In fact, diversity indices are higher for Cascais and Setúbal (Table 4) but the highest evenness occurs at OSO.

The analysis of the most dominant species (Table 5) also illustrates the high heterogeneity in the crustacean assemblages at 1000m. The amphipod *Carangoliopsis spinulosa* (in Nazaré, Setúbal and OSI) and the tanaid Apseudidae SP044 (in OSO, OSI and Setúbal) are the only species that rank amongst the six dominant in three sites. From the Amphipoda two Phoxocephalidae (*Metaphoxus* SP050 and *Harpinia* spp.065) and one Ampeliscidae (*Haploops* cf. *setosa*) species were dominant in Cascais and OSI, respectively and from the Tanaidacea a few other species are ranked among the dominant in all sites except Cascais. There were several dominant Isopoda, namely some Desmosomatidae (eg. *Chelator* cf. *verecundis* in Setúbal and OSI, *Chelator* cf. *insignis* in Nazaré; *Eugerda*

tetarta in OSI and Cascais), Anthuridea (*Bullowanthura* cf. *aquitanica* OSO; *Paranthura* SP066 in Cascais) and Munnopsidae (*Ilyarachna* SP078 in Setúbal OSO).
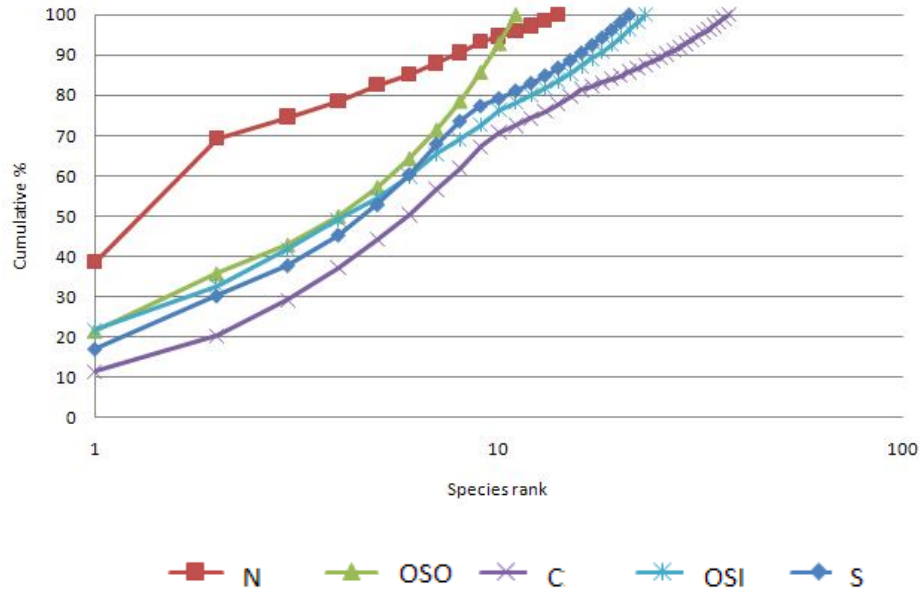
Figure 14: k –dominance curves for the five 64PE252 cruise sampling sites.

Table 4: Univariate biodiversity indices for the five stations sampled during 64PE252 cruise. Values are average from replicates in each station: n= number of replicates; S= number of species; N= densities (ind.m^{-2}); J'= Pielou's evenness index and H' (log e)= Shannon-Wiener diversity index.

Site	n	S	N	J'	H'(loge)
N	2	9.5	191.3	0.710	1.59
C	3	18.7	192.2	0.917	2.67
S	2	14.0	135.2	0.930	2.44
OSO	2	6.0	35.7	0.975	1.60
OSI	3	11.0	93.5	0.923	2.20

Among the Cumacea two species of *Leucon* SP004 are dominant in Cascais and Nazaré; Nannastacidae SP013 and Diastylidae SP014 also rank as dominant in OSO. Although Nazaré canyon and the adjacent open slope (OSO) show highly divergent assemblages, Setúbal Canyon shares three dominant species with its adjacent open slope (*Carangoliopisis spinulosa*, Apseudidae SP044 and *Chelator* cf. *verecundis*).

Table 5: Six dominant crustacean species for each studied site and depth (canyons and slopes; 1000 m, 3400 m and 4300 m) expressed in percentage.*Dominant species obtained during D297 cruise were kept separate.

	1000 m	%CUM	3400 m	%CUM	4300 m	%CUM
OSS	*Bullowanthura* cf. *aquitanica*	21.43				
	Apseudidae SP044	35.71				
	Sphyrapus malleolus	42.86				
	Nannastacidae SP013	50.00				
	Diastylidae SP014	57.14				
	Ilyarachna SP078	64.29				
OSI	*Carangoliopsis spinulosa*	21.82				
	TANSP037	32.73				
	Apseudidae SP044	41.82				
	Haploops cf. *setosa*	49.09				
	Chelator cf. *verecundis*	54.55				
	Eugerda tetarta	60.00				
N*			Pseudotanaidae SP051	83.33	TANSP066	31.65
			Chauliodoniscus SP046	88.10	TANSP052	48.92
			Harpinia spp. SP065	90.48	Pseudotanaidae SP051	65.47
			TANSP068	92.06	Desmosomatidae spp.	70.50
			Desmosomatidae spp.	93.25	Anarthuridae SP013	75.54
			Eugerda tetarta	94.05	*Macrostylis* aff. *subinermis*	79.86
N	*Carangoliopsis spinulosa*	38.67	Pseudotanaidae SP051	78.73	Pseudotanaidae SP051	19.14
	TANSP046	69.33	TANSP064	87.76	*Momedossa* SP089	35.96
	Chelator cf. *insignis*	74.67	*Iyarachna* SP077	90.73	*Chelator* cf. *insignis*	51.59
	Leucon SP004	78.67	Pseudotanaidae SP041	92.68	*Macrostylis* aff. *longiremis*	60.34
	Desmosomatidae spp.	82.67	*Eudorella* SP017	94.62	*Eugerdella* SP091	67.89
	cf.Tanaellidae SP040	85.33	*Eugerda tetarta*	96.57	Thambematidae SP098	72.62
C	Leucon SP004	11.50	*Macrostylis* cf. *abyssicola*	11.90	*Rapaniscus* SP095	11.27
	Metaphoxus SP050	20.35	Lampropidae SP018	21.38	*Chelator* cf. *insignis*	18.31
	Harpinia spp. SP065	29.20	*Chelator* cf. *insignis*	26.57	*Harpinia* spp. SP065	23.94
	Eugerda tetarta	37.17	TANSP057	31.40	*Haploniscus* aff. *antarticus*	29.58
	Leucon SP005	44.25	cf.Agathotanaidae SP048	35.96	*Macrostylis magnifica*	35.21
	cf. *Paranthura* SP066	50.44	cf. *Thambema* SP093	39.99	*Eurycope* SP079	39.44
S	*Carangoliopsis spinulosa*	16.98	*Haploniscus* cf. *charcoti*	12.00	Pseudotanaidae SP051	11.73
	Apseudidae SP044	30.19	*Harpinia* spp. SP065	20.00	*Ischnomesus* cf. *norvegicus*	21.18
	cf. Tanaellidae SP040	37.74	*Macrostylis* cf. *abyssicola*	27.33	*Chelator* cf. *insignis*	30.29
	Desmosomatidae spp.	45.28	AMPSP072	34.67	Desmosomatidae spp.	37.46
	Chelator cf. *verecundis*	52.83	*Haploniscus* cf. *foresti*	40.67	TANSP052	42.69
	Ilyarachna SP078	60.38	*Mirabilicoxa* sp. SP037	45.33	TANSP063	47.24

