Universidade de Aveiro Departamento de Biologia

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ROBERTO CARLOS DOMINGUES MARTINS

HABITATS BENTÓNICOS DA PLATAFORMA CONTINENTAL PORTUGUESA

THE PORTUGUESE CONTINENTAL SHELF SOFT-BOTTOM BENTHIC HABITATS

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Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Biologia, realizada sob a orientação científica da Professora Doutora Ana Maria de Jesus Rodrigues, Professora Auxiliar do Departamento de Biologia da Universidade de Aveiro e do Professor Doutor Victor Manuel dos Santos Quintino, Professor Auxiliar do Departamento de Biologia da Universidade de Aveiro.

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o júri

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palavras-chave

Plataforma continental Portuguesa; Península Ibérica Ocidental; substrato móvel; macrofauna bentónica; habitats; comunidades; espécies; padrões distribuição; relações ambientais e biológicas; biogeografia.

resumo

As comunidades de macrofauna bentónica são ecológica e economicamente relevantes, sendo fonte de diversos bens e serviços. A sua identificação, caracterização e mapeamento são importantes para identificar áreas marinhas protegidas e para uma melhor utilização do ambiente marinho. Este trabalho apresenta um estudo holístico da diversidade e distribuição espacial das comunidades de macrofauna bentónica ao longo da plataforma continental Portuguesa. Cerca de 145 locais posicionados ao longo da plataforma ocidental e setentrional foram amostrados com uma draga Smith-McIntyre de área 0,1 m^2, a profundidades que variaram entre os 13 e 195 metros. Os sedimentos foram caracterizados em termos de granulometria, de matéria orgânica e geoquímica. São propostos seis *habitats* bentónicos principais para a plataforma continental Portuguesa, analisada a relação entre os dados biológicos e ambientais e discutidas questões biogeográficas relacionadas com a distribuição espacial de espécies e das comunidades.

A distribuição da granulometria e assinatura geoquímica dos sedimentos da plataforma continental revelou-se bastante complexa, refletindo importantes diferenças nas fontes (naturais e antropogénicas), origem fluvial, geomorfologia da plataforma, hidrodinamismo e atividade biológica. Relativamente à macrofauna, entre os mais de 30 mil indivíduos recolhidos, foram identificados cerca de 737 taxa, dos quais quatro são novas espécies e aproximadamente 40 correspondem a primeiras ocorrências para a costa Portuguesa. As espécies mais frequentes foram a *Ampharete finmarchica, Ampelisca* sp. e *Lumbrineris lusitanica* **sp. nov**. enquanto as mais abundantes foram *Mediomastus fragilis, Polygordius appendiculatus* e *Ampharete finmarchica*. A abundância por local de amostragem variou entre 7 e 1.307 espécimens e a diversidade *alfa* atingiu um máximo de 96 taxa. Os sedimentos mais grosseiros apresentaram maior diversidade e abundância comparativamente com os sedimentos envasados. Foram identificados seis habitats bentónicos na plataforma continental Portuguesa: (a) sedimentos grosseiros com *Protodorvillea kefersteini, Pisione remota, Angulus pygmaeus* e várias espécies intersticiais; (b) areias finas hidrodinamicamente expostas e próximas da linha de costa com *Magelona johnstoni, Urothoe pulchella e Angulus fabula*; (c) comunidade de *Abra alba* em areia envasadas da plataforma profunda do noroeste; (d) *Galathowenia oculata, Lumbrinerides amoureuxi* e outros poliquetas escavadores e tubícolas em areais envasadas muito profundas na plataforma sudoeste; (e) *Euchone rubrocincta, Nematonereis unicornis* e várias espécies setentrionais nas areias envasadas da plataforma sul; (f) vasas com *Sternaspis scutata, Heteromastus filiformis e Psammogammarus caecus*. A granulometria do sedimento (particularmente teor em finos), matéria orgânica, profundidade e hidrodinamismo foram as variáveis ambientais com a maior relação com os padrões de distribuição da macrofauna.

