

**ALMA MATER STUDIORUM  
UNIVERSITÀ DI BOLOGNA**

**SCUOLA DI SCIENZE - CAMPUS DI RAVENNA**

**CORSO DI LAUREA MAGISTRALE IN BIOLOGIA MARINA**

**Polychaete fauna of the Northwest Portuguese  
Coastal Shelf: ecology, diversity and distribution**

**Tesi di laurea in Alterazione e Conservazione degli Habitat Marini**

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**II sessione**

Anno accademico 2014/2015

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## ***1- INTRODUCTION***

### ***1.1- Importance of polychaete fauna***

Polychaetes are one of the most abundant macroinvertebrates with more than 9000 species recognised (Rouse and Pleijel 2001). Most are comprised in the macrofauna, but there are some species belonging to the families Saccocirridae and Syllidae, included in the interstitial fauna.

As Surugiu *et al.*, (2015) stressed, the extremely wide ecological adaptations of the polychaetes contributed to their ability to colonise all benthic habitats. Their high population densities gives them a leading functional role in all benthic communities.

Macrobenthic polychaetes play an important role in the marine food chain and are used to assess the ecological status of benthic communities (Cacabelos *et al.*, 2008; Lourido *et al.*, 2008; Quiroz-Martinez *et al.*, 2011). In fact, they represent one of the main trophic resources for the fish fauna, thus having an indirect importance for human economy. Polychaetes are characterized by a relatively high caloric content, being integrally ingested and digested (undigested remains of their bodies are only the cuticle, seta, jaws and paragnaths); so, both pelagic larvae and adults, are consumed from the planktophagic and benthofagic fishes (Surugiu *et al.*, 2015). The exploitation derived by using them as a bait or food for aquacultured species is considerable and the Portuguese legislation (Portaria nº1102-B/2000) permits exclusively the harvesting of *Marphysa sanguinea* (Montagu, 1815), *Diopatra neapolitana* Delle Chiaje, 1841 and *Nereis diversicolor* O.F.Müller, 1776. Although legislation exists, control of the catch and policies to exploit baitworm stock in a sustainable way such as progressive exploitation of areas alternating with periods of recovery, is not in evidence (Costa *et al.*, 2006).

Other polychaetes, as burrowing ones, are considered relevant ecosystem engineers (Gutiérrez & Jones, 2006; Volkenborn & Reise, 2006; Herringshaw *et al.*, 2010) thanks to the capability

of some families, e.g. Sabellariidae and Serpulidae, to build calcareous and sediment structures. Furthermore, bioturbation, as a result of feeding, gallery construction, ventilation, may influence and create a complex mosaic of micro- and macro- environments important for the control of ecosystem functioning (Pischedda *et al.*, 2008).

Polychaetes are also commonly the first colonizers of impacted marine sediments (Grassle & Grassle, 1974; Shull, 1997) and are considered among the taxa with the highest level of sensitivity to perturbation of the soft substrata (Markert *et al.*, 2004). The presence, absence or relative biomass of specific polychaetes in marine sediments may provide an excellent indication on the condition or health of the benthic environment (Leal, 2013).

## **1.2- Description of the study area**

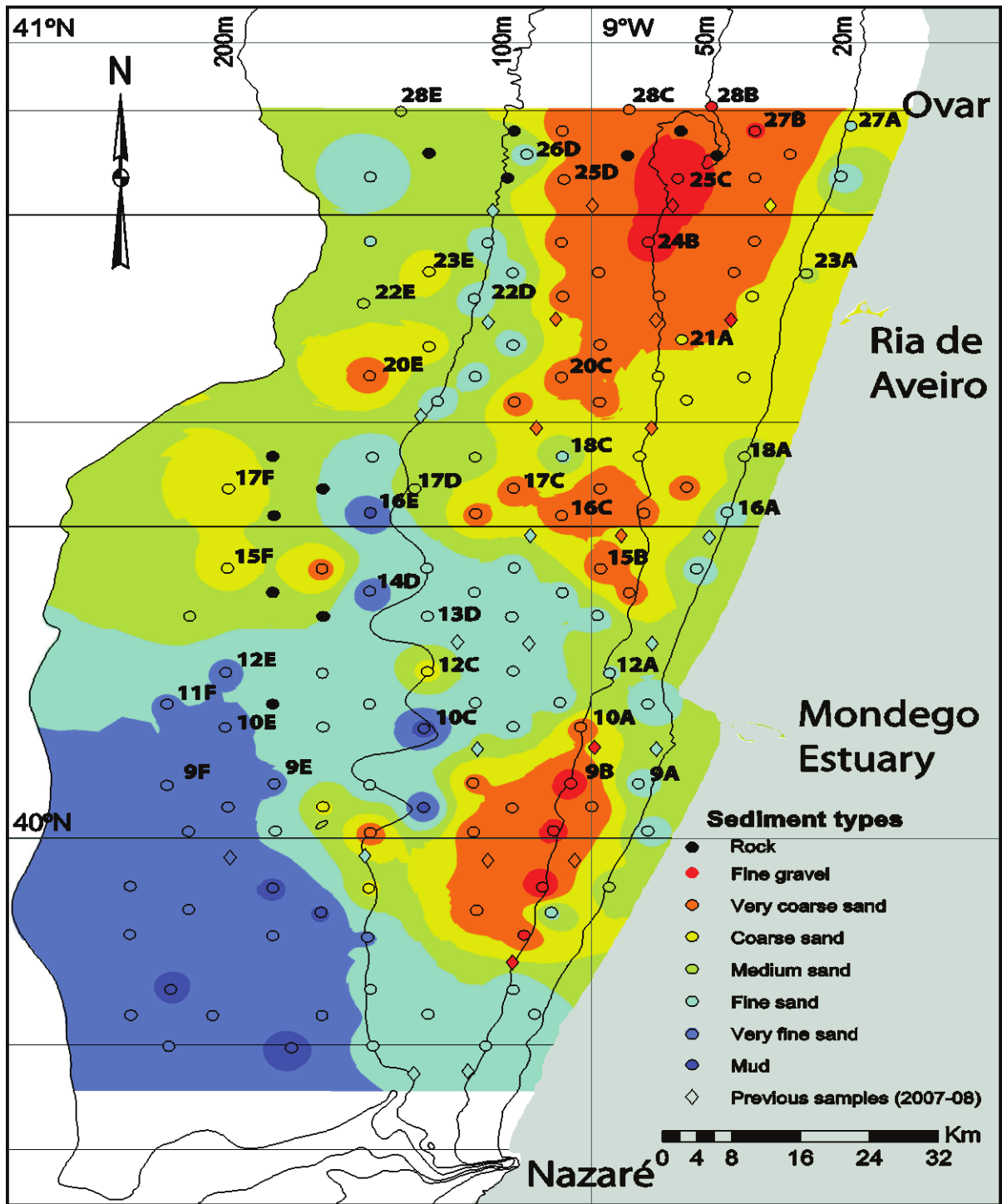
Portuguese continental shelf, as described by Martins *et al.*, (2012a), is comprised in the Atlantic Iberian Margin and extends from the Gulf of Cadiz to the Galicia Bank for approximately 900 km in length, with an average width of about 45 km and an irregular steep slope plunging to the abyssal plain. Shelf-break slope occurs approximately at 160 m depth; shelf is incised by several deep submarine canyons with a northeast-southwest trend. The three principals ones Nazaré, Setúbal and S. Vicente divide the Portuguese shelf into four main sectors: northwestern (Caminha-Nazaré), central (Nazaré-Setúbal), southwestern (Setúbal – Cape S. Vicente) and southern (Algarve, Cape S. Vicente – Vila Real St. António) (Vanney & Mougnot, 1990).

In general, most soft-bottom marine sediments include components from different origins: lithogenic, composed by detrital particles derived from weathering of continental rocks; biogenic consisting of skeletal remains and a hydrogenous or authigenic component (clays, ferromanganese oxyhydroxides), precipitated from seawater or through microbial activity (Schulz & Zabel, 2006).

The study area of this work goes from Ovar (40°55' N) to Mondego Estuary (40°03'N), covering an area of around 5665 km<sup>2</sup> from 20 m to 150 m of depth, and is comprised in the first sector, the northwestern. In this sector, the continental shelf is moderately wide (30-60 km) and receives a significant sedimentary input from several rivers (Minho, Lima, Cávado, Ave, Douro, Vouga and Mondego), with highest fluvial discharges in the winter season (Alveirinho Dias & Nittrouer, 1984). The Douro River is responsible for 79% of the total annual shelf sediment supply, estimated in  $2.25 \times 10^6$  t.y<sup>-1</sup> (Oliveira *et al.*, 1982).

In terms of hydrodynamic regime, Portuguese coast was divided by Bettencourt *et al.*, (2004) into: exposed, moderately exposed and sheltered areas. This study area is comprised in the exposed area and is characterized by an extremely energetic regime of waves and tides and a complex current system (Fiúza *et al.*, 1982).

Martins *et al.*, (2012a), and later Mamede *et al.*, (2015), described in detail the grain-size of the Shelf following the Wentworth scale (Wentworth, 1922) for the textural classification. As showed in the **figure 1.2**, sampling sites were almost all covered by sand of different grain size; occasionally the muddy sediment was found. In **table 1.2** data of the 39 sampling site are summarised, with relative coordinates, depth and grain size. Energetic regime, large fluvial sediment supply and the high total rainfall rates in the northern Portugal, may explain the spatial sediment distribution in the continental shelf. This area, in general, presents a high complex spatial sediment distribution with Mesozoic carbonated formations and discontinuous coarser deposit (ranging from gravel to coarse sand) mainly in the inner and mid-shelf between 20 and 80 m depth (Abrantes & Rocha, 2007); fine and very fine sand are found along a continuous band in the near shore shelf and in outer shelf of the northwestern sector (Martins *et al.*, 2012).



**Figure 1.2** Study area showing the position of each sampling site and the sediment types. Original figure taken by Mamede *et al.*, 2015 and modified adding labels of the 39 sampling sites investigated.

**Table 1.2** Table of the sampling sites, their geographic coordinates, depth and grain size. Grain size: FG= fine gravel; VCS= very coarse sand; CS= coarse sand; MS= medium sand; FS= fine sand; VFS= very fine sand; M= mud.

Sampling sites	Longitude	Latitude	Depth	Grain size
9 A	-8.9506	40.068501	27.1	FS
9 B	-9.021417	40.069099	56.8	FG
9 E	-9.3303	40.068352	127.7	VFS
9 F	-9.441867	40.066399	140.8	VFS
10 A	-9.011283	40.1394	51.8	VCS
10 C	-9.174183	40.137535	106.3	M
10 E	-9.3813	40.13895	135.5	VFS
11 F	-9.4423	40.168251	145	VFS
12 A	-8.980583	40.206917	47.6	FS
12 C	-9.170934	40.20895	102.2	CS
12 E	-9.3806	40.208218	133	VFS
13 D	-9.17075	40.278915	103.4	FS
14 D	-9.2308	40.310135	113.8	VFS
15 B	-8.990383	40.338566	63.2	VCS
15 F	-9.37885	40.339218	130.6	CS
16 A	-8.85845	40.40955	21.2	FS
16 C	-9.030467	40.405399	66.5	VCS
16 E	-9.230233	40.408669	121	M
17 C	-9.080916	40.439167	78.1	VCS
17 D	-9.18415	40.439018	102.2	MS
17 F	-9.378134	40.438999	140	CS
18 A	-8.84075	40.478783	22.3	MS
18 C	-9.029933	40.479465	68.5	FS
20 C	-9.031016	40.579266	77.1	VCS
20 E	-9.2305	40.580318	136.4	VCS
21 A	-8.900267	40.619267	47.8	CS
22 D	-9.1221	40.677933	102.7	FS
22 E	-9.229934	40.678902	148.1	MS
23 A	-8.7759	40.709084	21	MS
23 E	-9.16945	40.7117	127.3	CS
24 B	-8.940483	40.748585	54	FG
25 C	-8.909567	40.828602	54.7	FG
25 D	-9.02865	40.827351	85.3	VCS
26 D	-9.067284	40.859066	100	FS
27 A	-8.731584	40.889133	22.7	FS
27 B	-8.829483	40.888535	45.5	VCS
28 B	-8.871233	40.921349	52.4	FG
28 C	-8.964933	40.918266	70.9	VCS
28 E	-9.172767	40.919918	135	MS



### ***1.3- Aims of the work***

Despite the importance of polychaete fauna in characterising the structure and functioning of the benthic communities, the studies on most of the West Iberian coast are scarce and recent (e.g. Gil, 2011; Martins *et al.*, 2013). This work was part of a wider research project that includes a comprehensive study of the benthic macrofauna communities from the Western and Southern Portuguese coastal shelf (Martins *et al.*, 2012a; 2013a; 2013b) and their detailed spatial modelling in the Northwestern sector (Mamede *et al.*, 2015). In this sense, the aim of this work is to investigate the composition and the spatial distribution of the polychaete fauna in a number of sites along this geographical sector; sampling was planned to cover the overall sedimentary grain-size gradient of this part of the costal shelf. Relationship to environmental factors were considered and the study added original data to the existing biological data set.

## 2- MATERIAL AND METHODS

### 2.1- Field work

Samples were collected within the MeshAtlantic project ([www.meshatlantic.eu](http://www.meshatlantic.eu), 24.10.2012), with which the Northern Portuguese Continental Shelf was sampled from Ovar – 41°0' to Nazaré – 39°40'. A total of 121 sampling sites between 15 and 160 m of water depth and distanced each other no less than 5 km were taken along transects (Mamede *et al.*, 2015).

All the sediment samples were collected with a 0.1 m<sup>2</sup> Smith-McIntyre grab (**fig. 2.1**); a total of two samples were taken per site, one to study the macrofauna and the other to study the sediment descriptors (grain-size, total organic matter content and geochemistry analyses). Sediment samples were sieved on board over 1 mm mesh size and the macrofauna fixed in neutralized formalin (4%) stained with rose Bengal.



**Figure 2.1** Smith-McIntyre grab. Photo taken during the MeshAtlantic project.

## **2.2- Laboratory work**

The macrofauna samples were rinsed with water through a 0.5 mm mesh sieve under a fume hood and hand sorted. Following sorting, samples were fixed for long-term storage in 70% ethanol.

In this thesis 39 samples, distributed in the study area according to **figure 1.2** were analysed. In these samples, polychaetes were the only group left to identify and 37, out of the 39 samples, were already sorted to the family level. For the taxonomic identifications the stereomicroscope Leica M205 C and the microscope Leica DMLB were used. The stereomicroscope was used to recognise the general and the “macro” features of each family and the microscope to examine the smallest details of each specimen, necessary for the species identification, e.g. chaetae, hooks and papillae.