3.3. Variability Within and Between Canyons (CD179 cruise)

A total of 559 specimens (101 taxa) were sampled in CD179 cruise, from Nazaré, Cascais and Setúbal canyons at 3400 and 4300m depths. Isopoda was the most abundant order, with 250 individuals (49 taxa) fallowed by Tanaidacea with 223 individuals (27 taxa)

and then Amphipoda and Cumacea, with 54 (14 taxa) and 31 (10 taxa) individuals respectively. The Mysidacea order is represent only by one specimen.

The MDS plot in Figure 15 shows the variability between and within the three canyons samples. Along the horizontal axis there is a clear separation of the three canyons (Nazaré, Setúbal and Cascais, from left to right) while the vertical axis separated samples according depths (Cascais and Setúbal at 3400m and Nazaré at 4300m in the bottom and the remaining in the top). The samples from Cascais and Setúbal at 3400m show a low dispersion indicating a high similarity of these assemblages.
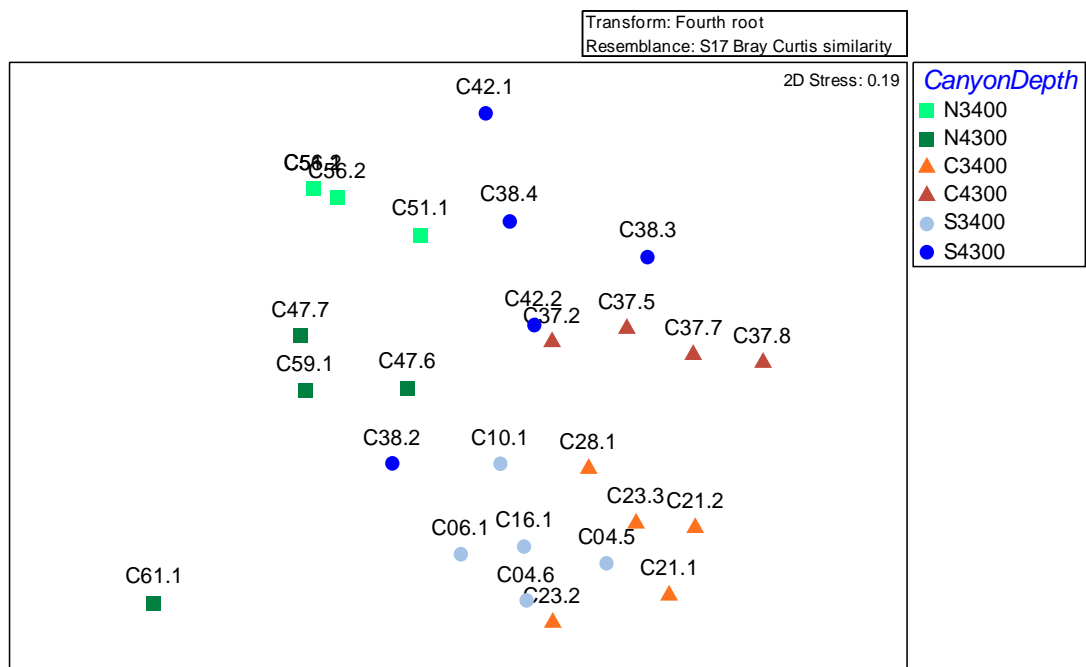
Figure 15: MDS plot of the analysis performed on the crustacean data from samples collected during CD179 cruise. Labels of sampling station as in Table 2.

The two-way crossed ANOSIM results show that the differences between canyons and between depths are both highly significant with a slight predominance of depth differences (R: 0.79) over canyon differences. Pairwise tests confirm the significant differences between canyons pointing out to a higher dissimilarity between Nazaré and Cascais or Nazaré and Setúbal than between Cascais and Setúbal (Table 6).

Table 6: Results of the ANOSIM global and pairwise tests for the MDS performed for the samples collected during CD179 cruise. Two-way crossed analysis; Factors: depth (3400 and 4300m); site N (Nazaré), S (Setúbal) and C (Cascais).

	Sample statistic (Global R)	Permutations used	Significant statistics	Significance level %
Global test				
Depth	0.79	999	0	0.1***
Canyon	0.72	999	0	0.1***
Pairwise tests				
N, C	0.869	999	0	0.1***
N, S	0.711	999	0	0.1***
C, S	0.561	999	1	0.2**

In terms of species richness the crustacean assemblages in Nazaré canyon show much lower values than Cascais and Setúbal (Fig. 7) but the difference in densities is not so remarkable. In fact the major differences in densities are related to the depth gradient with the deeper assemblages showing lower densities in all canyons (Fig. 8). The composition and structure of the assemblages (Fig. 9) in Cascais and Setúbal is dominated by Asellota and Tanaidomorpha with also an important contribution of Gammaridea at 3400m; in Nazaré the assemblage is highly dominated by Tanaidomorpha at 3400m while at 4300m the structure of the assemblage at the sub-order level is closer to the other canyons.

The higher dominance of the Nazaré assemblages is reflected by the elevated k-dominance curves (Fig. 16); in the other two canyons at both depths, the k-dominance curves are low and almost overlapping. These features are confirmed by the univariate diversity and evenness indices with globally higher values in Cascais and Setúbal and rather low values in Nazaré. The depth trend is towards a decrease in diversity and increase in evenness at the deeper stations in Cascais and Setúbal while in Nazaré both the diversity and the evenness are higher at 4300m (Table 7).