As espécies cosmopolitas e de latitudes superiores (clima Boreal ou Temperado Frio) dominaram o setor noroeste, sendo substituídas por espécies mais quentes na área de transição entre os canhões da Nazaré e S. Vicente, que dominaram por conseguinte a plataforma sul. O presente estudo evidenciou a abundância e diversidade da macrofauna bentónica ao longo da área costeira de Portugal, na qual coexistem faunas das províncias biogeográficas do norte da Europa, bem como subtropicais. Integrado com outro estudos, este poderá ser a base para uma melhor gestão da plataforma continental Portuguesa.

keywords

Portuguese continental shelf; Western Iberia; soft-bottom; benthic macrofauna; habitats; communities; species; distribution patterns; biological-environmental relationships; biogeography.

abstract

Macrofauna benthic communities are ecologically and economically relevant, providing important ecological goods and services. Their identification, characterization and mapping are important to identify marine protected areas and to an overall better use of the marine environment. This work presents a comprehensive assessment of the diversity and spatial distribution of the soft-bottom benthic macrofauna communities along the Portuguese continental shelf. A total of 145 sites positioned along the west and south coasts of Portugal were sampled with a 0.1 m^2 Smith-McIntyre grab, at depths ranging from 13 to 195 metres. Sediment grain-size, total organic matter and bulk geochemistry were characterized. It is proposed six major soft-bottom benthic habitats for the Portuguese continental shelf, analysed the relationship between the macrofauna patterns and environmental variables and discussed the biogeographic issues related to the spatial distribution of species and communities.

The sediments grain-size distribution and geochemical signature were complex, reflecting differences in the sources, fluvial input, shelf morphology, hydrodynamic energy and biological activity. Concerning the macrofauna, 737 taxa were identified in more than 30000 specimens. Four new species and nearly 40 new species occurences for the Portuguese coast were recorded in the scope of this work. The most frequent species were *Ampharete finmarchica*, *Ampelisca* sp. and *Lumbrineris lusitanica* sp. nov., while the most abundant were *Mediomastus fragilis*, *Polygordius appendiculatus* and *Ampharete finmarchica*. Abundance per site ranged from 7 to 1307 specimens per 0.1 m^2 and *alpha* diversity reached a maximum of 96 taxa per 0.1 m^2. Coarser sediments presented higher diversity and abundance than mud sediments. Six major soft-bottom benthic habitats were identified and characterized: (a) coarse sediments with *Protodorvillea kefersteini*, *Pisione remota*, *Angulus pygmaeus* and other interstitial species (Lusitanean *Venus* community); (b) Near shore hydrodynamic exposed fine sands with *Magelona johnstoni*, *Urothoe pulchella* and *Angulus fabula* (Boreal Lusitanean *Tellina* community); (c) *Abra alba* community in northwestern deep muddy sands (with northern biogeographic affinity); (d) *Galathowenia oculata*, *Lumbrinerides amoureuxi* and other burrowers and tubicolous polychaetes in southwestern deep muddy sands (biological community with warmer affinity); (e) *Euchone rubrocincta*, *Nematonereis unicornis* and other warmer water species in muddy sands of the southern and sheltered shelf; (f) Muds of *Sternaspis scutata*, *Heteromastus filiformis* and *Psammogammarus caecus*. Sediment grain-size, organic matter, depth and hydrodynamic energy were the variables best related with the macrofauna distribution patterns.

Cosmopolitan and northern species (Cold Temperate and Boreal affinity) dominated the northwestern sector, were replaced by warmer species (Lusitanean, Mediterranean and African affinity) in a transition area between the Nazaré and S. Vicente Canyons, which then dominated the southern shelf. The present study highlighted the abundance and diversity of the macrofauna along a coastal area where cold temperate, warm temperate and subtropical faunas can coexist. Integrated with other studies, it can support a better management of the Portuguese coastal shelf.

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Chapter 1

Introduction

1.1. The general context: marine environment importance

The oceans contain 97% of the globe's water and cover 71% of the Earth. The oceanic environment influences the biosphere, regulates the atmosphere and climate and plays an integral role supporting the largest and the most dynamic ecosystem on Earth. Due to this, several human activities (fisheries, industry, trading/transportation, recreation, research, among others) are marine-related. Over one-third of the U.S. (nearly $700 billion)[1] and almost 40% of the EU's[2] Gross National Products are generated in the coastal areas, where the majority of the population worldwide lives. Moreover, 90% of the EU's foreign trade is conducted by sea[2]. Reflecting this key importance, several European policies, strategies and legislation (e.g. the Integrated Maritime Policy for the European Union (COM (2007) 575)[3]; the Marine Strategy Framework Directive[4]; the Europe 2020, a strategy for smart, sustainable and inclusive growth[5]) have been established and applied since the OSPAR Convention[6] and the United Nations Convention on the Law of the Sea[7], to protect the marine environment and to promote a better use of the North-East Atlantic Ocean and its resources. In this context Portugal, with one of world's biggest Exclusive Economic Zones, have been following this international trend launching recently, for instance, the National Ocean Strategy[8], created by the Task Group for Maritime Affairs[9] (Resolution n.º 128/2005 of the Council of Ministers), intended to "prepare a proposal setting measures to be implemented by the Portuguese Government in order to establish an integrated policy for maritime affairs and articulate all entities with authority in ocean-related issues". Furthermore, the Portuguese marine´s interest was also shown by the presentation of the proposal for the extension of the Portuguese continental shelf beyond 200 nautical miles (in a total of nearly 2.15 million squares of seabed), to the Commission on the Limits of the Continental Shelf of the United Nations by the Task Group for the Extension of the Portuguese Continental Shelf (Estrutura de Missão para a Extensão da Plataforma Continental – EMEPC), aiming to find new exploitable resources[10].