The taxonomic identification up to the family level was carried out using Hayward & Ryland, (1995) and Rouse & Pleijel, ( 2001), as well as the DELTA database (Dallwitz *et al.*, 2010) based on the interactive key Polikey (Glasby & Fauchald, 2003). For the taxonomic identifications to the species level several papers were consulted, as well as in-house laboratory keys and species description (**tab. 2.2**).

The validity and the authority of each species were confirmed in the World Register of Marine Species (WoRMS) (Read, 2015), and all the identifications were cross-checked by experienced colleagues from the same laboratory.

**Table 2.2** Bibliography consulted for the taxonomic identifications up to species level. \* denotes unpublished in-house species descriptions, notes and keys.

<b>Family</b>	<b>References</b>
Acrocirridae	Banse, 1969; Rouse & Pleijel, 2001
Ampharetidae	Holthe, 1986
Amphinomidae	Fauvel, 1923
Capitellidae	Capaccioni-Azzati & Martin, 1992; Gravina & Somaschini, 1990; *
Chaetopteridae	Bhaud <i>et al.</i> , 1994; *
Cirratulidae	Chambers <i>et al.</i> , 2011; de Kluijver <i>et al.</i> , 2015; Unicomarine, 1996; *
Dorvilleidae	Jumars, 1974; *
Eunicidae	Salazar-Vallejo & Carrera-Parra, 1998; Fauchald, 1992; Brito & Nunez, 2002; Nunez <i>et al.</i> , 1997; *
Flabelligeridae	Støp-Bowitz, 1948
Glyceridae	O'Connor, 1987; Støp-Bowitz, 1941
Goniadidae	Støp-Bowitz, 1941
Hesionidae	VV.AA., 2004
Lumbrineridae	Martins <i>et al.</i> , 2012b; Oug, 2012
Magelonidae	Fiege <i>et al.</i> , 2000
Maldanidae	Garwood, 2007
Nephtyidae	Ravara, 2010
Nereididae	Chambers & Garwood, 1992
Oeonidae	Maron Ramos, 1973
Onuphidae	Fauchald, 1982; Paxton, 1986; *
Opheliidae	Rowe, 2010
Orbiniidae	Gil, 2011
Oweniidae	Martin, 1989
Paralacydoniidae	VV.AA., 2004
Paraonidae	Aguirrezabalaga & Gil, 2009; Barwick, 2006; Blake, 1996; de Kluijver <i>et al.</i> , 2015; Laubier & Ramos, 1973; Sardá <i>et al.</i> , 2009; *
Pectinariidae	Castelli & Valentini, 1995; Jirkov & Leontovich, 2013; Holthe, 1986
Phyllodocidae	VV.AA., 2004
Pilargidae	Katzmann <i>et al.</i> , 1974; VV.AA., 2004
Poecilochaetidae	Cantone, 1989; Pilato & Cantone, 1976
Polygordiidae	Westheide, 1990
Polynoidae	Barnich & Fiege, 2003; Fauvel, 1923; Pettibone, 1996
Sabellariidae	Kirtley, 1994; *
Sabellidae	Banse, 1979; Knight-Jones, 1983; Knight-Jones & Perkins, 1998; *
Saccocirridae	Westheide, 1990
Scalibregmatidae	Worsfold, 2006
Serpulidae	Zibrowius, 1968; *
Sigalionidae	Barnich & Fiege, 2003; Martins <i>et al.</i> , 2012c; VV.AA., 2004
Spionidae	Bick <i>et al.</i> , 2010; de Kluijver <i>et al.</i> , 2015; Maciolek, 1985; Pardal <i>et al.</i> , 1992; Pettibone, 1962
Sternaspidae	Rouse & Pleijel, 2001
Syllidae	San Martin, 2003
Terebellidae	Holthe, 1986
Trichobranchidae	Holthe, 1986

### **2.3- Data analysis**

The abundance of all polychaetes and the species richness were calculated per sampling site. Abundance refers to the total quantity of specimens per sampling unit (0.1 m<sup>2</sup>); species richness (S), or alpha diversity ( $\alpha$ ) (Whittaker, 1960) corresponds to the number of species per sampling unit (0.1 m<sup>2</sup>). Other diversity indices were also calculated per site, namely, the Margalef richness (d), the Shannon-Wiener diversity ( $H'$ ), the Pielou evenness ( $J'$ ), and Simpson diversity ( $1-\lambda'$ ).

The Margalef richness index (d) (Margalef, 1958) is the ratio between the number of the species and the number of specimens in a sample. It is given by  $d = (S - 1)/\ln(N)$  where,  $S$  is the number of the species found in the sample and  $N$  is the total number of specimens of that sample.

The Shannon-Wiener diversity index ( $H'$ ,  $\log_2$ ) (Shannon & Weaver, 1963) takes into account both the number of species present in the sample and how the specimens are distributed among the species; it is calculated as  $H' = -\sum_{i=1}^S p_i \log p_i$  where,  $p_i = n_i/N$  and  $S$  is the number of the species of the sample.

The Pielou evenness index ( $J'$ ) (Pielou, 1966) refers to the abundance of the species in a sample.

It is calculated as  $J' = \frac{H'}{H'_{max}} = \frac{H'}{\log_2 S}$  where,  $H'$  is the Shannon-Wiener index and  $H'_{max}$  is the maximum value of  $H'$  for a given sample  $= \sum_{i=1}^S \frac{1}{S} \log_2 \frac{1}{S} = \log_2 S$ .

The Simpson diversity index (D) (Simpson, 1949) refers to the probability to drawn at random two different species from the same sample. The formula is  $D = 1 - \lambda$  where,  $\lambda = \sum_{i=1}^S p_i$ .

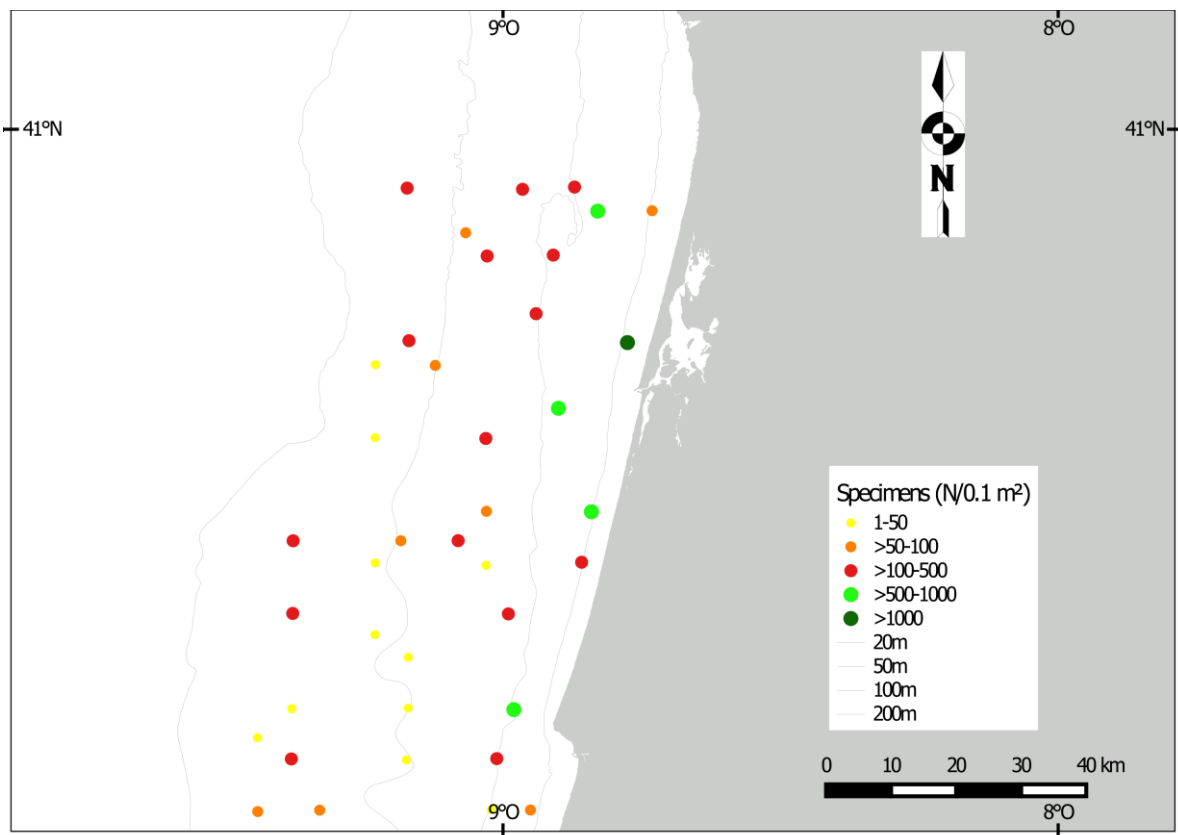
Primer v.6 (Clarke & Gorley, 2006) was employed to perform all the data analyses. The data matrix with all the polychaete species abundance per site was  $\log(X+1)$  transformed and the resemblance between sites done using the Bray-Curtis similarity coefficient. For the identification of polychaete assemblages, named in this thesis biological affinity groups, the transformed data matrix was submitted to agglomerative hierarchical clustering using the un-

weighted pair-group mean average algorithm (UPGMA) and to ordination analysis using non-metric multidimensional scaling (nMDS). For each species the constancy (C) and the fidelity (F) were calculated. The constancy of a species to an assemblage corresponds to  $C_{ij} = \frac{P_{ij}}{P_j} * 100$  where,  $P_{ij}$ = the number of sites in the assemblage in which the species was recorded, and  $P_j$ = the total number of sampling sites in the assemblage (Dajoz, 1971). Fidelity of a species to an assemblage is  $F_{ij} = \frac{C_{ij}}{C_j} * 100$ , where  $C_{ij}$  = species constancy in that assemblage and  $C_j$  = the sum of the constancies of the same species in all the assemblages where it exists (Retière, 1979). Both indices are in percentage; for constancy, species were classified in constant ( $C > 50.0\%$ ), common ( $50.0 \geq C > 25.0\%$ ), occasional ( $25.0 \geq C > 12.5\%$ ) and rare ( $C \leq 12.5\%$ ). For fidelity species were ranked in elective ( $F > 90.0\%$ ), preferential ( $90 \geq F > 66.6\%$ ), indifferent ( $66.6 \geq F > 33.3\%$ ), accessory ( $33.3 \geq F > 10.0\%$ ) and accidental ( $F \leq 10.0\%$ ). The characteristic species for each assemblage is the product of the combination of C and F. The most characteristic are species with the highest value of the product between C and F. Excel 2010 was employed to calculate both indices and to organize the dataset. To examine the relationship between the environmental variables and the biological data, the procedure BIOENV was performed. Environmental data were obtained from Quintino and co-workers (see namely Mamede *et al.*, (2015)). QGIS 2.8 Wien (QGIS Development Team, 2015) was used to plot the distribution of all the polychaete specimens found, the distribution of the biological affinity groups and some selected species and/or families. The figures were improved in Adobe Illustrator CS6 and Inkscape 0.91 (Harrington, 2005).

### 3 - RESULTS

#### 3.1- Data analysis

A total of 9532 specimens belonging to 197 species and 41 families were found (**Annex 7.1**). In all 39 sites polychaetes abundance per site ranged from 14 to 2584 specimens. The sites with a major number of polychaetes were the shallower, with 5 sites that reached or exceeded 1000 individuals. The majority of sites (15) had a total abundance comprised between 100 and 500, followed by a total of 10 sites with specimens comprised between 50 and 100, and 9 sites with a range of 1 and 50 specimens (**fig.3.1a**).



**Figure 3.1a** Abundance distribution of all specimens among the sampling sites.

The families with the highest number of species were Syllidae with 18 species, Spionidae with 17, Cirratulidae with 13, Paraonidae with 10 and Ampharetidae, Lumbrineridae, Maldanidae and Phyllodocidae with a total of 9 species.

The most abundant families were Phyllodocidae (3616 ind.), Capitellidae (1071 ind.), Sigalionidae (859 ind.), Syllidae (635 ind.) and Dorvilleidae (506 ind.). The 5 species with the highest abundance were *Hesionura elongata* (family Phyllodocidae; 36.8% of the total abundance,  $A_T$ ), *Mediomastus fragilis* (family Capitellidae;  $A_T = 10.5\%$ ), *Pisione parapari* (family Sigalionidae;  $A_T = 7\%$ ), *Protodorvillea kefersteini* (family Dorvilleidae;  $A_T = 5.2\%$ ) and *Polygordius appendiculatus* (family Polygordiidae;  $A_T = 4.9\%$ ).

The highest abundance value was of 2584 individuals per  $0.1 \text{ m}^{-2}$  in medium sand, followed by 885 and 824 individuals per  $0.1 \text{ m}^{-2}$ , respectively in medium and fine sand. The lowest values were 20, 19 and 14 specimens per  $0.1 \text{ m}^{-2}$ , found respectively in very coarse sand, fine gravel and mud.