Table 7: Univariate biodiversity indices for the 27 stations sampled during 27 CD179 cruise. Values are average from replicates in each station: n= number of replicates; S= number of species; N= densities (ind.m^{-2}); J'= Pielou's evenness index and H'(log e)= Shannon-Wiener diversity index.

	n	S	N	J'	H'(loge)
N3400	4	10	533.5	0.392	0.90
N4300	4	13	112.7	0.914	2.34
C3400	5	46	510.7	0.898	3.44
C4300	4	33	281.7	0.940	3.29
S3400	5	47	476.2	0.881	3.39
S4300	5	23	139.3	0.950	2.98
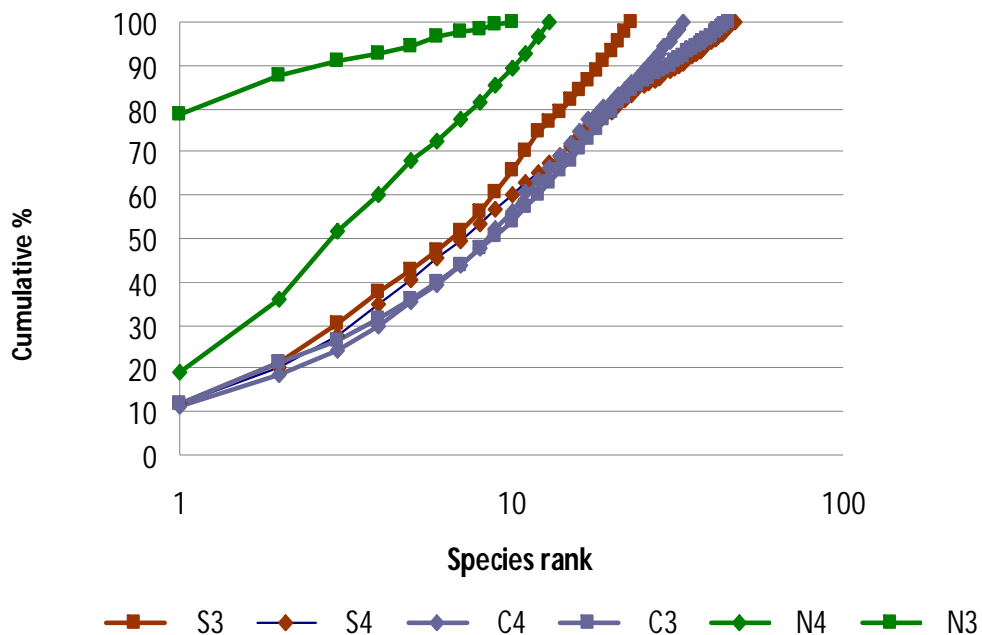
Figure 16: k –dominance curves for the twenty seven CD179 cruise sampling sites.

Although the crustacean assemblages in the three canyons are dominated by Tanaidomorpha and Asellota only one tanaid and one isopod are common to more than two stations in the listing of dominant taxa (Table 5; Pseudotanaidae SP051 in Nazaré 3400, Nazaré 4300m and Setúbal 4300m and *Chelator* cf. *insignis* in Nazaré 4300m, Cascais 3400m, Cascais 4300m and Setúbal 4300m). Several other species of Tanaidomorpha are among the dominant in Nazaré 3400m, Cascais 3400m and Setúbal 4300m and other different species of Desmosomatidae in Nazaré and Setúbal at both

depths. Other dominant isopods include Macrostylidae (4 species in Nazaré 4300m, Setúbal 3400m and Cascais at both depths), Haploniscidae (3 species in Setúbal 3400m and Cascais 4300m), Munnopsidae (2 species), Thambematidae (2 species), Nannoniscidae (1 species) and Ischnomesidae (1 species). Amphipoda (Phoxocephalidae) and Cumacea rank among the dominant only in Setúbal 3400m and Cascais 4300m and in Nazaré 3400m and Cascais 3400m, respectively (Table 5).

3.4 Variability Between Sampling Gears / years (D297 vs CD197)

Samples from the Nazaré canyon at 3400 and 4300m were collected in 2005 (D297) and in 2006 (CD179) using different sampling gears (USNEL box core vs UKORS megacore) and covering different sampling areas (see Table 2). The change in methodology may influence the biological collection and difficults the interpretation of putative interannual variability in the composition and structure of the assemblages. The MDS plot of the Nazaré samples (Fig. 17) show a clear segregation of the 3400m and 4300m samples along the horizontal axis and of the sampling gear/year along the vertical axis.
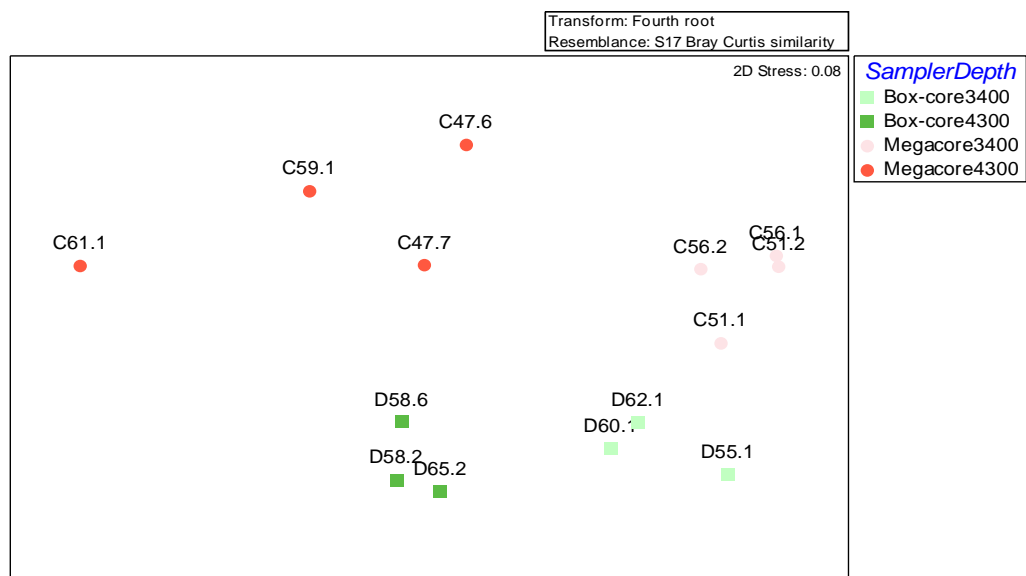
Figure 17: MDS plot of the analysis performed on the crustacean data from samples collected in Nazaré canyon during D297 and CD179 cruises. Labels of sampling station as in Table 2.

The two way crossed ANOSIM results confirm that both the differences between samplers/years and depths are very significant (Table 8).

Table 8: Results of the ANOSIM global tests for the MDS performed for the samples collected during D297 and CD179 cruises. Two-way crossed analysis, factors: depth (3400 and 4300m) and sampler/year (Box core/2005 and megacore/2006) in Nazaré Canyon.

	Sample statistic (Global R)	Permutations used	Significant statistics	Significance level %
Global test				
Depth	0.887	350	1	0.3**
Sampler	0.722	999	1	0.2**

The effect of the smaller area collected during 2006 is readily noticed by the decrease in the average number of species per replicate (S in Table 9). This decrease is also seen in the pooled taxa richness per station (Fig. 7) but only at 3400m. Although the number of individuals collected was lower in 2006 (smaller sampling area) the estimated density of the assemblages suffers an increase at 3400m and a decrease at 4300m (Fig.8). The composition and structure of the assemblages at the sub-order level (Fig. 9) changes little at 3400m with the Tanaidomorpha accounting for more than 80% of the total abundance in both years. However, at 4300m there is a marked shift in dominance from Tanaidomorpha in 2005 to Asellota in 2006. Apparently this strong taxonomic shift in dominance has little effect in the k-dominance curves (Fig. 17): the curves for the 4300m assemblages are close together and much lower than the ones for the 3400m assemblages.