To better protect this fragile environment is key to study all compartments. In this study, only the bottom will be focused.

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[1] http://www.OceanEconomics.org/nationalreport, 30.10.12

[2] http://ec.europa.eu/maritimeaffairs/atlas/seabasins/index_en.htm, 30.10.12

[3] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0575:FIN:EN:PDF, 30.10.2012

[4] http://ec.europa.eu/environment/water/marine/directive_en.htm, 29.10.2012

[5] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF, 29.10.2012

[6] http://www.ospar.org/html_documents/ospar/html/ospar_convention_e_updated_text_2007.pdf, 30.10.2012

[7] http://www.un.org, 30.10.12

[8] https://webgate.ec.europa.eu/maritimeforum/system/files/National_Ocean_Strategy_Portugal_en.pdf, 29.10.2012

[9] http://www.emam.com.pt/, 29.10.2012

[10] http://www.emam.com.pt, www.campanhasmarbis.org, 24.10.2012

1.2. Concepts

The ocean floor can be generally divided in the continental margin, corresponding to the submerged edge of the continent, and the abyssal plain (or deep-sea floor) which lies at a depth of 4000 m, in average (Castro and Huber, 2008). The continental margin includes the continental shelf (up to the shelf break, i.e. the edge of the shelf where slope gradient abruptly increases toward deep waters), the continental slope (a very steep region, from shelf break to deep-sea floor) and the continental rise (a gentle sloping region at the base of the continental slope) (Castro and Huber, 2008). The continental shelf, which corresponds to nearly 8% of the ocean´s surface area, is the shallowest part of the continental margin, being characterized by gentle slopes and variable worldwide widths (less than 1 Km in the Pacific coast of the South America to 750 km in the Siberian Arctic coast) and shelf breaks (often 120 to 200 m water depth) (Castro and Huber, 2008). Continental shelf systems have high economic and ecological importance and are the major sinks for sediments exported from land. They are highly complex due to combination of diverse gradients of abiotic factors, like salinity, oxygen, temperature, bottom currents, organic matter, geochemistry, sediment type (e.g. Castro and Huber, 2008; Levinton, 2009). In most shelf sediments, it is possible to recognize different types of source components: (a) a lithogenic component, essentially composed by detrital particles derived from weathering of continental rocks; (b) a biogenic component consisting of skeletal remains and (c) a hydrogenous or authigenic component (clays, ferro-manganese oxyhydroxides), directly precipitated from seawater or produced by the reaction of sediment particles with seawater or through microbial activity (Schulz and Zabel, 2006 and references therein). The relative contribution of these inputs for shelf marine sediments is the dominant factor controlling their bulk chemical composition, which can therefore provide valuable insights into the mechanisms involved in sediment formation, transport, dispersal and deposition patterns, hydrodynamic regimes and lithology of the adjacent land areas (Rubio et al., 2000; Stevenson, 2001; Daesslé et al., 2004; Karageorgis et al., 2005; Machado et al., 2005; Preda and Cox, 2005; Jouanneau et al., 2008; Corredeira et al., 2009; Delgado et al., 2010; Nobi et al., 2010; Sánchez-García et al., 2010).