Species richness highest values were 45 per  $0.1 \text{ m}^{-2}$ , in medium sand, followed by 44 and 41 per  $0.1 \text{ m}^{-2}$  in fine gravel; the lowest values were 11, 10 and 8 per  $0.1 \text{ m}^{-2}$ , in very coarse sand, fine sand and mud. The highest values of the diversity indices were: Margalef (d) 7.88, 7.80, 7.79 in coarse, very fine and fine sand; Pielou ( $J'$ ) 0.97, 0.96, 0.95 in very fine, fine sand and fine gravel, respectively; Shannon-Wiener ( $H'$ ) with 3.38, 3.34, 1.99 in very fine, fine and coarse sand; and Simpson with 0.972, 0.971, 0.968 in fine and very fine sand. The lowest ones were: Margalef with 2.05, 1.78, 1.65 in fine and medium sand, Pielou with 0.37, 0.30, 0.27 in coarse and medium sand, Shannon with 1.12, 0.78, 0.72 in coarse and medium sand, and Simpson with 0.386, 0.380, 0.352 in coarse and medium sand. The results of the diversity indices, showed, in general, that sites at depths shallower than 60 m presented lowest values. Of this range of bathymetry, a total of 13 sampled sites were analysed, of which 7 characterised by coarse sediments (fine gravel, very coarse sand, coarse sand), and 6 by medium and fine sands. The homogeneity of species abundance per each sampled site seemed to increase with

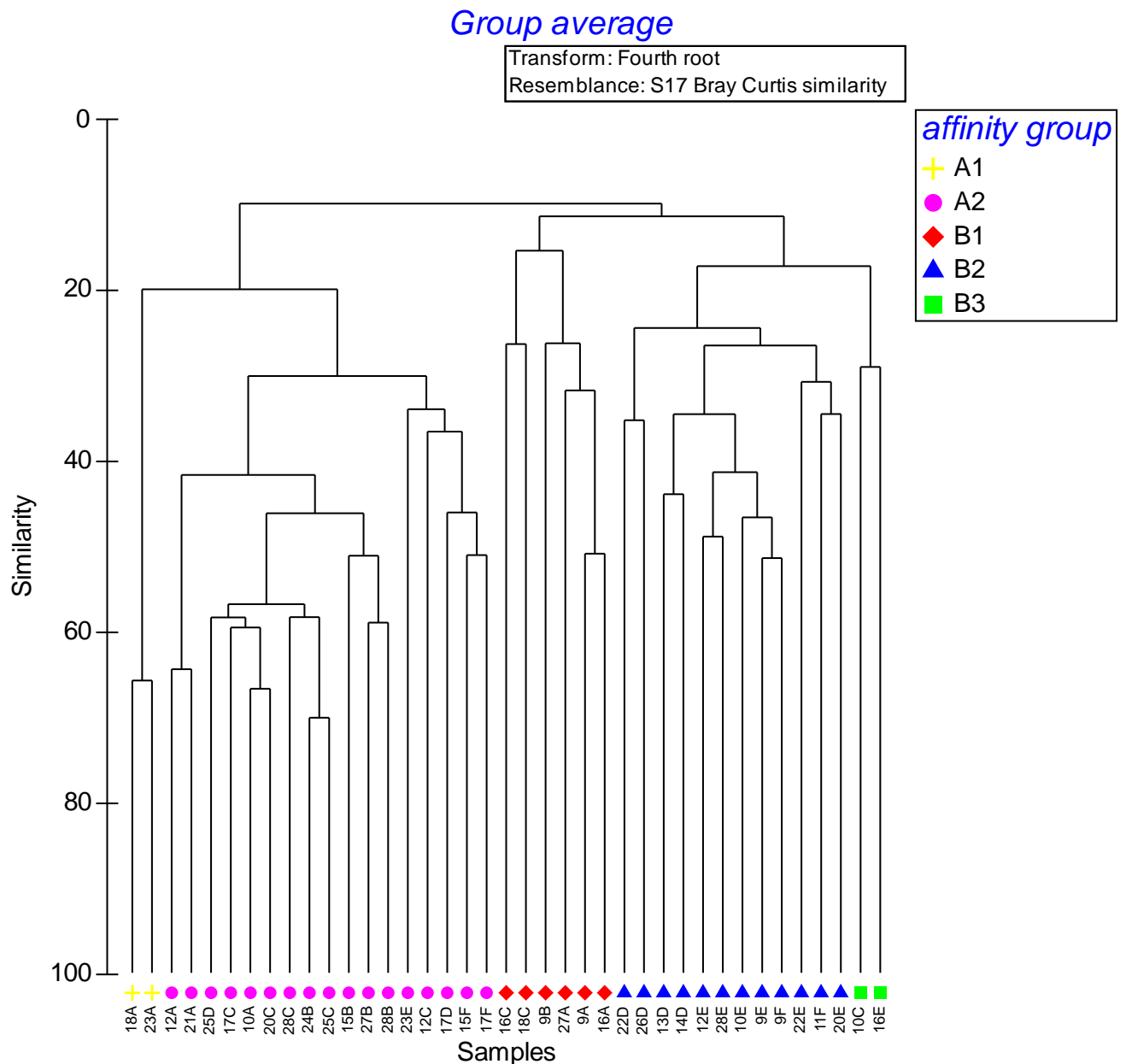


depth, according to the values of the Pielou index. This trend was less evident with the Margalef index (d), in which only few shallow sites reached high d values (**tab. 3.1**).

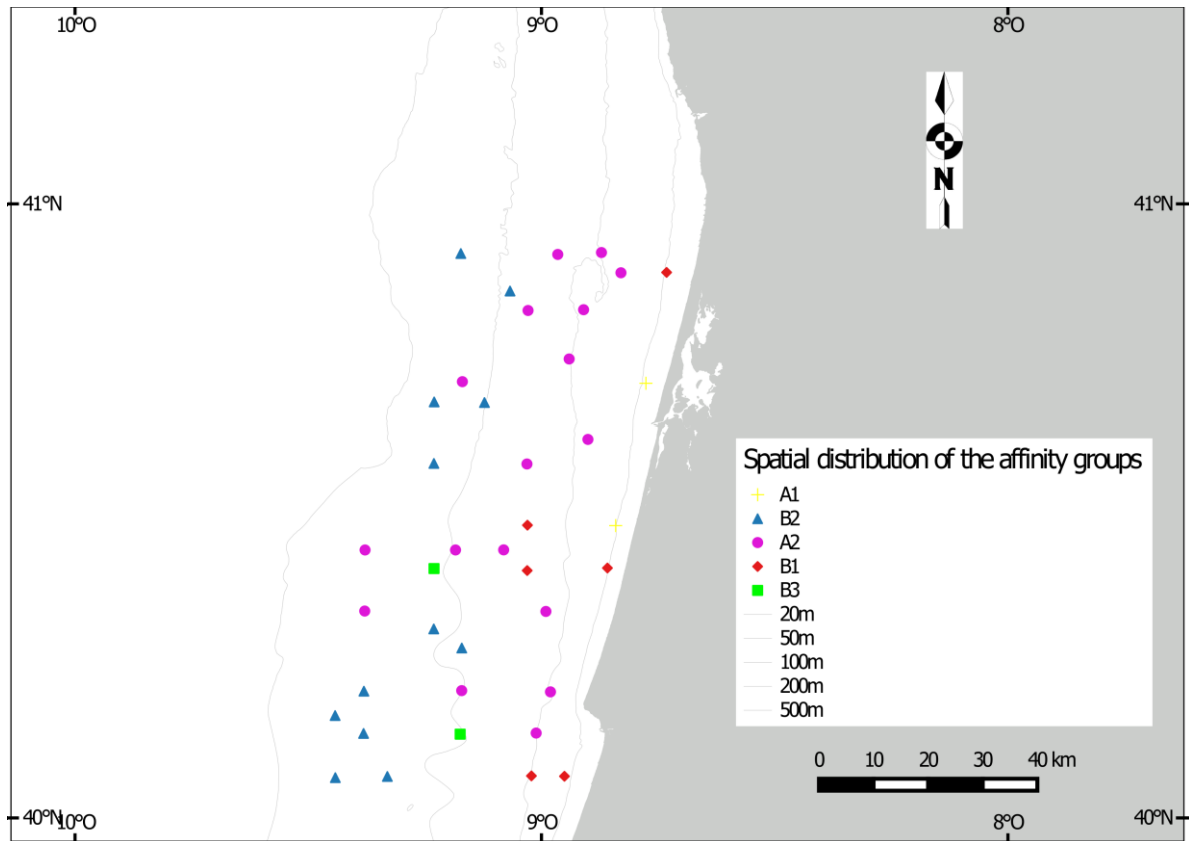
**Table 3.1** Diversity indices. S= no. species; N= no. specimens;d= Margalef index; J'= Pielou evenness index; H'= Shannon-Wiener diversity index;  $1-\lambda'$ = Simpson diversity index. In red the highest values, in yellow the lowest ones.

Sampling site	S	N	d	J'	H'(loge)	1-Lambda'
9 A	16	93	3.3093592	0.7500965	2.0797091	0.8300608
9 B	12	19	3.735856	0.9572272	2.3786202	0.9473684
9 E	29	87	6.2697215	0.8002936	2.6948253	0.8770382
9 F	29	57	6.9254625	0.851872	2.8685051	0.9154135
10 A	30	211	5.4186788	0.8176375	2.7809466	0.891582
10 C	8	14	2.6524623	0.8881659	1.8468891	0.8681319
10 E	37	101	7.8004464	0.9361804	3.3804704	0.9687129
11 F	22	41	5.6549327	0.9354273	2.8914456	0.954878
12 A	39	885	5.6001045	0.41727	1.5286943	0.531076
12 C	30	50	7.4130443	0.9304331	3.1645865	0.962449
12 E	28	50	6.9017999	0.9249099	3.0819889	0.957551
13 D	24	45	6.0420382	0.9699042	3.0824076	0.9717172
14 D	23	39	6.0050852	0.9585771	3.005613	0.9689609
15 B	28	141	5.4030124	0.6838597	2.2787605	0.7906784
15 F	39	124	7.8833569	0.8733872	3.1997079	0.9454498
16 A	15	119	2.9294075	0.6381464	1.7281325	0.6877938
16 C	11	20	3.338082	0.8986144	2.1547832	0.8947368
16 E	12	19	3.735856	0.9389474	2.3331967	0.9356725
17 C	32	277	5.5120739	0.7461007	2.585788	0.8833778
17 D	34	91	7.315679	0.8912848	3.1429914	0.9492063
17 F	45	304	7.6963069	0.57859	2.2024967	0.6781093
18 A	13	824	1.7872647	0.3070856	0.7876591	0.3527292
18 C	23	58	5.418128	0.8744191	2.7417359	0.922565
20 C	31	166	5.8685586	0.8477706	2.9112335	0.9264695
20 E	22	37	5.8156958	0.9484005	2.9315463	0.963964
21 A	24	750	3.4742818	0.5699897	1.8114581	0.7731126
22 D	18	73	3.9622796	0.6613621	1.9115823	0.7317352
22 E	21	30	5.8802821	0.9531573	2.9019087	0.9655172
23 A	14	2584	1.6545558	0.272233	0.7184386	0.3860488
23 E	20	113	4.0191329	0.3743621	1.1214887	0.3800569
24 B	41	329	6.9012425	0.8080459	3.0007367	0.9172289
25 C	33	194	6.0745751	0.8390978	2.9339117	0.9286897
25 D	29	150	5.5881138	0.7727975	2.6022379	0.8605817
26 D	34	69	7.7938521	0.9467797	3.3386866	0.9710145
27 A	10	79	2.0597568	0.5242724	1.2071817	0.5186628
27 B	25	575	3.7769283	0.4323344	1.3916306	0.4990456
28 B	44	450	7.03851	0.600982	2.2742297	0.7421727
28 C	25	155	4.7586708	0.7569972	2.43668	0.8329284
28 E	34	109	7.0342257	0.8372679	2.9525085	0.9245668

The results of the cluster analysis based on the abundance data are shown in the **figure 3.1b**. Following the first ramification at 15% of similarity, two affinity groups appeared (group A and B). The group A is divided, with a similarity of 20% in two groups, A1 and A2; the group B gathered B1, B2 and B3 with a similarity of 20 % and 30%. In the **figure 3.1c** is plotted the distribution of the groups. Almost all the sites of the group B2 and B3 occurred between the isobaths of 100 and 200 meters of depth; the group B1 didn't exceed 70 m of depth. The sites in the group A1 were both along the isobath of 20 m and sites in the group A2 were all, except for three sites, lower than 100 m of depth.



**Figure 3.1b** Cluster analysis based on the abundance of polychaetes. Subdivision in biological affinity groups based on different resemblance levels.



**Figure 3.1c** Spatial distribution of the affinity groups in the study area.

**Figure 3.1d a** showed the nMDS with the affinity groups plotted. Polychaete species found in the study area, in the **figure 3.1d b**, are superimposed on the analysis to explain distribution of each site in the plot. It is possible to see the sites in the left side of the plot, in which were distributed the groups A1 and A2, is explained by various species, of which some are exclusive of both groups, e.g. *Oxydromus pallidus*, *Psamathe fusca*, *Eulalia mustela* (**tab. 3.1a**). In the right side of the plot, clearly, the species *Labioleanira yhleni*, *Ampharete finmarchica* and *Poecilochaetus serpens* described the group B3. Further, this species are also exclusive of this group (**tab 3.1a**); various species, e.g. *Terebellides stroemii*, *Sarsonuphis bihanica*, *Aricidea (Aricidea) laubieri*, described the group B2. Again, some of the species are characteristic or exclusive. The group B1 is supported by *Glycera tridactyla* and *Spiophanes bombyx*. The environmental data used as vectors (**fig 3.1d c**) showed that grain size (median), depth and fine

contents seemed to describe the deeper groups (B2 and B3), instead longitude, gravel and sand fractions described both groups A, and B1.

**Table 3.1a** presents the overall characteristics of the various affinity groups.

The group A1 comprised 2 sites and was characterised only by medium sand. It is the shallowest group, with the highest value of sand fraction. These groups showed the highest abundance and the lowest values the diversity indices. No exclusive were species found, and the most characteristic were *Ophelia neglecta*, *Pisione parapari*, *Nephtys cirrosa* and *Hesionura elongata*.

The group A2 comprised 17 sites and was characterised by a prevalence of coarser sediments; sand fraction was the most abundant, followed by gravel. Fine sediments were low. This assemblage reached the highest value of species richness. In this group was also recorded the highest abundance of syllids (7.41%). In this group a total of 59 exclusive species were recorded, and the most characteristic were *Psamathe fusca*, *Goniadella gracilis*, *Protodorvillea kefersteini* and *Syllis garciai*.

The group B1 included 6 sites of sand sediments. The most abundant sediment fraction was sand, followed by gravels and a low percentage of fine sediments. Abundance, species richness and diversity indices were moderate comparing with the other groups. The exclusive species were 6 and the most characteristic were *S. bombyx*, *G. tridactyla*, *Phyllodoce rosea* and *Spio filicornis*.

The group B2 included 12 sites and was characterised by a prevalence of sand. Abundance of the sandy fraction, was followed by the contents of fine sand and gravel. It was the deepest group with high values of abundance, species richness and diversity. Paraonidae family in this group reached also the highest abundance (10.98%). The exclusive species were 39 and the most characteristic species *A. laubieri*, *Amage* sp., *Aponuphis brementi* and *A. pseudoarticulata*.