Despite the high dominance at the sub order level of all crustacean assemblages from Nazaré the H′ and J′ values show a high evenness and rather high diversity at 4300m and low evenness and low diversity at 3400m (Table 9). Differences between gears/years are less marked but point out to a decrease in diversity and increase in evenness from the box core samples in 2005 to the megacore samples in 2006.
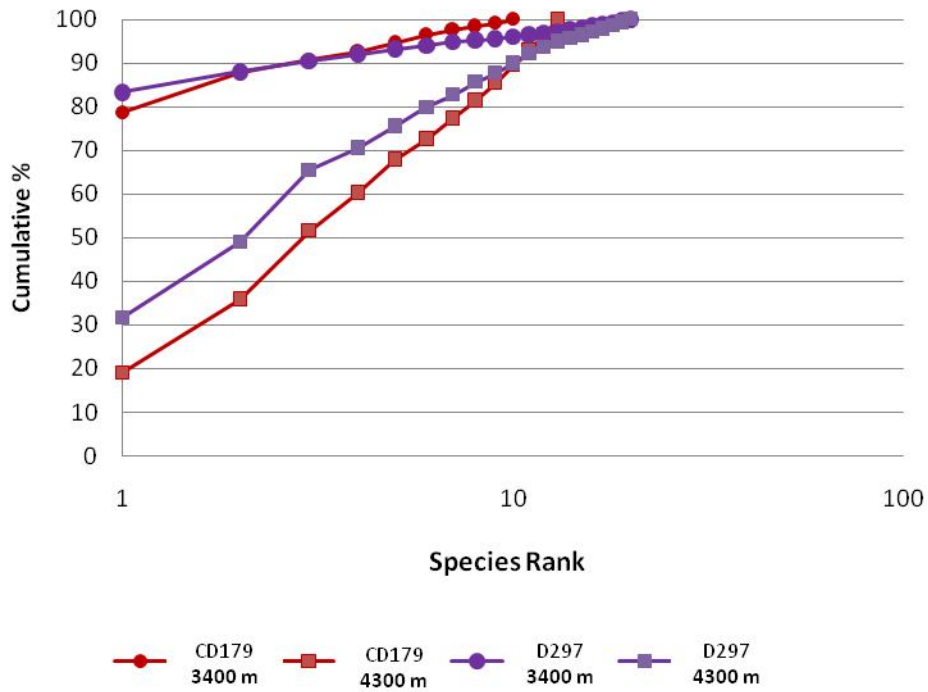
Figure 18: k –dominance curves for the fourteen D279 and CD179 cruises sampling sites.

Table 9: Univariate biodiversity indices for the 14 stations sampled with a box-core during the D297 cruise (2005) and with a megacore during the CD179 cruise (2006). Values are average from replicates in each station: n= number of replicates; S= number of species; N= densities (ind.m^{-2}); J'= Pielou's evenness index and H'(log e)= Shannon-Wiener diversity index.

Cruise/Depth	n	S	N	J'	H'(loge)
D297/3400m	3	9.7	336.0	0.348	0.782
D297/4300m	3	12.3	185.3	0.814	2.03
CD179/3400m	4	4.8	533.5	0.492	0.733
CD179/4300m	4	5.0	112.7	0.966	1.53

Besides Pseudotanaidae SP051 that accounts for ~80% of the total abundance at 3400m in both years, 32% at 4300 in 2005 and 16% at 4300m in 2006 there is a marked change in the species composition of the assemblages at both depths from one year to the following (Table 5); at 3400m the asellote *Eugerda tetarta* ranks among the dominant species in both years but at 4300m there are no other common species in the six dominant listing.

Discussion and Conclusion

The results on the vertical distribution of Crustaceans in the Portuguese canyons show that these animals remain mostly at the surface or subsurface layers (0-3cm below the seafloor). At 1000m there was a greater percentage of the crustacean fauna living deeper in the sediment mostly because of the occurrence of larger sized amphipods (eg. *Carangoliopsis spinulosa*) and leuconid cumaceans that may burrow in the sediments. The results obtained with crustacean fauna from canyons and slopes in the present work are coherent with previous studies on vertical distribution within the sediment on canyons from west Iberia Margin reporting that in general there are decreasing faunal abundance with increasing sediment depth (Cúrdia 2001; Cúrdia *et al.* 2004; Tiago 2008). The decreasing abundance towards deeper sediment layers may be associated to the distribution of total organic carbon (TOC) that reveals the same trend (Ingels *et al.* 2009).

The analyses on the data obtained during the Pelagia cruise allowed to compare the biodiversity and abundance patterns in canyons and slopes at 1000m. Multivariate analysis confirmed the significant differences between slopes and canyons but the interpretation of the results showed that the assemblages sampled at this depth were highly heterogeneous and that the only consistent pattern was the higher density of the canyon assemblages. The organically enriched sediment present in the canyons (Garcia *et al.* 2007). Is likely to provide trophic conditions that favour the increased densities of macrofauna in canyons. These results follow previous comparisons between canyons and open slopes, where higher abundances and biomass were found in canyons (Sarda *et al.* 1994; Tiago 2008).

The data collect from Charles Darwin 176 cruise was analyzed to assess differences within and between canyons (depth-related differences). Globally the results of the multivariate analyses confirmed that are significant differences both between and within canyons, with the Nazaré canyon assemblages clearly segregated from the Cascais and Setúbal that revealed less dissimilarities. The Nazaré canyon showed low diversity and high abundance resulting in highly dominated assemblages, while Cascais and Setúbal showed assemblages with opposite features.

Because Nazaré canyon is not connected with a major river basin and Cascais and Setúbal canyon are linked to Tejo and Sado Rivers (Arzola *et al.* 2008) it could be expected that the latter should be more active and organically enriched favouring in this case high abundance and assemblages dominated by small-sized opportunistic detritivore species. In fact, recent studies show that in Nazaré canyon the Total organic carbon (TOC) content of the sediments much higher than in others canyons or in slopes but the C/N ratios also support that these high concentrations of organic matter are of terrestial origin (Kiriakoulakis *et al.* 2009), meaning that they have poor quality as food for the benthos when compared to more labile matter of marine origin. Furthermore Stiger *et al.* (2009) based on sedimentation rates measured in sediment traps, defend that Setúbal canyon (and probably also Cascais) are, at the moment, canyons where the transport of sediments from shallow waters to deep sea is not effective. These characteristics are crucial for setting trophic conditions in the Nazaré canyon contrasting with the other two studied canyons. The occurrence of a constant source of high concentrations of refractory organic matter in Nazaré may lead to the occurrence of a less diverse but abundant assemblage of crustaceans almost dominated by small-sized opportunist detritivore species such as the pseudotanaids (Tanaidaomorpha) and desmosomatids (Asellota). Presumably higher quality food in the other two canyons associated with more stable hydrodynamic conditions may support assemblages that are lower in density but also much more diverse.