Biodiversity has a quite complex definition, which can be, simply, the diversity of life on Earth. The Convention on Biological Diversity[11], defines it as “the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic

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[11] http://www.cbd.int/, 30.10.2012

ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems", comprehending therefore the diversity of genes, species and ecosystem. It is estimated that European Union loses 3% of Gross Domestic Product per year (€450 billion) due to the loss of biodiversity.[12] To avoid those loses, the EU Biodiversity Strategy to 2020 (COM (2011) 244)[12] has being implemented to better protect the biodiversity and ecosystems and to use more green infrastructures. It is well known that the biological diversity in coastal and ocean environments is high and very important. However, no consensus has been found regarding the number of the total known marine species. According to Mora et al. (2011) nearly 194 thousand of marine species (180 thousand animals and plants) are catalogued, while Heip et al. (2009) refer that 230 thousand of marine plants and animals species are known worldwide. Approximately 12 thousand metazoans species are recognized in the western European seas, despite those assessments are clearly underestimated for most groups (Heip et al., 2009). The marine sediments, which cover more than 80% of the ocean floor, support a large diversity of organisms being the greater benthic biomass dominated by macrofauna invertebrates. Macrofauna corresponds to the animal species retained on a 1.0 mm sieve (or 0.5 mm for some authors, due to the quantification of smaller "macrobenthic" species, Levinton, 2009) and benthos comprehend those that have a relation with the seabed (infauna, if invertebrates live below the sediment-water interface and epifauna if they live on the surface). These organisms tend to live in particular environmental conditions and interact with other species by several processes (e.g. competition, predation; Seitz, 2011), forming self-regulated ecological communities (or biocoenosis/biocenosis) (Levinton, 2009). Continental shelves can present several physical benthic habitats, such as mudflats, extensive sandy areas, coarser sediments or rocky outcrops. This habitat variability influences the distribution of benthos which is not uniform but rather patchily distributed (Brooks et al., 2006). The distribution range of species is conditioned by habitat-physiology limitations, but also geographic barriers to dispersal (Levinton, 2009). Their combination breaks up the marine environment into a sequence of relatively distinct species assemblages. The geographic regions containing these assemblages are known as provinces (Figure 1), which can be characterized by some exclusive species, while others tend to occurs in adjacent provinces.

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[12] http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm, 29.10.2012

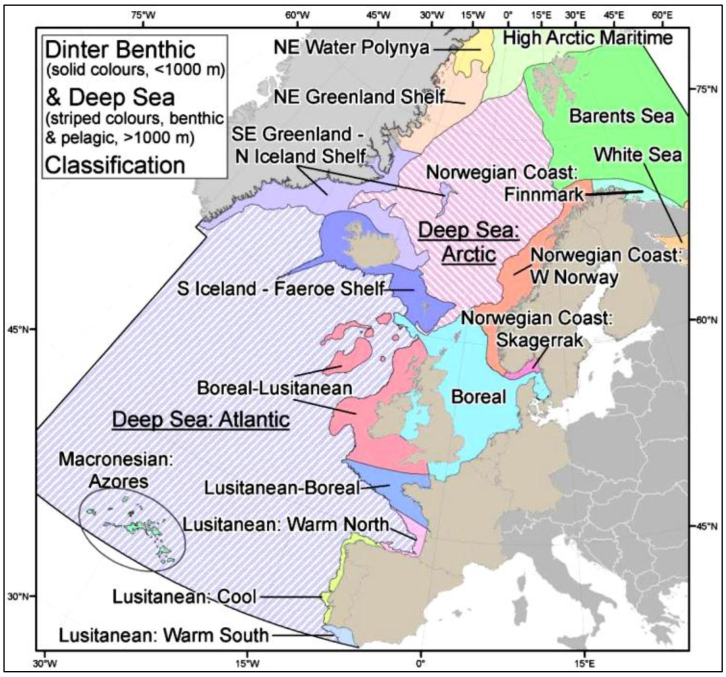

Figure 1 – Classification of the biogeographic subprovinces of benthic (<1000 m) and deep sea biomes (>1000 m, including pelagic and benthic biomes) adopted for the OSPAR Maritime Area (Dinter, 2001 *in* UNESCO, 2009).

Habitat was historically defined as the physical environment where an organism lives (e.g. Castro and Huber, 2008; Levinton, 2009). However, with the implementation of the EUNIS classification system (Connor et al., 2004), that definition matched with the definition of biotope, combining both the physical habitat (the abiotic conditions) and the biological community supported by it. Hereinafter, the terminology marine habitat will correspond to the marine biological community (as the characterizing elements of the biotic environment), together with the abiotic factors, operating together at a particular scale (Moss, 2008). The need to recognize and protect the European´s habitats, lead the Council to implement the EU Habitats Directive (92/43/EEC)[13], one of the bases of Europe's nature conservation policy, being built around two pillars: the Natura 2000 network of protected sites and the strict system of species protection. The European Nature Information System, EUNIS, compiles data on species, habitat types and sites gathered in the framework of Natura 2000 (and other sources considered as reference data), including a pan-European classification system. This classification aims to simplify the harmonized description and collection of data across Europe through the use of criteria for habitat identification, covering all types of habitats (natural and artificial, from terrestrial to freshwater and marine)[14].