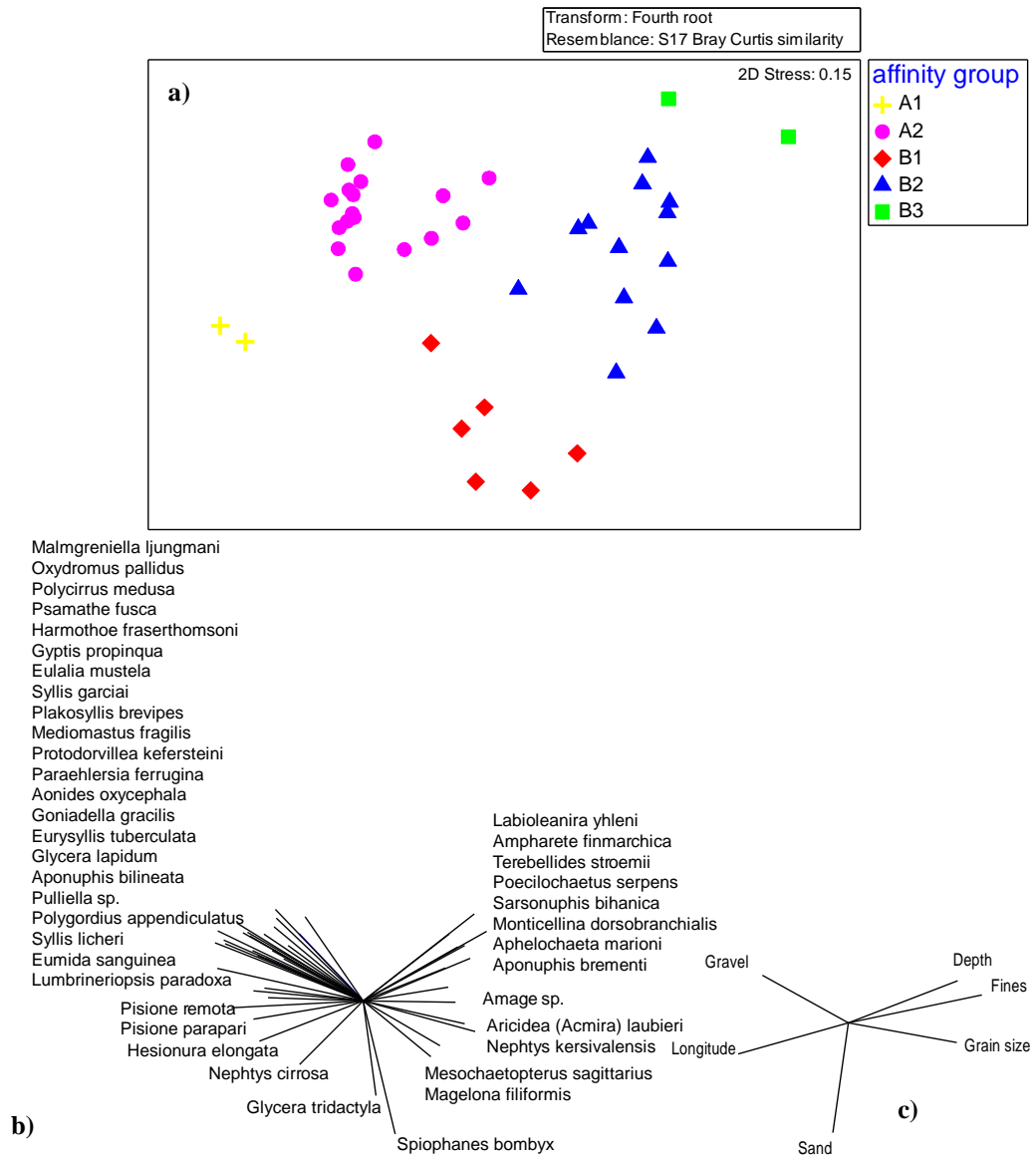
The group B3 gathered only 2 sites, characterised by mud sediments. Sediment in these sites lacked gravel, sandy fraction was low and the highest level of fine contents was recorded. Only two exclusive species were found, and the most characteristic were *P. serpens*, *L. yhleni*, *A. finmarchica* and *Melinna* sp.1.

**Table 3.1a** Total characterisation of each affinity group. FG= fine gravel; VCS= very coarse sand; CS= coarse sand; MS= medium sand; FS= fine sand; VFS= very fine sand; M= mud. Constancy: Cn = constant, C = common, O = occasional; Fidelity: E = elective, P = preferential, I = indifferent; \* = exclusive species in each group

Affinity group	Group A1	Group A2	Group B1	Group B2	Group B3
Nr. of sampling sites	2	19	6	12	2
Main sediment type	medium sand	very coarse sand	fine sand	very fine sand	Mud
Sediment types	MS (2)	FG (3), VCS (7), CS (5), MS (3), FS (1)	FG (1), VCS (1), FS (4)	VCS (1), MS (2), FS (3), VFS (6)	M(2)
Gravel content (mean; %)	0.76	29.6	16.2	4.7	0
Sand content (mean; %)	98.9	69.4	82.5	77.9	26.8
Fines content (mean; %)	0.16	0.9	1.3	17.6	73.4
Depth (mean; m)	21.6	72.3	43.8	126.8	113.6
Abundance (mean)	1704	441	64.7	61.5	16.5
Total species richness	18	137	56	112	17
Mean <i>alpha</i> diversity	13.5	30.3	14.5	26.7	10
Shannon-Wiener (mean; H', logn)	0.75	2.3	2	2.9	2.1
Pielou's evenness (mean; J')	0.3	0.7	0.8	0.9	0.9
Margalef (mean; d)	1.72	5.4	3.5	6.3	3.2
Simpson (mean; 1-λ')	0.37	0.7	0.8	0.9	0.9
Nr. of exclusive species	0	59	6	39	2
Characteristic species (with Constancy and Fidelity indications)	<i>Ophelia neglecta</i> (Cn/E); <i>Pisione parapari</i> (Cn/P); <i>Nephtys cirrosa</i> (Cn/I); <i>Hesionura elongata</i> (Cn/I); <i>Pisione remota</i> (Cn/I); <i>Eulalia mustela</i> (Cn/I); <i>Polygordius appendiculatus</i> (Cn/I); <i>Mysta picta</i> (C/P); <i>Saccocirrus papillocercus</i> (C/P); <i>Glycera oxycephala</i> (C/P); <i>Parapionosyllis brevicirra</i> (C/P); <i>Scolecopsis (Scolecopsis) squamata</i> (C/I); <i>Scolecopsis (Parascolecopsis) tridentata</i> (C/I); <i>Eumida sanguinea</i> (C/I); <i>Spio decoratus</i> (C/I)	<i>Psamathe fusca</i> (Cn/E)*; <i>Goniadella gracilis</i> (Cn/E)*; <i>Protodorvillea kefersteini</i> (Cn/E)*; <i>Syllis garciai</i> (Cn/E)*; <i>Sphaerosyllis taylori</i> (Cn/P); <i>Sphaerosyllis hystrix</i> (Cn/E)*; <i>Eulalia mustela</i> (Cn/E)*; <i>Sphaerosyllis bulbosa</i> (Cn/P); <i>Aonides oxycephala</i> (Cn/P); <i>Pullia sp.</i> (C/E)*; <i>Gyptis propinqua</i> (C/E)*; <i>Eurysyllis tuberculata</i> (C/E)*; <i>Mediomastus fragilis</i> (Cn/I); <i>Caulerella bioculata</i> (C/E)*; <i>Oxydromus pallidus</i> (C/E)*	<i>Spiophanes bombyx</i> (Cn/P); <i>Glycera tridactyla</i> (Cn/E)*; <i>Phyllodoce rosea</i> (C/E)*; <i>Spio filicornis</i> (C/P); <i>Magelona johnstoni</i> (C/P); <i>Prionospio steenstrupi</i> (C/E)*; <i>Nephtys assimilis</i> (C/P); <i>Owenia fusiformis</i> (C/I); <i>Mediomastus fragilis</i> (Cn/I); <i>Scoloplos (Scoloplos) armiger</i> (C/I); <i>Orbinia sertulata</i> (O/E)*; <i>Acholoe squamosa</i> (O/E)*; <i>Sigalion mathildae</i> (O/E)*; <i>Mesochaetopterus sagittarius</i> (C/I); <i>Phyllodoce longipes</i> (O/P)	<i>Aricidea (Acmira) laubieri</i> (Cn/E)*; <i>Amage</i> sp. (Cn/E)*; <i>Aponuphis brementi</i> (C/E)*; <i>Aricidea (Aricidea) pseudoarticulata</i> (Cn/P); <i>Euclymene</i> sp.A (C/E)*; <i>Prionospio ehlersi</i> (C/E)*; <i>Mesochaetopterus sagittarius</i> (Cn/I); <i>Magelona minuta</i> (C/P); <i>Aricidea (Aricidea) wassi</i> (C/P); <i>Nephtys kersivalensis</i> (Cn/I); <i>Magelona filiformis</i> (Cn/I); <i>Pterolysippe vanelli</i> (C/E)*; <i>Chirimia biceps</i> (C/E)*; <i>Prionospio pulchra</i> (C/E)*; <i>Pista cristata</i> (C/I)	<i>Poecilochaetus serpens</i> (Cn/P); <i>Labioleanira yhleni</i> (Cn/P); <i>Ampharete finmarchica</i> (Cn/I)*; <i>Melinna</i> sp.1 (C/E)*; <i>Ancilostyrellis groenlandica</i> (C/E)*; <i>Abyssoninoe hibernica</i> (C/P); <i>Trichobranchus roseus</i> (C/P); <i>Terebellides stroemii</i> (C/I); <i>Aphelochaeta</i> sp. (C/I); <i>Monticellina heterochaeta</i> (C/I); <i>Sarsonuphis bihanica</i> (C/I); <i>Aphelochaeta marioni</i> (C/I); <i>Lumbrineris lusitanica</i> (C/I); <i>Monticellina dorsobranchialis</i> (C/I); <i>Galathowenia oculata</i> (C/I)

Except done for the group A1, the diversity indices highlighted a good homogeneity in specie abundance per each group (**tab. 3.1a**). A1, on the contrary, showed the highest value of abundance, but low values of  $d$ ,  $H'$ ,  $J'$  and  $1 - \lambda'$ .

The analyses of the relationships between the environmental variables and the structure of the polychate assemblages, done with BIOENV routine, showed that depth, grain size (median) and fine contents were the best related with the biological data ( $\rho=0.598$ , significance of 0.1%).



**Figure 3.1d a)** nMDS based on the abundance of polychaetes; **b)** polychaete species as vectors with Spearman correlation ( $\rho > 0.5$ ); **c)** environmental data used as vectors with Spearman correlation ( $\rho > 0.5$ ).

### **3.2- Description of selected families**

Following WoRMS website (Read, 2015) scheme, a classic, commonly accepted way to classify polychaete families is into Errantia and Sedentaria subclasses. A brief description of some selected families is presented in this section, based on DELTA database (Dallwitz *et al.*, 2010), on the interactive key Polikey (Glasby & Fauchald, 2003), and on the book Polychaetes (Rouse & Pleijel, 2001), together with a commenting on their distribution in the study area.

#### **SUBCLASS: SEDENTARIA**

##### **Infraclass: Scolecida**

##### **Family: Capitellidae**

Family authority: Grube, 1862.

Capitellids are marine, freshwater or estuarine deposit feeders, present from the coastal shelf to the deep sea and distributed worldwide.

Their body is vermiform in shape, characterised by a division in thorax (with capillary chaetae only) and abdomen (with long-handled hooks) (**plate I c-d, annex 2**); the head has no appendages and appears discrete and compact. Pygidium is simple ring or cone, or plate-like (rarely). Pygidial appendages absent, or present; one pair of cirri, or single medial cirrus. Branchiae, if present, may be retractile and arise from the parapodia or from the dorsum. Their range size is from less than 10 mm to more than 200 mm.

Capitellids live in mucus-lined burrow or tubes, in detritus, mud and fine sand/mud sediments. Some species of the *Capitella capitata* complex are used as indicators of organic pollution because of their spread in areas with reduced species diversity due to natural causes or anthropogenic effects.

In the study area Capitellids were found with a total of 1071 specimens and 6 species. **Table**

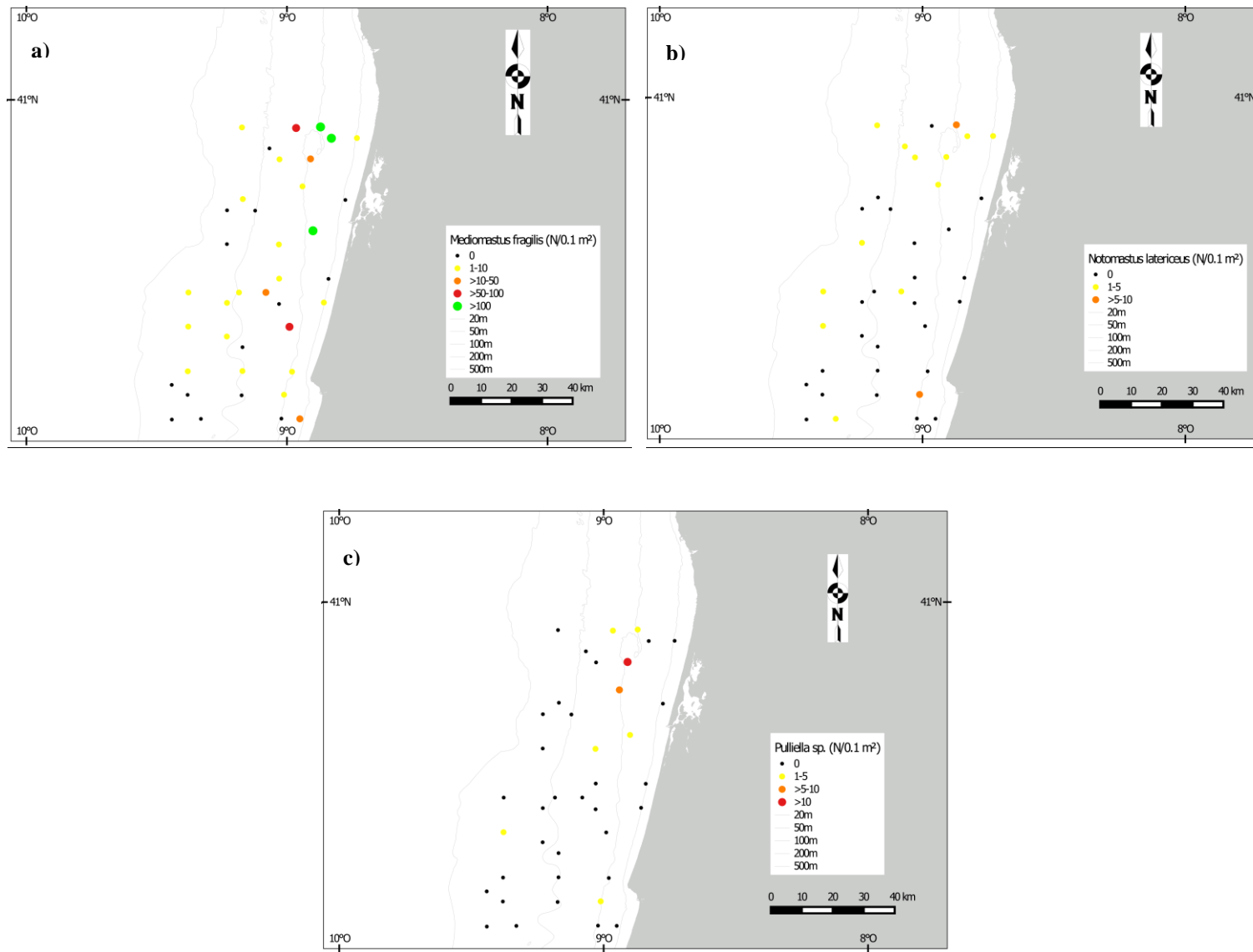


**3.2a** showed that the most abundant species were *Mediomastus fragilis* Rasmussen, 1973, *Notomastus latericeus* Sars, 1851 and *Pulliella* sp. Gravier, 1904. In general these species occurred more and with a higher abundance in coarse sediments; *M. fragilis* and *N. latericeus* were found in all the sediment types, even if with clearly different abundances. Further, *M. fragilis* is a characteristic species of the group A2 sites, and *Pulliella* sp. is exclusive of it (**tab. 3.1a**).