Differences within canyons are expressed mainly by the higher densities and species richness at 3400m and globally impoverished assemblages at 4300m in all canyons. These results agree with previous studies in the Nazaré canyon (Cúrdia *et al.* 2004) and comparing the assemblages from Setúbal canyon at 3400m and the Tagus abyssal plain at ~5000m (Gage *et al.* 1995; Lamont *et al.* 1995). Recently, studies of the nematode assemblages of the Nazaré canyon revealed similar trends (Ingels *et al.* 2009) and explain these depth related differences by the higher TOC content in the middle canyon (3.70% at 3400m and 3.03% at 4300m). In Setúbal canyon a well developed nepheloid layer and moderate to strong tidal currents able to resuspend fine grained sediment characterize the middle depths while at greater depths the seafloor is covered

by thick and relatively undisturbed hemipelagic deposits (Stiger *et al.* 2009). Again these factors may set different conditions with higher food availability and intermediate levels of environmental disturbance at the middle canyon favouring higher densities and slightly lower evenness but also higher species richness and subsequently higher diversity.

The use of different sampling gear with different areas sampled in the three cruises carried out during this study is a considerable limitation for the interpretation of the results. Because the NIOZ box core was the only sampler used at 1000m a comparison between the assemblages at this depth and greater ones was not considered. However, the use of the USNEL box core and the UKORS megacore in consecutive years in the middle and lower Nazaré canyon allowed some considerations on the implications of the methodological change for the interpretation of results.

Since 1949, the United States Naval Electronics Laboratory (USNEL) box core is used worldwide for the quantitative investigation of the deep sea which makes this technique almost the standard for benthic biological investigations (Hessler & Jumars 1974; Gage & Tyler 1991). The UKORS device provide an alternative method to obtain small diameter cores; it was designed to reduce penetrating velocity and bow wave, using an hydraulic mechanism and it keeps both sediment and the overlying water tightly sealed after the sampling (Shirayama *et al.* 1995) decreasing the loss of epibenthic crustaceans and other highly mobile organisms.

In principle, the UKORS megacore is considered more efficient but, as it collects smaller areas than the USNEL box core, it may require more replicate sampling. The lower number of species collected in 2006 at both depths in Nazaré is clearly influenced by the smaller area sampled by the UKORS megacore but, the similarity in the community structure of the assemblages collected in consecutive years indicates that both sampling devices can be used effectively to represent the benthic assemblages. Once the UKORS is considered more efficient for the collection of mobile organisms, such as many peracarids, it would be expected to obtain higher density estimates for the crustacean assemblages collected in 2006, however this was not the case at 4300m suggesting that interannual variability must be considered in the interpretation of results. In fact the significant differences confirmed by the multivariate analysis between samples collected

during D297 and C179 cruises are more likely to be explained by interannual variability then to the difference in the samplers' efficiency. This is clearly illustrated, for instance, by the marked change in the dominant species at both depths.

The importance of crustacean studies from the deep sea is well recognized; the diversity of feeding modes and life styles of peracarid crustacean is crucial for the functioning of the benthic communities and the burrowing detritivore species (several Isopoda and Tanaidacea) that contribute to the carbon cycling in benthic environments (Brandt 1995) may be especially important in canyons due to their characteristic organic enrichment.

Studies on canyon ecosystems are scarce and the main difficulties of the present work were the comparison to other benthic assemblage studies and the interpretation of the results in relation to environmental data. This thesis investigated crustacean abundance and diversity from the Portuguese canyons at the species level which is a rare achievement and despite the limitations in data analysis and interpretation we expect to contribute to a better knowledge of the biodiversity and understanding of the functioning of these interesting but still understudied deep sea ecosystems.

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APPENDIX 1

Reino Animalia Linneaus, 1753

Phylum Arthropoda Latreille,1829

Subphylum Crustacea Brunnich, 1772

Classe Malacostraca Latreille, 1802

Subclasse Eumalacostraca Grobben, 1892

SUPERORDEM EUCARIDA Calman, 1904

Order Decapoda Latreille, 1802

SubOrder Pleocyemata Burkenroad, 1963

Infra order Brachyura Latreille, 1803
Family Cymonomidae Bouvier, 1897
Cymonomus Milne-Edwards, 1881
Cymonomus granulatus Thomson, 1873

SUPERORDER PERACARIDA Calman, 1904

Order Mysidacea Haworth, 1825

SubOrder Mysida Haworth, 1825

Family Mysidae Dana, 1850
Mysidae sp.A (MYSPSP001)

Order Amphipoda Latreille, 1816

SubOrder Gammaridea Latreille, 1803

Family damage/undetermined (AMPSP072)

Family Ampeliscidae Costa, 1857
Ampelisca Kroyer, 1842
Ampelisca sp.A (AMPSP074)
Ampelisca sp.B (AMPSP075)

Haploops Liljeborg, 1856
Haploops cf. setosa Boeck, 1871

Family Eusiridae Stebbing, 1888
Eusirus Krøyer, 1845
Eusirus longipes Boeck, 1861

Family Haustoriidae Stebbing, 1906

Bathyporeia Lindstrom, 1855
      Bathyporeia sp. (AMPSP063)

Family Liljeborgiidae Stebbing, 1899
    Liljeborgia Bate, 1862
      Liljeborgia sp. (AMPSP068)

Family Lysianassidae Dana, 1849
    Lysianassa Milne-Edwards, 1830
      Lysianassa sp.A (AMPSP066)
      Lysianassa sp.B (AMPSP076)
      Lysianassa sp.C (AMPSP077)
      Lysianassidae?

Family Melitidae Bousfield, 1973
    Eriopisa Wrzesniovsky, 1890
      Eriopisa elongata Bruzelius, 1859

Family Carangoliopsidae Bousfield, 1977
    Carangoliopsis
      Carangoliopsis spinulosa Ledoyer, 1970

Family Oedicerotidae Lilljeborg, 1865
    Perioculodes Sars, 1895
      Perioculodes cf. aequimanus Korssman, 1880

    Monoculodes Stimpson, 1853
      Monoculodes sp. (AMPSP069)

    Bathymedon Sars, 1892
      Bathymedon sp.A (AMPSP080)
      Bathymedon sp.B (AMPSP081)

    Synchelidium Sars, 1892
      Synchelidium cf. longidigitatum Ruffo, 1947

    Halicreion Boeck, 1871
      cf. Halicreion sp. (AMPSP083)

Family Pardaliscidae Boeck, 1871
    Halice abyssi Boeck, 1871
    Pardaliscidae SP. A (AMPSP079)
    Pardaliscidae?