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[13] http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm, 29.10.2012

[14] http://eunis.eea.europa.eu/about.jsp, 30.10.12

1.3. Macrofauna benthic communities: the state of the art

Marine benthic communities are ecologically and economically relevant, providing important ecological goods and services (e.g. fisheries of target commercially valuable bivalves, shrimps and crabs), having major roles in the trophic links in coastal ecosystems, recycling nutrients, detoxifying pollutants and being an important food source for other larger animals (Lenihan and Micheli, 2000). Those communities tend to vary greatly in terms of abundance, biomass and species richness and that is why several works have been focused in the study of the biogeographic, spatial and temporal patterns of benthic communities and the governing factors affect them, namely the sediment type, organic matter content, depth, latitudinal gradients and correlated variables (e.g. nutrients, pH and temperature, among others) (e.g. Hily et al., 2008; Serrano et al., 2008; Przeslawski et al., 2011). Broadscale and holistic soft-bottom macrofauna communities studies were carried out in the past in several worldwide continental shelves (e.g. Petersen, 1918; Jones, 1950; Thorson, 1957; Pérès and Picard, 1964; Picard, 1965; Glémarec, 1973; Gentil, 1976; Cabioch, 1968; Marques, 1987; among others). Atlantic and Mediterranean benthic communities were qualitatively and quantitatively described by those studies and they still excellent sources of comparison with contemporaneous studies. Thorson (1957) made a general review of the benthic communities worldwide, from which the most important European communities can be here highlighted: (a) the *Tellina tenuis* and *Tellina fabula* (now *Angulus*) community (described by Petersen (1918) as boreal Lusitanean *Tellina* community) in pure sandy bottoms, from the tidal zone to about 10 m depth; (b) the *Venus gallina* (now *Chamelea*) community (also the boreo-mediterranean *Venus* community originally described by Petersen (1918) or the boreal offshore sand association of Jones (1950)), found in the near and midshelf; (c) the *Venus fasciata* (now *Clausinella), Spisula elliptica* and *Branchiostoma lanceolatum* community (described by Ford (1923) as the deep *Venus* community and by Jones (1950) as the boreal offshore gravel association) from shallow shelly gravels or deeper sands; (c) the *Syndosmya* (now *Abra*) *alba* community (originally described by Petersen (1918) or the boreal offshore muddy sand association of Jones (1950) in boreal near shore mixed and muddy bottoms; (d) the *Amphiura filiformis* and *A. chiajei* community (also the boreo-mediterranean *Amphiura* community originally described by Petersen (1918) as the *Echinocardium filiformis* community plus the *Brissopsis chiajei* community or the boreal offshore mud association of Jones (1950)) in muddy sand to muds, from 15 to 100 m; (e) the *Maldane sarsi* and *Ophiura sarsii* community in mud at greater depths (100 to 300 m).