The distribution of the abundance of the Capitellids may be appreciate in **figure 3.2a**, in which it is possible to see how *M. fragilis* distribution covered almost all the study area, but the abundance was higher in shallow water. *N. latericeus* and *Pulliella* sp. showed distributions concentrated mainly in the N-NE part of the study area, characterised by coarse sediments.

**Table 3.2a** Capitellids with the number of sites in which they were found, the total abundance of the species, the number of sites per sediment type, and the abundance of each species per sediment type. FG= fine gravel; VCS= very coarse sand; CS= coarse sand; MS= medium sand; FS= fine sand; VFS= very fine sand; M= mud. In bold the sediment types in which species were more abundant.

Species	Nr. sites	Total abundance	Sediment type (nr. sites)	Sediment type (nr. specimens)
<i>Capitella</i> sp.	1	1	CS (1)	CS (1)
cf. <i>Capitellethus</i> sp.	2	2	MS (2)	MS (2)
cf. <i>Pseudoleiocyathella</i> sp.	1	1	VCS (1)	VCS (1)
<i>Mediomastus fragilis</i>	25	997	<b>FG (3), VCS (7), CS (5), MS (2), FS (5), VFS (2), M (1)</b>	<b>FG (238), VCS (578), CS (129), MS (6), FS (42), VFS (3), M (1)</b>
<i>Notomastus latericeus</i>	14	36	<b>FG (3), VCS (5), CS (2), MS (1), FS (2), VFS (1)</b>	<b>FG (15), VCS (11), CS (2), MS (3), FS (2), VFS (3)</b>
<i>Pulliella</i> sp.	8	34	<b>FG (3), VCS (3), CS (2)</b>	<b>FG (19), VCS (9), CS (6)</b>



**Figure 3.2a** Abundance distribution of the dominant Capitellid species **a) *M. fragilis***; **b) *N. latericeus***; **c) *Pulliella* sp.**

**Order: Spionida**

**Suborder: Spioniformia**

**Family: Spionidae**

Family authority: Grube, 1850

Spionids are marine worms present from the shallow water to the deep sea. Their distribution is worldwide.

These animals have a vermiform body-shape with numerous segments (more than about 15). Head is discrete and compact; prostomium shape is triangular to trapezoidal (narrow end posteriorly), or T-shaped. Prostomial antennae present, or absent. Grooved palps paired, dorsolateral. Pygidium- simple ring or cone, or with multiple digitate lobes; pygidial appendages present. Branchiae present, arising from the parapodia or from the dorsum. Range size goes from several mm to several cm (**plate III a-b, annex 2**).

Spionids are deposit or filter feeders; they may occur on soft or hard substrata; some species are epizoic (on mollusc shells). Tubes, if present, membranous.

This family includes 282 specimens belonging to 17 species. Spionids were distributed over the whole study area, occurring in 35/39 sites and in all sediment types, except mud (**tab. 3.2b; fig. 3.2b a**).

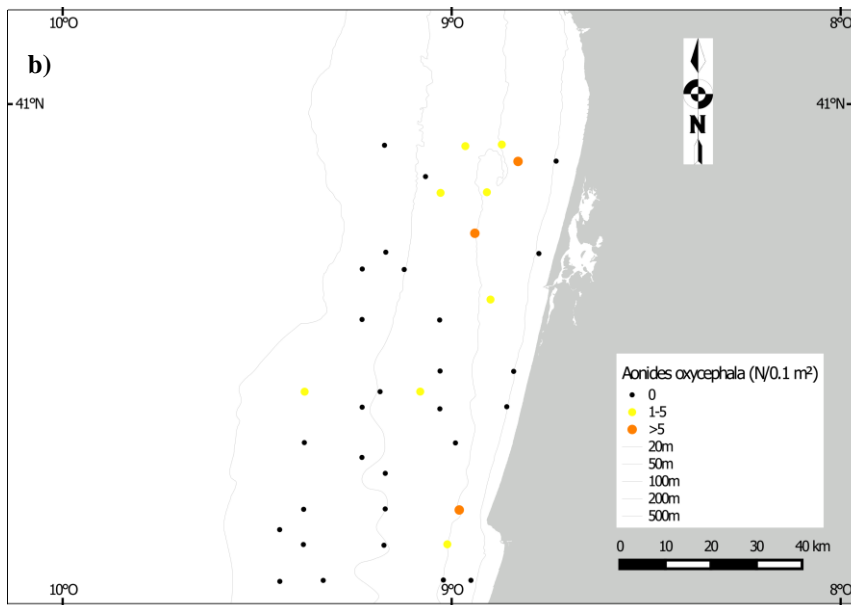
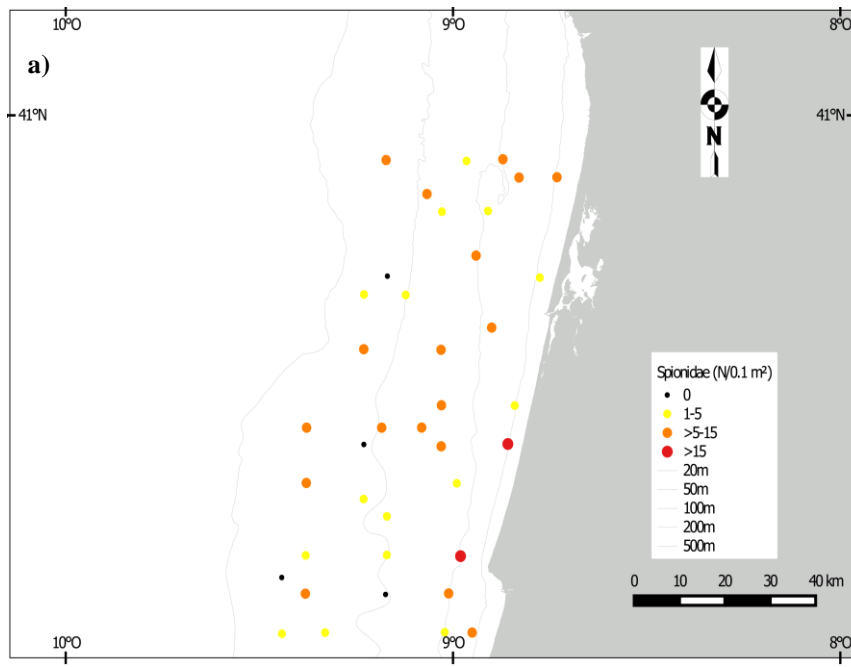
The most abundant species were *Prionospio multibranchiata* Berkeley, 1927, *Spiophanes bombyx* (Claparède, 1870) and *Aonides oxycephala* (Sars, 1862). *P. multibranchiata* was found with a total of 64 specimens in 18 sites. This species occurred from fine gravel to very fine sand; the abundance was higher in medium-fine sediments (medium sand, fine sand, very fine sand). *S. bombyx* was found with a total of 52 specimens in 13 sites. Fine and very fine sand were the sediment types in which the species occurred more often with a total of 8/13 sites.

Also the abundance was higher in these sediments with a total of 39/52 specimens. *A. oxycephala* was found with a total of 48 specimens distributed in 16 sites with the following

sediment types: fine gravel, very coarse sand, coarse sand, medium sand and fine sand. Further, *A. oxycephala* is a characteristic species of the group A2, and *S. bombyx* of the group B1 (**tab. 3.1a**). In the **figure 3.2b b** is possible to see that almost all the sites were located at depth less than 100 m. This species seemed to be more abundant in coarser sediments (fine gravel, very coarse and coarse sand) with a total of 40/48 animals.

**Table 3.2b** Spionids with the number of sites in which they were found, the total abundance of the species, the number of sites per sediment type, and the abundance of each species per sediment type. FG= fine gravel; VCS= very coarse sand; CS= fine sand; MS= medium sand; FS= fine sand; VFS= very fine sand. In bold the sediment types in which species were more abundant.

Species	Nr. sites	Total abundance	Sediment type (nr. sites)	Sediment type (nr. specimens)
<i>Aonides oxycephala</i>	16	48	FG (3), VCS (7), CS (3), MS (1), FS (2)	<b>FG (16), VCS (18), CS (6), MS (1), FS (7)</b>
<i>Laonice bahusiensis</i>	5	11	FG (1), VCS (1), CS (1), FS (1), VFS (1)	FG (1), VCS (1), CS (1), FS (1), VFS (7)
<i>Paraprionospio pinnata</i>	3	4	VFS (3)	VFS (4)
<i>Prionospio aluta</i>	1	1	VFS (1)	VFS (1)
<i>Prionospio ehlersi</i>	5	21	VCS (1), MS (1), FS (1), VFS (2)	VCS (4), MS (9), FS (3), VFS (5)
<i>Prionospio fallax</i>	3	3	VCS (1), FS (2)	VCS (1), FS (2)
<i>Prionospio multibranchiata</i>	18	64	FG (1), VCS (6), CS (3), MS (2), FS (3), VFS (3)	FG (2), VCS (14), CS (14), <b>MS (15), FS (16), VFS (3)</b>
<i>Prionospio pulchra</i>	4	7	FS (1), VFS (3)	FS (2), VFS (5)
<i>Prionospio sp.</i>	2	3	VCS (1), VFS (1)	VCS (2), VFS (1)
<i>Prionospio steenstrupi</i>	2	2	FG (1), FS (1)	FG (1), FS (1)
<i>Scolecopsis (Parascolecopsis) tridentate</i>	5	17	CS (1), MS (1), FS (3)	CS (1), MS (3), FS (13)
<i>Scolecopsis (Scolecopsis) squamata</i>	4	8	VCS (1), MS (1), FS (2)	VCS (1), MS (1), FS (6)
<i>Scolecopsis sp.</i>	1	1	FS (1)	FS (1)
<i>Spio decoratus</i>	9	21	VCS (2), CS (2), MS (1), FS (3)	VCS (9), CS (7), MS (1), FS (3)
<i>Spio filicornis</i>	4	10	VCS (1), FS (3)	VCS (6), FS (4)
<i>Spiophanes bombyx</i>	13	52	FG (1), VCS (2), CS (1), MS (1), <b>FS (7), VFS (1)</b>	FG (3), VCS (7), CS (2), MS (1), <b>FS (38), VFS (1)</b>
<i>Spiophanes kroyeri</i>	5	9	CS (1), FS (2), VFS (2)	CS (3), FS (3), VFS (3)



**Figure 3.2b** Abundance distribution of a) Spionidae family; b) *Aonides oxycephala*.

**Order: Terebellida**

**Suborder: Terebellomorpha**

**Family: Terebellidae**

Family authority: Johnston, 1846.

Terebellids (spaghetti worms) are marine worms, distributed worldwide, from the shallow water to the deep sea.

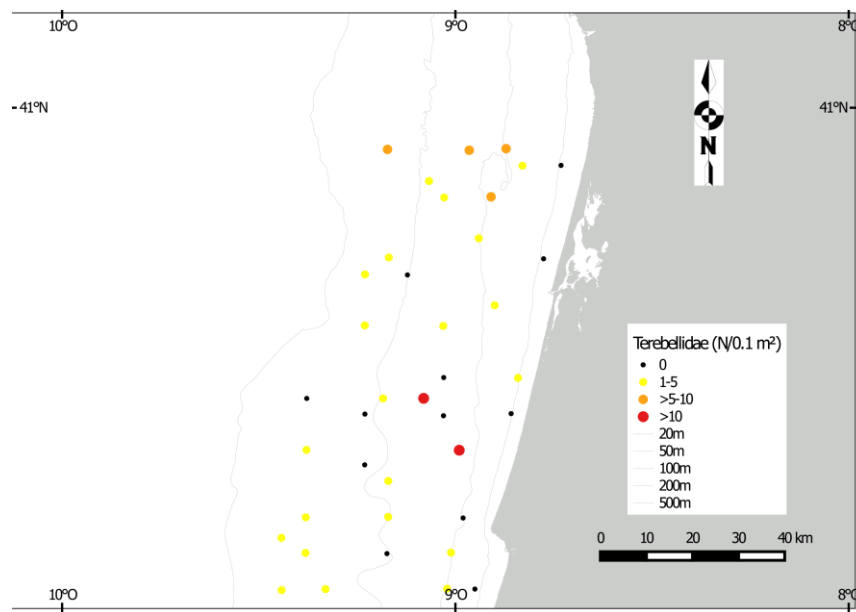
Spaghetti worms have a vermiform body-shape with or without division of the body in regions. The head bears many tentacles around the mouth. No palps. The pygidium is simple, in the shape of a cone or a ring, or with multiple lobes; no pygidial appendages. Branchiae, if present, occur from the dorsum, branching or filiform. Glandular ventral shield present. Range size is from 100 to 300 mm in length (**plate III d-e, annex 2**).

Terebellids are almost all deposit feeders, rarely may be filter feeders (using a mucus feeding net built into top of tube). Their tube, if present, is membranous, or leathery or parchment like. They may occur on soft substrata, or hard substrata (under stones and in crevices), or epizoic (algal holdfasts and seagrass).

A total of 121 Terebellids were found in the study area, belonging to 7 species plus 3 specimens of Terebellidae n.i. In general, almost all the species of this family occurred more in coarse sediments (fine gravel, very coarse sand, coarse sand) (**tab. 3.2c**). No species were found in mud. As is possible to see in the **figure 3.2c**, this family was well distributed in all the study area with a total of 27/39 sites. The most abundant species were *Pista cristata* (Müller, 1776) and *Polycirrus medusa* Grube, 1850. *P. cristata* was found with a total of 67 specimens, of which the most abundant were in coarse sediments (fine gravel, very coarse sand, coarse sand) with a total of 53/67 animals. This species is also characteristic of the group B2 (**tab. 3.1a**). *P. medusa* was found with a total of 37 specimens; of which 31/37 in coarse sediments (fine gravel, very coarse sand, coarse sand).

**Table 3.2c** Terebellids with the number of sites in which they were found, the total abundance of the species, the number of sites per sediment type, and the abundance of each species per sediment type. FG= fine gravel; VCS= very coarse sand; CS= coarse sand; MS= medium sand; FS= fine sand; VFS= very fine sand. In bold the sediment types in which species were more abundant.