Family Phoxocephalidae Sars, 1891
    Harpinia Boeck, 1876
      Harpinia spp. (AMPSP065)

    Leptophoxus G. O. Sars, 1891
      Leptophoxus falcatus Sars, 1882

    Metaphoxus Bonnier, 1896
      Metaphoxus sp.A (AMPSP064)
      Metaphoxus sp.B (AMPSP070)
      Metaphoxus sp.C (AMPSP050)

Family Synopiidae Dana, 1853

Syrrhoites **sp.** (AMPSP067)

Family Urothoidae Bousfield, 1978
Carangolia J.L. Barnard, 1961
Carangolia barnardi **Barnard, 1961**

SubOrder Corophiidea Leach, 1814

Family Caprellidae Leach, 1814
Liropus Mayer, 1890
Liropus elongatus **Mayer, 1890**

Family Dulichiidae Dana, 1849
Dulichiopsis Laubitz, 1977
Dulichiopsis nordlandicus **Boeck, 1871**

Order Isopoda Latreille, 1817

SubOrder Cymothoida Leach, 1818

Family Cirolanidae Dana, 1852
Eurydice Leach, 1815
Eurydice **sp.** (ISOSP064)

Metacirolana Nierstrasz, 1931
Metacirolana **sp.** (ISOSP065)

Family Hyssuridae Wagele, 1981
Kupellonura Barnard, 1925
Kupellonura **sp.** (ISOSP067)

Family Paranthuridae Menzies & Glynn, 1968
Paranthura Bate & Westwood, 1866
cf. *Paranthura sp.* (ISOSP066)

SubOrder Asellota Latreille, 1802

Family damage/undetermined

Family Leptanthuridae Poore, 2001
Bullowanthura Poore, 1978
cf. *Bullowanthura* **sp.** (ISOSP068)
Bullowanthura **cf.** *aquitanica* **Kensley, 1982**

Family Dendrotionidae Vanhoffen, 1914
Dendrotion G.O. Sars, 1872
Dendrotion **cf.** *elegans* **Lincoln & Boxshall, 1983**

Family Desmosomatidae G. O. Sars, 1897
    Mirabilicoxa Hessler, 1970
        Mirabilicoxa* aff. *gracilepes
        Mirabilicoxa* cf. *similis
        ***Mirabilicoxa* cf. *acuminata* Hessler, 1970**
        ***Mirabilicoxa* sp.** (ISOSP037)

    Eugerdella Kussakin, 1965
        ***Eugerdella* aff. *pugilator* Hessler, 1970**
        ***Eugerdella pugilator* Hessler, 1970**
        ***Eugerdella* cf. *Ischnomesoides* Hessler, 1970**
        ***Eugerdella* sp. A**
        ***Eugerdella* sp. B**
        ***Eugerdella* sp. C**

    Prochelator Hessler, 1970
        ***Prochelator* aff. *abyssalis* Hessler, 1970**
        ***Prochelator* sp.** (ISOSP086)
        cf. *Prochelator* sp.

    Eugerda Meinert, 1890
        ***Eugerda tetarta* Hessler, 1970**
        ***Eugerda* sp.**

    Chelator Hessler, 1970
        ***Chelator* cf. *verecundus* Hessler, 1970**
        Chelator* cf. *insignis
        ***Chelator* sp.** (ISOSP085)

    Momedossa Hessler, 1970
        ***Momedosa* sp.A** (ISOSP087)
        ***Momedosa s*p.B** (ISOSP089)

    Paradesmosoma Kussakin, 1965
        cf. *Paradesmosoma sp.*

    ***Desmosomatidae* spp.**

Family Eurycopidae
    Acanthocope Beddard, 1885
        ***Acanthocope* sp.** (ISOSP052)
    Eurycope Sars, 1864
        ***Eurycope* sp.A (**ISOSP079)
        ***Eurycope* SP.B?** (ISOSP080)
    Munnopsurus Richardson, 1912
        ***Munnopsurus* sp.** (ISOSP054)

Family Haploniscidae Hansen, 1916
    Haploniscus Richardson, 1909
        ***Haploniscus* cf. *antarticus* Vanhoff, 1914**
        ***Haploniscus* cf. *charcoti* Chardy, 1975**
        ***Haploniscus* cf. *foresti* Chardy, 1974**
        ***Haploniscus* cf. *angustus* Lincoln, 1985**
    Chauliodoniscus Lincon, 1985
        ***Chauliodoniscus* sp. nov.** (ISOSP046)

Family Ilyarachnidae Hansen, 1916
    Ilyarachna Sars, 1870
        ***Ilyarahcna* sp. A** (ISOSP077)
        ***Ilyarachna* sp. B** (ISOSP078)

Family Ischnomesidae Hansen, 1916
    Haplomesus Richardson, 1908
        ***Haplomesus* sp. A** (ISOSP057)
        ***Haplomesus* sp. B** (ISOSP058)
        ***Haplomesus* sp. C** (ISOSP060)

    Ischnomesus Richardson, 1908
        ***Ischnomesus gracilis* Chardy, 1974**
        ***Ischnomesus* cf. *norvegicus* Svavarsson, 1984**

Family Janirellidae Menzies, 1956
    Janirella Menzies, 1956
        ***Janirella* cf. *hanseni* Bonnier, 1896**

Family Macrostylidae Hansen, 1916
    Macrostylis Sars, 1864
        ***Macrostylis* cf. *abyssicola* Hansen, 1916**
        ***Macrostylis* aff. *longiremis* Meinert, 1890**
        ***Macrostylis magifica* Wolff, 1962**
        ***Macrostylis* aff. *subinermis* Hansen, 1916**

Family Nannoniscidae Hansen, 1916
    Nannoniscus G.O. Sars, 1870
        ***Nannoniscus* sp. A** (ISOSP094)
        ***Nannoniscus* sp. B** (ISOSP097)

    Rapaniscus Siebenaller & Hessler, 1981
        ***Rapaniscus* sp. A** (ISOSP095)

    Regabellator Siebenaller & Hessler, 1981
        ***Regabellator profugus* Siebenaller & Hessler, 1981**

    Thaumatosoma Hessler, 1970
        cf. *Thaumatosoma sp.*

Family Paramunnidae Vanhöffen, 1914
    Pleurogonium G.O. Sars, 1864
        ***Pleurogonium* cf. *rubicundum* Sars, 1864**

Family Thambetamatidae? Stebbing, 1913
        cf. Thambetamatidae
        sp.A (ISOSP098)
        SP.B (ISOSP063)
    Thambema
        cf. *Thambema* (ISOSP093)

Order Cumacea Kroyer, 1846

Family damage/undetermined

Family Diastylidae Bate, 1856
    SP. A (CUMSP002)
    SP. B (CUMSP003)
    SP. C (CUMSP007)
    SP. D (CUMSP008)
    SP. E (CUMSP014)

Family Lampropidae Sars, 1878
    SP. A (CUMSP011)
    SP. B (CUMSP018)

Family Leuconidae Sars, 1878
    Leucon Kroyer, 1846
        ***Leucon* sp. A** (CUMSP004)
        ***Leucon* sp. B** (CUMSP005)
        ***Leucon* sp. C** (CUMSP012)
        ***Leucon* sp. D** (CUMSP019)
        ***Leucon* sp. E** (CUMSP020)
        ***Leucon* sp. F** (CUMSP021)
        ***Leucon* sp. G** (CUMSP022)
    Eudorella Norman, 1867
        ***Eudorella* sp. A** (CUMSP017)

Family Nannastacidae Bate, 1866
    sp. A (CUMSP006)
    sp. B (CUMSP009)
    sp. C (CUMSP010)
    sp. D (CUMSP013)
    sp. E (CUMSP015)
    Nannastacidae spp.