Pérès and Picard (1964) and Picard (1965) summarized and fully described the dominating communities in the Mediterranean Sea, based in the studies carried out off the Marseille region. The most important communities presented were: (a) the well sorted fine sands biocenosis, in nearshore fine sands, up to 20 m; (b) the biocenosis of coarse sands and fine gravels under the influence of bottom currents, in coarse sands and gravels, up to 70 m; (c) the biocenosis of coastal detritic bottoms in heterogeneous/mixed sediments, up to 95 m; (d) the biocenosis of deep circalittoral detritic bottoms in mixed sediments, from 95 to 200/250 m; (e) the biocenosis of the circalitoral muddy detritic bottoms in bottoms influenced by high riverine fines input, up to 95 m; (f) the biocenosis of the terrigenous coastal muds in pure muds with some biogenic content; (g) the biocenosis of the deep muds in the deep circalittoral and bathyal zones. Glémarec (1973) studied the benthic communities from the North Gascony continental shelf (French Atlantic coast), dividing the study area in three main zones (étages), accordingly to their coastal proximity, seawater temperature and salinity: the infralittoral étage, the coastal étage and the open sea étage. In the infralittoral étage were recognized the clean fine sands of *Venus gallina* (now *Chamelea*) and *Mactra corallina* (now *M. stultorum*), the muddy sands with *Acrocnida brachiata* and *Euclymene oerstedi* (fines content from 10 to 50%), the sandy muds of *Nucula turgida, Abra alba* and *Sternaspis scutata* (with more than 80% of fines), the mixed sediments of *Nucula nucleus* and *Tapes* (now *Polititapes*) *aureus* and the gravels of *Dosinia exoleta*. The coastal étage included the following assemblages: the fine sands of *Venus gallina* (now *Chamelea*) and *Dosinia lupinus* (similar but deeper, >40 m, than the infralittoral fine sands), the muddy sands of *Amphiura filiformis* and *Tellina serrata* (fines content can range between 10 and 30%, in deeper than 10/15 m), the sandy muds of *Maldane glebifex* and *Clymene modesta* (now *Euclymene lombricoides*) (fines content vary between 30 and 90%), the muds of *Virgularia* spp. and *Sternaspis scutata* (fines near 80%), the mixed sediments of *Nucula nucleus* and *Venus ovata* (now *Timoclea*), the gravels of *Amphioxus* or of *Branchiostoma lanceolatum* and *Venus fasciata* (now *Clausinella)* (gravel content greater than 20%); the coarse sands of *Echinocyamus pusillus* and *Tellina pygmaea* (now *Angulus pygmaeus)* (gravel content below 20%). The open sea étage was characterized by: the medium shelly sands of *Ditrupa arietina* and *Dentalium entalis* (now *Antalis*), the muddy sands of *Onuphis lepta* and *Auchenoplax crinita*, the sandy muds of *Nucula sulcata* and *Brissopsis lyrifera* (fines ranging between 20 and 50%), the muds of *Ninoe armoricana* and *Sternaspis scutata* (fines greater than 50%), the mixed sediments of *Nucula nucleus* and *Pitar rudis* and the gravels of *Astarte sulcata* and *Venus casina*.

1.4. The Portuguese continental shelf: an holistic overview

The Portuguese continental shelf is integrated in the West Iberian Margin and extends from the Gulf of Cadiz to the Galicia Bank (Figure 2) 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. It is considered very well studied in terms of geomorphology, bathymetry, oceanography and sediments (mostly from SEPLAT Program, launched in the 70´s and finished in 2012; MAMAOT, 2012). Reviews of the main physiographic and geomorphological features of the Portuguese part of the West Iberian Margin, an example of a rifted and non-volcanic continental margin, can be found in Vanney and Mougenot (1981) and Mougenot (1989). The West Iberian Margin is characterized by the presence of three abyssal plains (Iberia, Tagus and Horseshoe) at nearly 4500m water depth. The western Portuguese shelf is incised by several deep submarine canyons with a northeast–southwest trend descending into the abyssal areas, namely, Porto, Aveiro, Nazaré, Cascais/Lisbon, Setúbal and S. Vicente; Portimão canyon, in the southern sector, presents a N – S trend (Vanney and Mougenot, 1990; Figure 2). Those canyons represent morphological, sedimentary and hydrological boundaries (Guerreiro et al., 2007; Oliveira et al., 2007). The Portuguese shelf has been divided into four main sectors (Figure 2): northwestern (Caminha-Nazaré), central (Nazaré-Setúbal), southwestern (Setúbal – Cape S. Vicente) and southern (Algarve, Cape S. Vicente – Vila Real St. António), mostly reflecting the dissection of three major Portuguese canyons: Nazaré, Setúbal and S. Vicente. In the northwestern 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 (Dias and Nittrouer, 1984). The Douro River is responsible for 79% of the total annual shelf sediment supply, estimated in 2.25×10^6 $t.y^{-1}$ (Oliveira et al., 1982). The central sector varies in width from 3 to 30 km, narrowing considerably at the heads of the Lisbon and Setúbal submarine canyons. It is largely fed by the Tagus River, which displays an average annual water discharge ranging from 80 to 720 $m^3.s^{-1}$ (Loureiro and Macedo, 1986; Jouanneau et al., 1998) and delivers an average suspended load to the shelf of approximately 4×10^5 $t.y^{-1}$ (Vale and Sundby, 1987). The southwestern continental shelf is 10–20 km wide. The Sado River is the major carrier of terrigenous sediments for this sector, but most of the riverborne material is trapped in the estuary before reaching the continental shelf (Monteiro et al., 1982; Jouanneau et al., 1998; Alt-Epping et al., 2007). To the south of latitude 38ºN, the riverine sediment supply to the shelf is poor (Dias and Nittrouer, 1984). Finally, the southern sector of the Portuguese continental shelf is relatively narrow (8 km to 28 km) and receives most of its sediment supply from the Guadiana River (Vanney and Mougenot, 1981; Dias and Nittrouer, 1984; Dias, 1987). The average suspended load delivered the Guadiana River to the shelf is estimated in 57.90 x 10^4 $m^3.y^{-1}$ (Morales, 1997).