Species	Nr. sites	Total abundance	Sediment type (nr. sites)	Sediment type (nr. specimens)
<i>Eupolymnia nebulosa</i>	1	1	VFS (1)	VFS (1)
<i>Lanice conchilega</i>	5	9	VCS (1), CS (1), MS (1), VFS (2)	VCS (1), CS (1), MS (4), VFS (3)
<i>Pista cristata</i>	16	67	<b>FG (2), VCS (7), CS (1), MS (2), FS (2), VFS (2)</b>	<b>FG (5), VCS (47), CS (1), MS (4), FS (7), VFS (3)</b>
<i>Pista lornensis</i>	1	2	VCS (1)	VCS (2)
<i>Polycirrus medusa</i>	15	37	<b>FG (4), VCS (5), CS (3), VFS (3)</b>	<b>FG (14), VCS (8), CS (9), VFS (6)</b>
<i>Streblosoma bairdi</i>	1	1	MS (1)	MS (1)
<i>Terebellidae n.i.</i>	2	3	FG (1), MS (1)	FG (1), MS (2)
<i>Neoamphitrite figulus</i>	3	4	VCS (1), CS (1), MS (1)	VCS (2), CS (1), MS (1)



**Figure 3.2c** Abundance distribution of Terebellidae family.

**SUBCLASS: ERRANTIA**

**Order: Phyllodocida**

**Suborder: Aphroditiformia**

**Family: Sigalionidae**

Family authority: Malmgren, 1867.

Sigalionids (scaleworms) are marine worms present from the shallow water to the deep sea.

They are cosmopolitan.

These animals have a vermiform body-shape with numerous segments (more than about 15).

Head discrete and compact, with a rounded to oval (anteriorly truncate) prostomium. Two pairs of eyes, if present; prostomial antennae present, a pair anterolateral and a single medial one.

Palps present. Pygidium simple with appendages. Branchiae present, digitiform, arising from the parapodia. Dorsal cirri modified as elytra (**plate VI a-b, annex 2**).

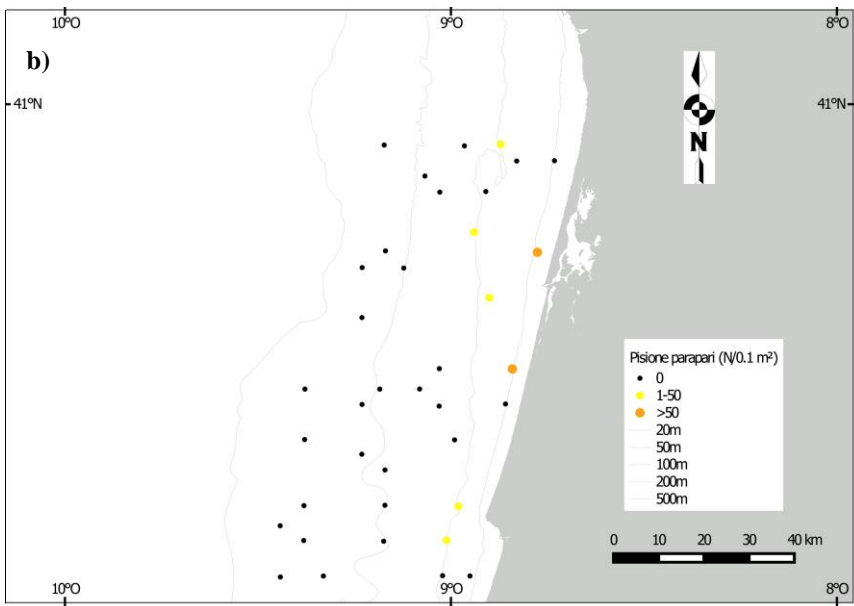
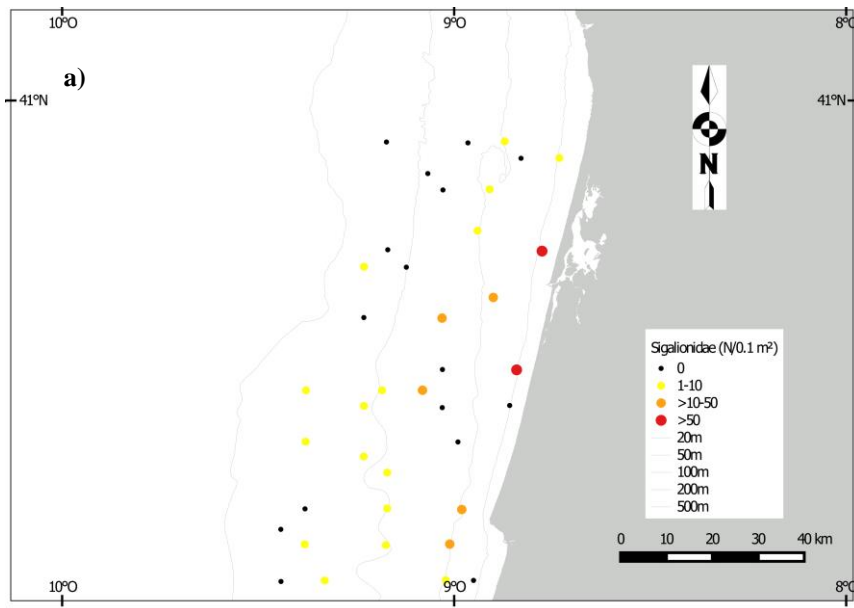
Sigalionids are raptorial feeders living in soft substrata.

Sigalionids were found with a total of 859 specimens belonging to 6 species. This family occurred in all the sediment types (**tab. 3.2d**), and, as the **figure 3.2d a** shows, the highest abundances were found in sites located up to 100 meters depth. The most abundant species were *Pisione parapari* Moreira, Quintas & Troncoso, 2000 and *P. remota* (Southern, 1914). *P. parapari* was found with a total of 670 specimens, reaching the peak of the abundance in medium-fine sediments (medium sand, fine sand). *P. remota* is characteristic of the group A1 (**tab. 3.1a**). It is possible to appreciate in the **figure 3.2d b** that all the animals were found between 20 and 50 m. *P. remota* was found with 167 specimens, of which 114 in medium and fine sand.



**Table 3.2d** Sigalionids with the number of sites in which they were found, the total abundance of the species, the number of sites per sediment type, and the abundance of each species per sediment type. FG= fine gravel; VCS= very coarse sand; CS= coarse sand; MS= medium sand; FS=fine sand; VFS= very fine sand; M= mud. In bold the sediment types in which species were more abundant.

Species	Nr. sites	Total abundance	Sediment type (nr. sites)	Sediment type (nr. specimens)
<i>Labioleanira yhleni</i>	6	12	FS (1), VFS (3), M (2)	FS (2), VFS (4), M (6)
<i>Pisone guanche</i>	1	1	FG (1)	FG (1)
<i>Pisone parapari</i>	7	670	FG (2), VCS (1), CS (1), MS (2), FS (1)	FG (3), VCS (6), CS (26), <b>MS (610)</b> , FS (25)
<i>Pisone remota</i>	13	167	FG (2), VCS (3), CS (4), MS (3), FS (1)	FG (10), VCS (32), CS (11), <b>MS (108)</b> , FS (6)
<i>Sigalion mathildae</i>	1	3	FS (1)	FS (3)
<i>Sthenelais limicola</i>	3	6	FG (1), CS (1), MS (1)	FG (2), CS (2), MS (2)



**Figure 3.2d** Abundance distribution of **a)** Sigalionidae family; **b)** *Pisione parapari*.

**Suborder: Nereidiformia**

**Family: Syllidae**

Family authority: Grube, 1850.

Syllids are marine worms, present from the coastal shelf to the deep sea. Their distribution is worldwide.

These animals have a vermiform or grube-like body, dorsoventrally flattened. Head is discrete to compact; prostomium is rounded to oval (anteriorly truncate). Eyes present (two or three pairs) with or without compound lenses. Prostomial antennae present; palps paired, ventrolateral. Pygidium is simple with appendages. Branchiae absent. Proventricle with radiating muscle fibres. Range size is from around 1 mm to several cm (**plate VI d-e, annex 2**).

Syllids may be raptorial feeders, or parasitic, or commensal living in both soft or hard substrata, or epizoic.

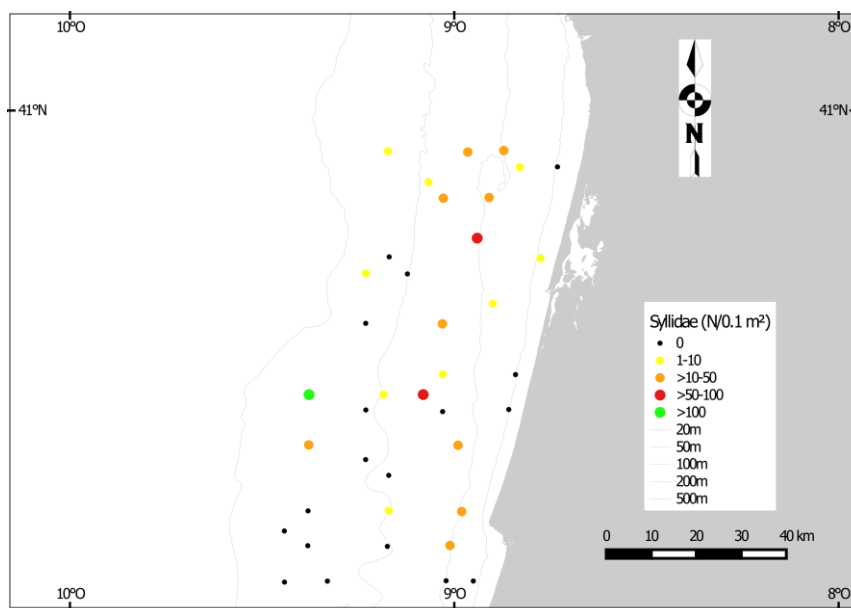
This family was found with a total of 635 specimens belonging to 18 species. Syllids occurred in 21/39 sites and the highest abundances, in general, were recorded in coarse sediments (fine gravel, very coarse sand, coarse sand). No individuals were found in very fine sand and mud.

The **figure 3.2e** shows that almost all the sites (17/21) were located at depth less than 100 m.

The most abundant species were *Syllis garciai* (Campoy, 1982) and *Sphaerosyllis bulbosa* Southern, 1914, both characteristic species of the group A2 (**tab. 3.1a**). *S. garciai* was found with a total of 207 specimens in 11/21 sites. This species reached the highest abundances in coarse sand. *S. bulbosa* was found with 170 animals in 14/21 sites, of which 11 were coarse sediments (fine gravel, very coarse sand, coarse sand). Also the highest abundances were found in these sediment types (**tab. 3.2e**).

**Table 3.2e** Syllids with the number of sites in which they were found, the total abundance of the species, the number of sites per sediment type, and the abundance of each species per sediment type. FG= fine gravel; VCS= very coarse sand; CS= coarse sand; MS= medium sand; FS=fine sand. In bold the sediment types in which species were more abundant.

Species	Nr. sites	Total abundance	Sediment type (nr. sites)	Sediment type (nr. specimens)
<i>Eurysyllis tuberculata</i>	8	70	FG (2), VCS (5), FS (1)	FG (53), VCS (15), FS (2)
<i>Myrianida brachycephala</i>	1	1	MS (1)	MS (1)
<i>Paraehlersia ferrugina</i>	5	9	FG (3), VCS (2)	FG (6), VCS (3)
<i>Parapionosyllis brevicirra</i>	2	7	VCS (1), MS (1)	VCS (1), MS (6)
<i>Plakosyllis brevipes</i>	5	10	FG (1), VCS (4)	FG (1), VCS (9)
<i>Prosphaerosyllis campoyi</i>	1	1	VCS (1)	VCS (1)
<i>Salvatoria sp.</i>	1	1	FG (1)	FG (1)
<i>Sphaerosyllis bulbosa</i>	14	170	<b>FG (3), VCS (6), CS (2)</b> , MS (1), FS (2)	<b>FG (35), VCS (106), CS (23)</b> , MS (3), FS (3)
<i>Sphaerosyllis hystrix</i>	10	16	FG (1), VCS (7), MS (1), FS (1)	FG (1), VCS (12), MS (1), FS (2)
<i>Sphaerosyllis sp.</i>	4	7	FG (2), VCS (1), MS (1)	FG (5), VCS (1), MS (1)
<i>Sphaerosyllis taylora</i>	13	53	FG (3), VCS (4), CS (3), MS (1), FS (2)	FG (8), VCS (31), CS (7), MS (4), FS (3)
<i>Streptodonta pterochaeta</i>	6	18	FG (2), VCS (2), CS (1), FS (1)	FG (9), VCS (3), CS (5), FS (1)
<i>Streptosyllis bidentate</i>	3	3	VCS (1), MS (1), FS (1)	VCS (1), MS (1), FS (1)
<i>Syllides convolutes</i>	2	3	CS (1), FS (1)	CS (1), FS (2)
<i>Syllis garciai</i>	11	207	FG (3), VCS (5), CS (3)	FG (11), VCS (23), <b>CS (173)</b>
<i>Syllis licheri</i>	9	40	FG (2), VCS (4), CS (1), FS (2)	FG (9), VCS (16), CS (1), FS (14)
<i>Synmerosyllis lamelligera</i>	4	17	FG (3), VCS (1)	FG (16), VCS (1)
<i>Trypanosyllis (Trypanosyllis) coeliaca</i>	1	2	FG (1)	FG (2)



**Figure 3.e** Abundance distribution of Syllidae family.

**Subclass: Polychaeta incertae sedis**

**Family: Polygordiidae**

Family authority: Czerniavsky, 1881

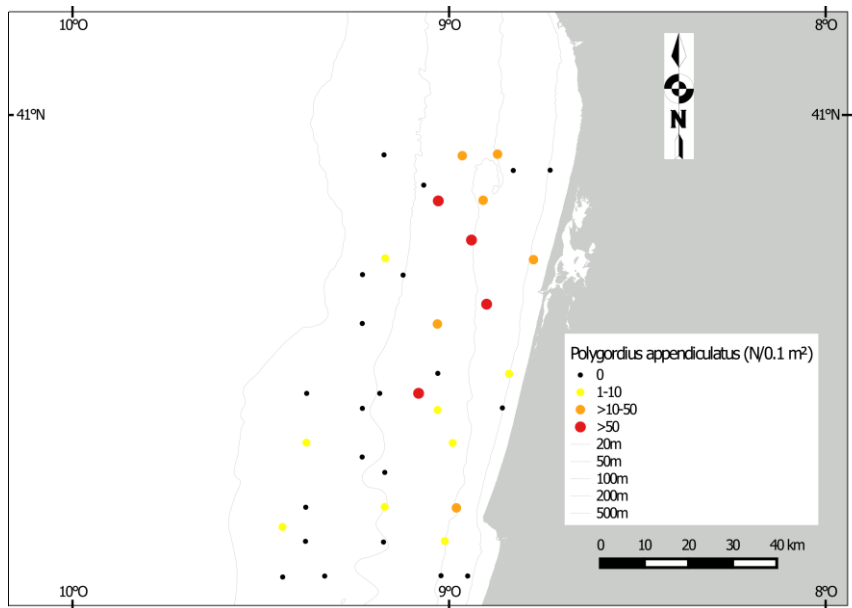
Polygordiids are marine worms of the continental shelf. Their distribution is cosmopolitan.