Order Tanaidacea Dana, 1849

SubOrder Tanaidomorpha Sieg, 1980

Family damage/undetermined (TANSP001)
    sp. A (TANSP002?)
    sp. B (TANSP037)
    sp. C (TANSP046)
    sp. D (TANSP047)
    sp. E (TANSP052)
    sp. F (TANSP054)
    sp. G (TANSP057)
    sp. H (TANSP059)
    sp. I (TANSP060)
    sp. J (TANSP062)
    sp. K (TANSP063)
    sp. L (TANSP064)
    sp. M (TANSP065)
    sp. N (TANSP066)

sp. O (TANSP067)
sp. P (TANSP068)
sp. Q (TANSP069)
sp. R (TANSP070)
sp. S (TANSP999)

Family Anarthuridae Lang, 1971
sp. A (TANSP013)
sp. B (TANSP043)
sp. C (TANSP056)

Family Pseudotanaidae Sieg, 1976
sp. A (TANSP039)
sp. B (TANSP051)
sp. C (TANSP041)

Family Tanaellidae Larsen &Wilson, 2002
sp. A (TANSP040)
sp. B (TANSP058)
sp. C (TANSP049)

Family Agathotanaidae Lang, 1971
Sp. A (TANSP048)

Family Colleteidae Larsen & Wilson, 2002
sp. A (TANSP053)

Family Typhlotanaidae Sieg, 1986
sp. A TANSP042
sp. B TANSP045
sp. C TANSP050
sp. D TANSP055
sp. E TYP

SubOrder Apseudomorpha Sieg, 1980

Family Apseudidae Leach, 1814
Sp. A (TANSP017)
Sp. B (TANSP044)
Apseudes Leach, 1814
***Apseudes grossimanus* Norman & Stebbigng, 1886**

Family Sphyrapidae Gutu, 1980
Sphyrapus Sars, 1882
***Sphyrapus malleolus* Norman & Stebbigng, 1886**

APPENDIX 2

SubOrder Corophiidea

Dulichiopsis norlandicus Boeck, 1977

(AMPHSP013)

Family Dulichiidae

Liropus elongatus Mayer, 1890 (AMPHSP011)

Family Caprelidae

SubOrder Gammaridea
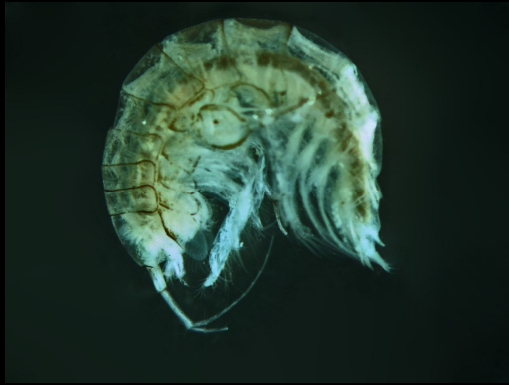
Haploops cf. *setosa*
Boeck, 1871 (AMPHSP062)

Ampelisca sp. A
(AMPHSP074)

Ampelisca sp. B
(AMPHSP075)

Family Ampeliscidae

SubOrder Gammaridea

Eusirus longipes
Boeck, 1861 (AMPHSP029)
Family Eusiridae

Bathyporeia sp.
(AMPHSP063)
Family Haustoridae

Liljeborgia sp.
(AMPHSP068)
Family Liljeborjiidae

SubOrder Gammaridea

(AMPHSP076)

(AMPHSP066)

(AMPHSP077)

(Lysianassidae und)

Family Lysianassidae

SubOrder Gammaridea

Carangoliopsis spinulosa
Ledoyer, 1970 (AMPHSP040)
Family Carangoliopsidae

Eriopisa elongata
Bruzelius, 1859 (AMPHSP018)

Family Melitidae

SubOrder Gammaridea

cf. *Bathymedon* sp. A
(AMPHSP080)

cf. *Bathymedon* sp. B
(AMPHSP081)

Synchelidium cf. *longiditatum*
Ruffo, 1947 (AMPHSP082)

cf. *Halicreion* sp.
(AMPHSP083)

Monoculodes sp.
(AMPHSP069)

Perioculodes cf. *aequimanos*
Korssman, 1880 (AMPHSP057)

Family Oedicerotidae

SubOrder Gammaridea

Metaphoxus sp.A
(AMPHSP064)

Metaphoxus sp.B
(AMPHSP070)

Harpinia spp.
(AMPHSP065)
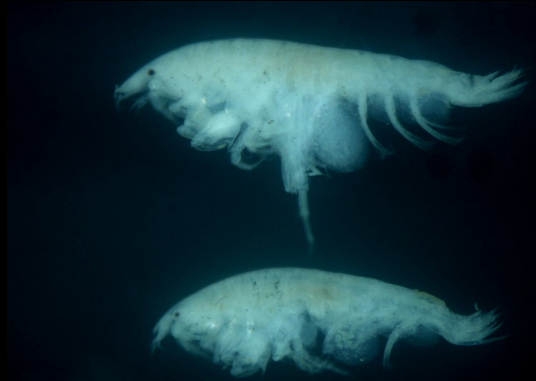
Metaphoxus sp.C
(AMPHSP050)

Leptophoxus falcatus, Sars, 1882
(AMPHSP058)

Family Phoxocephalidae

SubOrder Gammaridea
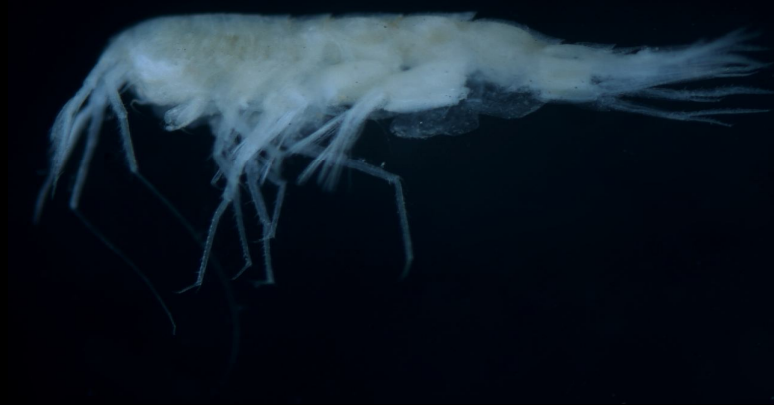
Syrrhoites sp.
(AMPHSP067)

Family Synopiidae

Carangolia barnardi Barnard, 1961
(AMPHSP051)

Family Urothoidae

SubOrder Gammaridea

Halice abyssi
Boeck, 1871 (AMPHSP078)

Pardalacisdae sp.A
(AMPHSP079)

Pardalacisdae?