The majority of the Portuguese rivers drain Late Proterozoic-Paleozoic metamorphic rocks and Variscan granitoids from the highland areas of Portugal and, to a lesser extent, the Meso-Cenozoic sedimentary formations from the Lusitanean and Algarve Basins. Variations in the lithology of the continental bedrock sources have intense effects on the sediment composition and grain-size distribution patterns (Monteiro et al., 1982; Dias and Nittrouer, 1984; Paiva et al., 1997; Araújo et al., 2002; Alves et al., 2003b; Machado et al., 2005; Abrantes and Rocha, 2007; Mil-Homens et al., 2006, 2009).

The total annual rainfall in southern Portugal is much lower than in the north. Approximately 65% of the total annual rainfall occurs to the north of the Tagus River, with an average mean value above 1000 mm per year (SNIRH, 2010). The highest values (> 2400 mm / year) are recorded in the Estrela and Gerês mountain ranges drained by the Mondego and the Cávado rivers, respectively (SNIRH, 2010).

Generally, in terms of the hydrodynamic regime, the Portuguese coast is divided in three areas: mesotidal exposed Atlantic coast, from the northern Portuguese border to Cape Carvoeiro west coast, mesotidal moderately exposed Atlantic coast, from Cape Carvoeiro to Ponta da Piedade south coast and mesotidal sheltered Atlantic coast, from Ponta da Piedade to Vila Real de Santo António, the remaining southern coast (cf. Figure 2; Bettencourt et al., 2004). Therefore, the western coast of Portugal is a high energy shelf environment exposed to NW swells from the North Atlantic, whereas the southern shelf sector has a lower energy regime with dominant SW-S and SE swells (Mil-Homens et al., 2007). Near the 50 m water depth and near the thermocline zone the salinity in the North Atlantic can range between 35.8 and 36.0, however this parameter exhibits a complex depth related pattern due to the circulation of different water currents (Van Aken, 2000). The current system affecting the Iberian Atlantic coast is quite complex and comprises the following main currents: (a) the slow Portugal Current (PC), generally southward flowing, that extends from about 10°W to about 24°W longitude; (b) the fast and poleward flowing Portugal Coastal Current (PCC), that dominates during summer, favoring coastal upwelling processes and (c) the Portugal Coastal Countercurrent (PCCC), a southward surface current that flows along the coast to about 10-11°W longitude during the downwelling season (Ambar and Fiúza, 1994; Álvarez-Salgado et al., 2003). Due to upwelling events, the biological productivity is particularly high to the north of the Nazaré

Canyon and around the cape S. Vicente (southwestern and southern shelf sectors) where marine biological productivity can be enhanced up to 60 - 90 g C/m^2 per year (Fiúza et al., 1982; Fiúza, 1983; Peliz et al., 2005; Martins et al., 2006a, 2006b).

In terms of biogeography, the Portuguese shelf is integrated in the Temperate Northern Atlantic realm, Lusitanean province and South European Atlantic Shelf ecoregion (Spalding et al., 2007); the Lusitanean province is thus subdivided in three subprovinces, two of them located in Portugal, the Lusitanean Cool subprovince, from the Spanish Cantabrian shelf to S. Vicente Canyon and the Lusitanean Warm South subprovince, including the southern shelf and the Gulf of Cádiz (Figure 1; Dinter, 2001).