Their body-shape is vermiform with a weak, or absent, segmentation. Head discrete and compact with a blunty conical to trapezoidal (narrow end anteriorly). Prostomial antennae present, paired arising anterolaterally. No palps. Pygidium simple ring or cone, or with multiple digitate lobes. Branchiae absent. No parapodia. Range size from 10 to 100 mm (**plate VII a, annex 2**).

Polygordiids are interstitial worms living in soft substrata.

This family was found in the study area in 18 sites, with a total of 473 specimens belonging to the species *Polygordius appendiculatus* Fraipont, 1887. Polygordiids were sampled in 14 sites of coarser sediments (fine gravel, very coarse sand, coarse sand), 2 of medium sand and 2 of fine sediments (fine and very fine sand). No species were found in mud. The majority of the sites were shallower than 100 meters depth, reaching the highest abundances in the NE part of

the study area (**fig. 3.2f**). *P. appendiculatus* was also one of the characteristic specie of the group A1 (**tab. 3.1a**).



**Figure 3.2f** Abundance distribution of *Polygordius appendiculatus*.

## 4 - DISCUSSION AND CONCLUSION

The aim of this section is to integrate and discuss all the results presented in the thesis.

Being the West Iberian Coast scarcely and recently studied, the aim of this work was focused on a more detailed description of the spatial distribution of the polychaete fauna in the Northwestern Portuguese Coastal Shelf. Polychaetes are one of the most abundant benthic taxa along the Portuguese Continental Shelf (Martins *et al.*, 2013); in fact, despite the small area investigated, 197 species belonging to 41 families were found. In general, sediment characteristic, depth, salinity and temperature (Gray, 1974; Hutchings, 1998), as well as hydrodynamics, are the principal factor related to the distribution of this taxon (Simboura *et al.*, 2000).

The species richness recorded in the study area may reflect the structure of the communities, characterised not only by small-sized fast-colonising species with high growth rates, but also by larger slowly growing species (Lourido *et al.*, 2008). Moreover, the presence of families with different ecology and behaviour can be justified by the various types of the sediments that characterise this part of the Portuguese Coastal Shelf, ranging from fine gravel to mud. Such sediment diversity was attributed by Martins *et al.*, (2012) to the co-existence of a number of driving factors, namely mainland lithology, fluvial input, hydrodynamics, physiography of the shelf (slope, morphological barriers), but also the biological activity, paleoclimatic changes and anthropogenic contamination. The precipitation and the presence of rivers play also an important role in the large fluvial input in this sector of the shelf. In general, the northwestern sector is characterised by a discontinuous seaward decreasing trend in grain size, because of the presence of some relict deposits (Abrantes & Rocha, 2007). According to this scenario, the results of BIOENV routine could be interpreted, giving importance to these variables and to their correlation with the polychaete assemblages.

The decreasing abundance trend related to the depth confirms what Martins *et al.*, (2013) described for the Portuguese shelf and also agrees to what other authors reported for different coasts around the world, e.g. Brooks *et al.*, (2006); Moulart *et al.*, (2007), Montiel *et al.*, (2011), Hernández-Alcántara *et al.*, (2014). Obviously, as Fitzhugh, (1984) wrote, polychaete distribution was not only influenced by the depth itself, but also by other depth-related parameters, as bottom-water variability, sedimentary stability and food availability. In this work, maybe for the small-scale observation, latitude did not seem to influence the patterns of distribution.

In this study, for the first time, mud assemblages were recorded and described in the Northwestern part of the Shelf. The presence of this group (B3) at depth higher than 100m, and the low number of sites belonging to it, may be explained by the extremely energetic regime of waves and tides characterising in this sector, that remove and deplete the fine component of the sediments. This affinity group was characterised by the species *Labioleanira yhleni*, *Poecilochaetus serpens* and *Ampharete finmarchica*. All these species occur in soft substrata, and in particular *P. serpens* and *A. finmarchica* are both tubicolous deposit or filter feeders. Furthermore, *L. yhleni* is known already in the literature to be representative of silt assemblages in other parts of the world (e.g. Papazacharias & Voultziadou, 1998; Simbora *et al.*, 2000), and it is an important bioturbator of soft substrata (Queirós *et al.*, 2013). It is also important to underline how, despite having low values of the diversity indices, the group B3 and its sediment composition played a role in the general trend of the polychaete distribution as revealed in BIOENV routine.

The groups with the highest mixture in sediment types (groups A2 and B2) reached the highest values in species richness and diversity indices and the exclusive species were all of relatively small sizes belonging to the families e.g. Dorvilleidae, Hesionidae, Spionidae, Paraonidae, Sigalionidae and Syllidae. This may be related to the heterogeneity established in these mixed sediments that provide interstitial spaces for small specimens of these families. Further, the



considerable abundance of the latter family may be explained also by their wide diversity of the reproductive phenomena (Franke, 1999).

Also the considerably high abundance of Capitellidae family may be explained in this study by their high reproductive capability, being characterised by opportunistic species inhabitant of polluted and disturbed areas (Papazacharias & Voultsiadou, 1998; Horng & Taghon, 1999; Stark *et al.*, 2014). Polluted areas are related in literature to fine and silt sediments (e.g. Palanques & Diaz, 1994; Ünlü & Alpar, 2015), on the contrary in this work these specimens reached the highest abundances in fine gravel, very coarse sand and coarse sand. Moreover, as Martins *et al.*, (2012) said, the Portuguese Continental Shelf, except done for some located areas nearshore, seems to be non- polluted; it may be endorsed by the presence also of other families or species (e.g. Maldanidae, Lumbrineridae, Terebellidae, and *Terebellides stroemii*, *Scalibregma inflatum*) linked to the good state of the habitat (Dean, 2008). Further, the most abundant capitellid was *Mediomastus fragilis*, considered only tolerant to pollution, but not an indicator species.

On the other hand, the lowest values of biodiversity indices were reached in one of the groups with the highest homogeneity of sediment types (e.g. A1), confirming the data from literature about the lower faunal diversity related to the homogeneity of the sediment and the scarcity of microhabitats (Moreira *et al.*, 2006). This group (A1), the medium sand one, did not show exclusive species and characteristic ones, e.g. *P. parapari*, *P. remota* and *Hesionura elongata*, whilst in previous studies these species were generally related to coarser assemblages (Byrnes *et al.* 2003; Martins *et al.*, 2013).

*Spiophanes bombyx*, one of the characteristic species of the group B1, in literature, as well as in this study, is linked to fine sand assemblages with *Glycera tridactyla* (Moreira *et al.*, 2010; NPWS, 2011; Martins *et al.*, 2013) strengthening the correlation between these species and sand sediments. An exclusive species of this group was also *Phyllodoce rosea*, species present only in the Northwestern sector of the shelf (Martins, 2013).

The affinity among groups found in this work generally support the ones belonging to the northwestern sector described by Martins *et al.*, (2013). Actually, except for the mud assemblages that are newly described for this sector, the coarser sediment assemblages (A1 and A2) presented the same characteristic species belonging to the Syllidae and Sigalionidae families, as well as the assemblages of fine and very fine sand (B1 and B2) were characterised by species of Terebellidae and Magelonidae.

In conclusion, this study allows to have a more complete view of the polychaete fauna in the Northwestern part of the Portuguese Continental Shelf. In fact, not only the general spatial distribution of polychaetes and the relationships found with the environmental parameters, as depth and grain size, endorsed previous studies done in different parts of the world, but, thanks to the high sampling effort, mud assemblages were firstly described and some species representative of coarser mixed assemblages (fine gravel, very coarse and coarse sand) occurred and appeared as characteristic of a sandy homogeneous groups. Future studies may be done to analyse and better understand which other parameters might influence the distribution of species (e.g. *Phyllodoce rosea*) or families not explained yet.

## 5- BIBLIOGRAPHY

- Abrantes I, Rocha F. 2007. Sedimentary Dynamics of the Aveiro Shelf (Portugal). *Journal of Coastal Research* 1005–1009.
- Aguirrezabalaga F, Gil J. 2009. Paraonidae (Polychaeta) from the Capbreton Canyon (Bay of Biscay, NE Atlantic) with the description of eight new species. *Scientia Marina* 73: 631–666.
- Alveirinho Dias JM, Nittrouer CA. 1984. Continental shelf sediments of northern Portugal. *Continental Shelf Research* 3: 147–165.
- Banse K. 1969. Acrocirridae n.fam. (Polychaeta Sedentaria). *J Fish Res Board Can* 26: 2595–2620.
- Banse K. 1979. Sabellidae (Polychaeta) principally from the Northeast Pacific Ocean. *Journal de l'Office des recherches sur les pecheries du Canada* 36: .
- Barnich R, Fiege D. 2003. The Aphroditoidea (Annelida: Polychaeta) of the Mediterranean Sea. Frankfurt: Abh. senckenberg. naturforsch. Ges.
- Barwick K. 2006. Key to the Paraonidae ( Annelida : Polychaeta ) reported from the City of San Diego Ocean Monitoring program. 1: .
- Bettencourt AM, Bricker SB, Ferreira JG, Franco A, Marques JC, Melo JJ, Nobre A, Ramos L, Reis CS, Salas F, Silva MC, Simas T, Wolff WJ. 2004. Typology and reference conditions for Portuguese transitional and coastal waters. INAG and IMAR.
- Bhaud M, Lastra MC, Petersen ME. 1994. Redescription of *Spiochaetopteus solitarius* (Rioja, 1917), with notes on tube structure and comments on the generic status (Polychaeta: Chaetopteridae). *Ophelia* 40: 115–133.
- Bick A, Otte K, Meißner K. 2010. A contribution to the taxonomy of spio (Spionidae, Polychaeta, Annelida) occurring in the north and baltic seas, with a key to species recorded in this area. *Marine Biodiversity* 40: 161–180.
- Blake JA. 1996. Family Paraonidae, Cerruti, 1909. Blake, James A., Brigitte Hilbig & Paul H. Scott (eds.). *Taxonomic Atlas of the Benthic Fauna of the Santa Maria Basin and the Western Santa Barbara Channel. Volume 6, The Annelida Part 3: Polychaeta: Orbiniidae to Cossuridae*. Santa Barbara, California: Santa Barbara Museum of Natural History. p. 27–70.
- Brito MC, Nunez J. 2002. A new genus and species of Questidae (Annelida: Polychaeta) from the central Macaronesian region and a cladistic analysis of the family. *Sarsia: North Atlantic Marine Science* 87: 281–289.
- Brooks R., Purdy CN, Bell SS, Sulak KJ. 2006. The benthic community of the eastern US

- continental shelf: a literature synopsis of benthic faunal resources. *Cont. Shelf Res.* 26: 804–818.
- Byrnes MR, Hammer, R.M, Vittor BA, Kelley SW, Snyder, D.B. Côté JM, Ramsey JS, Thibaut TD, Phillips, N.W. Wood JD, Germano JD. 2003. Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal and Beach Restoration. .
- Cacabelos E, Moreira J, Troncoso JS. 2008. Distribution of Polychaeta in soft-bottoms of a Galician Ria (NW Spain). *Scientia marina* 72: 655–667.
- Cantone G. 1989. Censimento dei policheti dei mari italiani Poecilochaetidae. *Atti soc. Tosc. Sci. Nat.* 23–29.
- Capaccioni-Azzati R, Martin D. 1992. *Pseudomastus deltaicus* gen. et sp. n. (Polychaeta: Capitellidae ) from a shallow water bay in the North- Western Mediterranean Sea. *Zoologica Scripta* 21: 247–250.
- Castelli A, Valentini A. 1995. Censimento dei policheti dei mari Italiani Pectinariidae. *Atti soc. Tosc. Sci. Nat. Mem., Seri:* 51–54.
- Chambers S, Lanera P, Mikac B. 2011. *Chaetozone carpenteri*, McIntosh, 1911 from the Mediterranean Sea and records of other bi-tentaculate Cirratulids. 37–41.
- Chambers SJ, Garwood PR. 1992. Polychaetes from Scottish waters. A guide to identification. Part 3. Family Nereidae. Scotland: National Museums of Scotland.
- Clarke KR, Gorley RN. 2006. *PRIMER v.6: User Manual/Tutorial PRIMER-E.* 190.
- Costa PFE, Gil J, Passos AM, Pereira P, Melo P, Batista F, da Fonseca LC. 2006. SCIENTIFIC ADVANCES IN POLYCHAETE The market features of imported non-indigenous polychaetes in Portugal and consequent ecological concerns. *Scientia Marina* 70S3: 287–292.
- Dajoz R. 1971. *Précis d'Ecologie.* Paris: Ed. Dunod.
- Dallwitz MJ, Paine TA, Zurcher EJ. 2010. User's Guide to the DELTA Editor. *Delta* 1–31.
- Dean H. 2008. The use of polychaetes (Annelida) as indicator species of marine pollution: a review. *Rev Biol Trop* 56: 11–38.
- DeKluyver MJ, Ingalsuo SS, vanNieuwenhuijzen AJL, Veldhuijzen van Zanten HH. 2015. [Internet]. Available from: [http://species-identification.org/species.php?species\\_group=Macrobenthos\\_polychaeta&selected=foto&menuentry=inleiding&record=Introduction](http://species-identification.org/species.php?species_group=Macrobenthos_polychaeta&selected=foto&menuentry=inleiding&record=Introduction)
- Fauchald K. 1982. Revision of *Onuphis*, *Nothria*, and *Paradiopatra* (Polychaeta: Onuphidae) based upon type material. *Smithsonian Contributions to Zoology* 356: .
- Fauchald K. 1992. A Review of the Genus *Eunice* (Polychaeta: Eunicidae) Based upon Type Material. *Smithsonian Contributions to Zoology* 1–422.