Family Pardalaliscidae

APPENDIX 3

SubOrder Cymothoidea

Eurydice sp.

(ISOSP064)

Metacirolana sp.

(ISOSP065)

Family Cirolanidae

Kupellonura sp.

(ISOSP067)

Family Hyssuridae

cf. *Paranthura* sp.

(ISOSP066)

Family Paranthuridae

cf. *Bullowanthura*

(ISOSP068)

Bullowanthura cf. *aquitanica*
Kensley, 1982 (ISOSP076)

Family Leptanthuridae
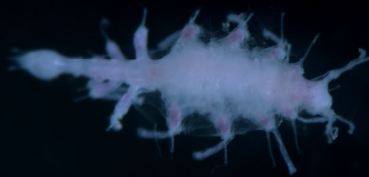
Dendrotion cf. *elegans*
Lincon & Boxshall, 1983 (ISOSP047)

Family Dendrotiidae

SubOrder Asellota

Mirabilicoxa cf. *similis*
(ISOSP081)

Mirabilicoxa aff. *gracilepes*
(ISOSP082)

Mirabilicoxa cf. *acuminata*
Hessler, 1970 (ISOSP036)

Mirabilicoxa sp.
(ISOSP037)

Family Desmosomatidae

SubOrder Asellota

Eugerdella aff. *Pugilator*
Hessler, 1970 (ISOSP083)

Eugerdella pugilator
Hessler, 1970 (ISOSP084)

Eugerdella sp.A
(ISOSP090)

Eugerdella sp.B
(ISOSP091)

Eugerdella cf.
Ischnomesoides
Hessler, 1970 (ISOSP092)

Family Desmosomatidae

SubOrder Asellota

Eugerda tetarta
Hessler, 1970 (ISOSP005)

Chelator cf. *verecundis*
Hessler, 1970 (ISOSP003)

Chelator cf. *insignis*
(ISOSP002)
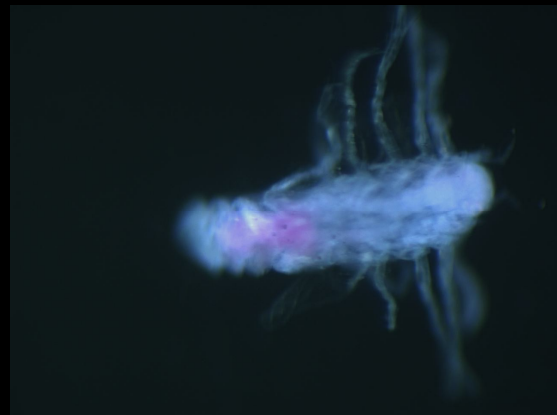
Chelator sp.
(ISOSP085)

Family Desmosomatidae

Momedosa? sp.A
(ISOSP087)

Momedosa sp.B
(ISOSP089)

Prochelator aff. *abyssalis*
Hessler, 1970 (ISOSP039)

Prochelator sp.
(ISOSP086)
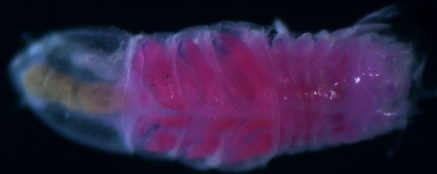

cf. *Prochelator* sp.

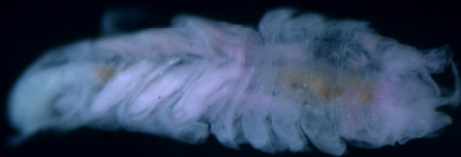cf. *Paradesmosoma* sp.

Family Desmosomatidae

SubOrder Asellota

Acanthocope sp.

(ISOSP052)

Eurycope sp.A

(ISOSP079)

Eurycope sp.?B

(ISOSP080)

Munnopsurus

(ISOSP054)

Family Eurycopidae

SubOrder Asellota

Haploniscus cf. *antarticus*
Vanhoff, 1914 (ISOSP042)

Haploniscus cf. *charcoti*
Chardy, 1975 (ISOSP043)

Haploniscus cf. *foresti*
Chardy, 1974 (ISOSP044)

Haploniscus cf. *angustus*
Lincoln, 1985 (ISOSP045)

Chauliodoniscus (sp.nov)

(ISOSP046)
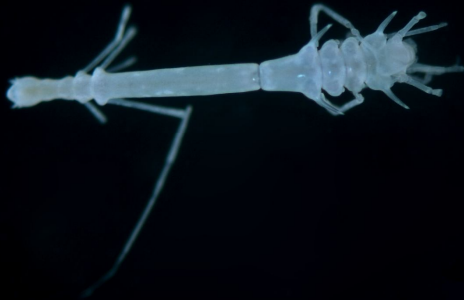
Family Haploniscidae

SubOrder Asellota

Ilyaracna sp.A

(ISOSP077)

Ilyaracna sp.B

(ISOSP078)

Family Ilyaracnidae

SubOrder Asellota

Haplomesus sp.B

Haplomesus sp.A
(ISOSP057)

Ischnomesus gracilis
Chardy, 1974 (ISOSP059)

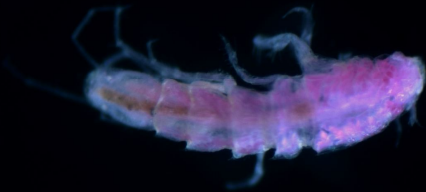*Haplomesus* sp.C
(ISOSP060)

Ischnomesus cf. *norvegicus*
Svavarsson, 1984 (ISOSP056)

Family Ischnomesidae

SubOrder Asellota

Macrostylis cf. *abyssicola*
Hansen, 1916 (ISOSP049)

Macrostylis aff. *Longiremis*
Meinert, 1890 (ISOSP050)

Macrostylis aff. *subinermis*
Hansen, 1916 (ISOSP051)

Macrostylis *magnífica*
Wolff, 1962 (ISOSP048)

Family Macrostylidae

Regabellator profugus
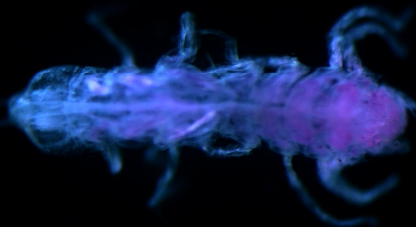Siebenaller & Hesseler, 1981
(ISOSP096)

Nannoniscus sp. A
(ISOSP094)

Rapaniscus sp. A
(ISOSP095)

Nannoniscus sp. B
(ISOSP097)

cf. *Thaumatosoma* sp.
(ISOSP088)

Family Nannoniscidae

SubOrder Asellota

Pleurogonium cf. *rubicundum*
Sars, 1864 (ISOSP055)
Family Paramunnidae

Janirella cf. *hanseni*
Bonnier, 1896 (ISOSP029)
Family Janirellidae

cf. *Thambema*
(ISOSP093)
Family Thambetamatidae