- Fauvel P. 1923. Faune de France 5: Polychètes errantes. Paris: Office centrale de faunistique.
- Fiege D, Licher F, Mackie ASY. 2000. A partial review of the European Magelonidae (Annelida: Polychaeta): *Magelona mirabilis* redefined and *M. johnstoni* sp. nov. distinguished. *Journal of the Marine Biological Association of the UK* 80: 215–234.
- Fitzhugh K. 1984. Temporal and spatial patterns of the polychaete fauna on the central Northern Gulf of Mexico continental shelf. p. 211–225.
- Fiúza A, DeMacedo M, Guerreiro M. 1982. Climatological space and time-variation of the Portuguese coastal upwelling. *Oceanologica Acta* 5: 31–40.
- Franke HD. 1999. Reproduction of the Syllidae (Annelida: Polychaeta). *Hydrobiologia* 402: 39–55.
- Garwood PR. 2007. Family Maldanidae: A guide to species in waters around the British Isles. 1–32.
- Gil JCF. 2011. The European fauna of Annelida Polychaeta. Universidade de Lisboa.
- Glasby CJ, Fauchald K. 2003. POLiKEY. .
- Grassle JF, Grassle JP. 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. *Journal of Marine Research* 32: 253–284.
- Gravina MF, Somaschini A. 1990. Censimento dei policheti dei mari italiani: Capitellidae Grube, 1862. *Atti soc. Tosc. Sci. Nat. Mem.*: 259–285.
- Gray JS. 1974. Animal-sediment relationships. *Oceanogr. Mar. Biol. Ann. Rev.* 12: 223–261.
- Gutiérrez JL, Jones CG. 2006. Physical Ecosystem Engineers as Agents of Biogeochemical Heterogeneity. *BioScience* 56: 227.
- Harrington B. 2005. Inkscape. .
- Hayward PJ, Ryland JS. 1995. Handbook of the Marine Fauna of North-West Europe. Oxford, UK: Oxford University Press.
- Hernández-Alcántara P, León DAS, Solís-weiss V, Monreal-Gómez MA. 2014. Bathymetric patterns of polychaete ( Annelida ) species richness in the continental shelf of the Gulf of California , Eastern Pacific. *Journal of Sea Research* 91: 79–87.
- Herringshaw LG, Sherwood OA, McIlroy D. 2010. Ecosystem Engineering By Bioturbating Polychaetes in Event Bed Microcosms. *Palaios* 25: 46–58.
- Holthe T. 1986. Polychaeta Terebellomorpha. Marine invertebrates of Scandinavia, no. 7. Oslo: Norwegian university press.
- Hornig C, Taghon GL. 1999. Effects of contaminated sediments on particle size selection by the polychaete *Capitella* sp. I. *Journal of Experimental Marine Biology and Ecology* .
- Hutchings P. 1998. Biodiversity and functioning of polychaetes in benthic sediments. *Biodiv. Conserv.* 7: 1133–1345.

- Jirkov IA, Leontovich MK. 2013. Identification keys for Terebellomorpha (Polychaeta) of the eastern Atlantic and the North Polar Basin. *Invertebrate Zoolog* 10: 217–243.
- Jumars PA. 1974. A generic revision of the Dorvilleidae (Polychaeta), with six new species from the deep North Pacific. *Zool. J. Linn. Soc.* 54: 101–135.
- Katzmann W, Laubier L, Ramos JM. 1974. Pilargidae (annélides polychètes errantes) de Méditerranée. p. 40.
- Kirtley DK. 1994. A review and taxonomic revision of the family Sabellariidae Johnston, 1865 (Annelida; Polychaeta). Stuart, Florida: Sabecon Press-Science Series.
- Knight-Jones P, Perkins TH. 1998. A revision of Sabella, Bispira and Stylomma (Polychaeta: Sabellidae). *Zoological Journal of the Linnean Society* 385–467.
- Knight-Jones P. 1983. Contributions to the taxonomy of Sabellidae (Polychaeta). *Zoological Journal of the Linnean Society* 79: 245–295.
- Laubier L, Ramos J. 1973. Paraonidae (Polychètes sédentaires) de Méditerranée. *Bulletin du Muséum National d'Histoire Naturelle* .
- Leal MC. 2013. Effects of Sewage Discharge on Polychaete Communities in East African Peri-urban Equatorial and Subtropical Mangroves Effects of Sewage Discharge on Polychaete Communities in East African Peri-urban Equatorial and Subtropical. .
- Lourido A, Cacabelos E, Troncoso JS. 2008a. Patterns of distribution of the polychaete fauna in subtidal soft sediments of the Ría de Aldán (north-western Spain). *Journal of the Marine Biological Association of the UK* 88: .
- Lourido A, Cacabelos E, Troncoso JS. 2008b. Patterns of distribution of the polychaete fauna in subtidal soft sediments of the Ría de Aldán (north-western Spain). *Journal of the Marine Biological Association of the UK* 88: 263–275.
- Maciolek NJ. 1985. A revision of the genus *Prionospio* Malmgren, with special emphasis on species from the Atlantic Ocean, and new records of species belonging to the genera *Apoprionospio* Foster and *Paraprionospio* Caullery (Polychaeta, Annelida, Spionida). *Zoological Journal of the Linnean Society* 325–383.
- Mamede R, Rodrigues AM, Freitas R, Quintino V. 2015. Single-beam acoustic variability associated with seabed habitats. *Journal of Sea Research* 100: 152–159.
- Margalef R. 1958. Information theory in ecology. *Gen. Systems* 3: 36–71.
- Markert BA, Breure AM, Zechmeister HG. 2004. *Bioindicators & Biomonitoring*. Oxford, UK: Elsevier.
- Maron Ramos J. 1973. Annélides polychètes du plateau continental de la cote catalane espagnole. *Systématique et écologie*. Université Paris VI.
- Martin D. 1989. Revision de las especies de Owenidae (Annelida, Polychaeta) de la Peninsula Iberica. *Scientia marina* 53: 47–52.

- Martins R, Azevedo MR, Mamede R, Sousa B, Freitas R, Rocha F, Quintino V, Rodrigues AM. 2012a. Sedimentary and geochemical characterization and provenance of the Portuguese continental shelf soft-bottom sediments. *Journal of Marine Systems* 91: 41–52.
- Martins R, Carrera-Parra LF, Quintino V, Rodrigues AM. 2012b. Lumbrineridae (Polychaeta) from the Portuguese continental shelf (NE Atlantic) with the description of four new species. *Zootaxa* 21: 1–21.
- Martins R, Martín GS, Rodrigues AM, Quintino V. 2012c. On the diversity of the genus *Pisione* (Polychaeta, Pisionidae) along the Portuguese continental shelf, with a key to European species. *Zootaxa* 22: 12–22.
- Martins R, Quintino V, Rodrigues AM. 2013a. Diversity and spatial distribution patterns of the soft-bottom macrofauna communities on the Portuguese continental shelf. *Journal of Sea Research* 83: 56–64.
- Martins R, Sampaio L, Rodrigues AM, Quintino V. 2013b. Soft-bottom portuguese continental shelf polychaetes: Diversity and distribution. *Journal of Marine Systems* 123-124: 41–54.
- Montiel A, Quiroga E, Gerdes D. 2011. Diversity and spatial distribution patterns of polychaete assemblages in the Paso Ancho, Straits of Magellan Chile. *Continental Shelf Research* 31: 304–314.
- Moreira J, Quintas P, Troncoso JS. 2006. Spatial distribution of soft-bottom polychaete annelids in the Ensenada de Baiona (Ría de Vigo, Galicia, north-west Spain). *Scientia Marina* 70: 217–224.
- Moreira J, Veiga P, Rubal M. 2010. First record of *Pisione guanche* (Polychaeta: Pisionidae) at the Azores archipelago. *Marine Biodiversity Records* 3: .
- Moulaert I, Hostens K, Hillewaert H, Wittoeck J. 2007. Spatial variation of the macrobenthos species and communities of the Belgian Continental Shelf and the relation to environmental variation. *ICES A* 9: 1–13.
- NPWS. 2011. Raven Point Nature Reserve SAC ( site code: 0710 ). Conservation objectives supporting document -marine habitats.
- Nunez J, Pascual M, Delgado JD, C.M. B. 1997. Anélidos poliuetos de Canarias: familia Eunicidae. *VIERAEA* 26: 47–75.
- O'Connor BDS. 1987. The Glyceridae (Polychaeta) of the North Atlantic and Mediterranean, with descriptions of two new species. *Journal of Natural History* 21: 167–189.
- Oliveira IBM, Valle AJSF, Miranda FCC. 1982. Littoral Problems in the Portuguese West Coast. *Coastal Engineering* 3: 1950–1969.
- Oug E. 2012. Guide to identification of Lumbrineridae (Polychaeta) in north east Atlantic waters. [Nmbaqcs.Org](http://Nmbaqcs.Org) .
- Palanques A, Diaz JI. 1994. Anthropogenic heavy metal pollution in the sediments of the Barcelona continental shelf (Northwestern Mediterranean). *Marine Environmental*

- Research 38: 17–31.
- Papazacharias A, Voultziadou E. 1998. Infra- and Circalittoral Soft Substratum Macrofaunal Assemblages of Kavala Gulf (Aegean Sea). *Internat. Rev. Hydrobiol.* 83: 461–477.
- Pardal MA, Caldeira AM, Marques JC. 1992. Contribution to knowledge of the Polychaete fauna of Portugal Part I. Orbiniida, Cossurida and Spionida. *Cienc. Biol. Ecol. Syst.* .
- Paxton H. 1986. Generic revision and relationships of the family Onuphidae (Annelida: Polychaeta).
- Pettibone MH. 1962. New species of Polychaete worms (Spionidae: Spiophanes ) from the East and West coast of North America. p. Vol.75; 77–88.
- Pettibone MH. 1996. Revision of the scaleworm genera *Acholoe* Claparède, *Arctonoella* Buzhinskaja, and *Intoshella* Darboux (Polychaeta: Polynoidae) with the erection of the new subfamily Acholoinae. p. 629–699.
- Pielou EC. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* 13: 131–144.
- Pilato G, Cantone G. 1976. Nuove specie di *Poecilochaetus* e considerazioni sulla famiglia dei *Poecilochaetidae* (Annelida, Polychaeta). *Animalia* 3: 29–63.
- Pischedda L, Poggiale JC, Cuny P, Gilbert F. 2008. Imaging oxygen distribution in marine sediments. The importance of bioturbation and sediment heterogeneity. *Acta Biotheoretica* 56: 123–135.
- QGIS Development Team. 2015. QGIS Geographic Information System. Open Source Geospatial Foundation Project. .
- Queirós AM, Birchenough SNR, Bremner J, Godbold JA, Parker RE, Romero-Ramirez A, Reiss H, Solan M, Somerfield PJ, Van Colen C, Van Hoey G, Widdicombe S. 2013. A bioturbation classification of European marine infaunal invertebrates. *Ecology and Evolution* 3: 3958–3985.
- Quiroz-Martinez B, Schmitt FG, Dauvin J-C, Dewarumez J-M, Foveau A, Garcia C. 2011. Regional patterns of continental shelf polychaete diversity: examples for the North Sea, English Channel, Irish Sea and Outer Bristol Channel areas. *Ital. J. Zool.* 78: 324–332.
- Ravara A. 2010. A revision of the polychaete family *Nephtyidae*, based on morphological and molecular data. Universidade de Aveiro.
- Read G. 2015. [Internet]. Available from:  
[www.marinespecies.org/aphia.php?p=taxdetails&id=883](http://www.marinespecies.org/aphia.php?p=taxdetails&id=883)
- Retière C. 1979. Contribution à la Connaissance des Peuplements Benthiques du Golfe Normano-Breton. Université Rennes I, France.
- Rouse GW, Pleijel F. 2001. *Polychaetes*. New York: Oxford University Press.
- Rowe G. 2010. A provisional guide to the family *Opheliidae* (Polychaeta) from the shallow



- waters of the British Isles. Report EMU Limited 44: 1–12.
- Salazar-Vallejo SI, Carrera-Parra LF. 1998. Eunícidos (Polychaeta) del Caribe mexicano con claves para las especies del Gran Caribe: Eunice. *Revista de Biología Tropical*, 45(4): 1499-1521, 10 figures. 45: .
- San Martín G. 2003. *Fauna Ibérica. Annelida: Polychaeta II*. Vol.21. Madrid: CSIC.
- Sardá R, Gil J, Taboada S, Gili JM. 2009. Polychaete species captured in sediment traps moored in northwestern Mediterranean submarine canyons. *Zoological Journal of the Linnean Society* 155: 1–21.
- Schulz HD, Zabel M. 2006. *Marine Geochemistry*. Springer-Verlag Berlin Heidelberg.
- Shannon CE, Weaver W. 1963. *The Mathematical Theory of Communication*. Illinois: The University of Illinois Press.
- Shull DH. 1997. Mechanisms of infaunal polychaete dispersal and colonization in an intertidal sandflat. *Journal of Marine Research* 55: 153–179.
- Simboura N, Nicolaidou A, Thessalou-Legaki M. 2000. Polychaete communities of Greece: An ecological overview. *P.S.Z.N.I.:Mar. Ecol.* 21: 129–144.
- Simpson EH. 1949. Measurement of diversity. *Nature* .
- Stark JS, Kim SL, Oliver JS. 2014. Anthropogenic disturbance and biodiversity of marine benthic communities in Antarctica: A regional comparison. *PLoS ONE* 9: .
- Støp-Bowitz C. 1941. Les Glycériens de Norvège. *Medd. Zool. Mus. Oslo* 51: 181–250.
- Støp-Bowitz C. 1948. Les Flabelligériens Norvégiens. *Bergens museums årbok 1946 og 1947. Naturvitenskapelig rekke. Nr 2*.
- Surugiu V, Alexandru U, Cuza I. 2015. Preliminary study concerning the role of the benthic polychaetes in the feeding of some fish species from Romanian coast of the Black Sea. .
- Unicomarine. 1996. *A guide to the Family Cirratulidae, including a key to anterior portions. Version 1.00 (RT09)*. .
- Ünlü S, Alpar B. 2015. An assessment of metal contamination in the shelf sediments at the southern exit of Bosphorus Strait, Turkey. *Toxicological & Environmental Chemistry* 97: 723–740.
- Vanney J, Mougnot D. 1990. Un canyon sous-marin du type «gouf», le Canhão da Nazaré (Portugal). *Oceanologica Acta* 13: 1–14.
- Volkenborn N, Reise K. 2006. Lugworm exclusion experiment: Responses by deposit feeding worms to biogenic habitat transformations. p. 169–179.
- VV.AA. 2004. *Fauna Ibérica: Annelida Polychaeta I*. Vol. 25. Madrid: CSIC.
- Wentworth CK. 1922. A scale of grade and class terms for clastic sediments. *Journal of Geology* 30: 377–392.

- Westheide W. 1990. Polychaetes: Interstitial Families. Keys and notes for the identification of the species. Synopses of the British Fauna, (New Series). Oegstgeest, The Netherlands: Universal Book Services.
- Whittaker RH. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. *Ecol. Monogr.* 30: 279–338.
- Worsfold T. 2006. Identification guides for the NMBAQC Scheme: 1. Scalibregmatidae (Polychaeta) from shallow seas around the British Isles. *Porcupine Marine Natural History Society Newsletter* 15–18.
- Zibrowius H. 1968. Etude morphologique, systématique et écologique, des Serpulidae (Annelida Polychaeta) de la région de Marseille. *Rec. Trav. St. Mar. End. Bull.* 43: .