The macrofauna benthic communities from the Portuguese coast are well known, mainly in lagoons (e.g. Quintino et al., 1986, 1987, 1989; Carvalho et al., 2011b), estuaries (e.g. Moreira et al., 1993; Rodrigues and Quintino, 1993; Rodrigues et al., 2006, 2011), sandy beaches (e.g. Dexter, 1988; Vale et al., 2010), intertidal rocky shores (e.g. Saldanha, 1974, 1995; Araújo et al., 2005; Pereira et al., 2006), submarine canyons (e.g. Cúrdia et al., 2004; Cunha et al., 2011) and seamounts (e.g. Corral et al., 2006; Surugiu et al., 2008; Reveillaud et al., 2010). However, soft-bottom benthic communities in the Portuguese continental shelf are poorly studied, from which only some particular coastal shelf areas were focused, namely the southern shelf, mostly the near shore shelf (Marques, 1987; Alves et al., 2003a; Gonçalves et al., 2010; Carvalho et al., 2011a; Freitas et al., 2011), the near shore shelf between Óbidos and Peniche (Reis et al., 1982), the near shore shelf off Aveiro (Cunha et al., 1997; Freitas et al., 2003a; Silva, 2011) and the near shore shelf off Lisbon (Freitas et al., 2003b). The most important study was carried out in the eastern part of the southern shelf sector by Marques (1987), in which the following five bioceonosis were defined, based on the data of 28 samples: (a) the biocenosis of the infralittoral sands dominating the nearshore coast, being recognized two facies: *Spisula solida* in well calibrated medium sands from 8/9 to 12 m and *Branchiostoma lanceolatum* in clean coarse sand under strong bottom currents influence, from 11 to 15/20 m; (b) the biocenosis of the costal detritic bottoms found in the low infralittoral and circalittoral zones (up to 100 m water depth), in sands with high biogenic content and low to moderate content in fines (usually up 10%); (c) the biocenosis of the deep circalittoral detritic bottoms found in gravelly sands with high biogenic content, from 100 to 180 water depth; (d) the biocenosis of the circalittoral muddy detritic bottoms noticed often between 50 and 150 m in muddy sands; (e) the biocenosis of the offshore muds characterized by the species in pure muds or slightly sandy muds, from 50 to 200 m water depth. Thorson (1957) also found records in the Portuguese coast of the *Venus* *gallina* community (off Faro; notes of Sparck, 1931 *in* Thorson, 1957), deep *Venus* community (32 m, off Faro; Sparck, 1931 *in* Thorson, 1957) and *Tellina tenuis* (now *Angulus*) community (Ria de Faro; Vilela, 1947 *in* Thorson, 1957). Invaluable knowledge was also taken from diversity studies of particular faunistic groups, such as, Marques (1989) and Marques and Bellan-Santini (e.g. 1990, 1993; for the amphipods of the northernmost, southwestern and southern Portuguese continental shelf), Almaça (1985; for the Brachyura fauna of Iberian Peninsula), Cúmano (e.g. 1939, 1945 1953; for the echinoderm fauna of Portugal), Jesus and Fonseca (1998; for echinoderms of the southwestern shelf), Nobre (e.g. 1903 a,b, 1904, 1937, 1942; for molluscan and other faunistic groups), Macedo et al. (1999; for molluscs) and Gil (2011; for the polychaetes Portuguese fauna), Other studies spread in internal reports of the Portuguese Fisheries Institute (IPMA[15]), focusing the benthic macrofauna diversity (and in the environmental characterization), were undertaken off Lisbon and Sesimbra by Cabeçadas et al., (2002, 2003, 2004) and Gaudêncio and Guerra (1994, 1998) and near Sines (Gaudêncio and Guerra, 2012). First occurrences of some species in the Portuguese coast was highlighted in dispersed publications (e.g. Ashworth, 1912; Carvalho, 1929; Augener, 1933; Machado, 1942; Bellan 1960; Laubier, 1968; Amoureux, 1974; Gil and Sardá, 1999).The distribution and abundance status of the most important commercial species of bivalves were being monitored by IPMA since 1983. Those studies focused mainly the white clam (*Spisula solida*), striped venus (*Chamelea gallina*), sabre clam (*Ensis siliqua*), razor clam (*Pharus legumen*), dog cockle (*Glycymeris glycymeris*), among others, which constitute important banks in the nearshore southern and northwestern coasts (e.g. Gaspar et al., 2004, 2005, 2010a, b). Recently, it was presented an approach to identify the soft-bottom macrobenthic communities in the report of the State of the Art regarded to the Portuguese implementation of the Marine Strategy Framework Directive (Continent subdivision), resulting mostly from the sparse data from IPMA (MAMAOT, 2012). The Portuguese coast was divided in three major depths (<50 m; 50 – 150 m; >150 m) and in three main geographical areas (northern border to Nazaré Canyon – Area A, Nazaré Canyon to Ponta da Piedade – Area B and Ponta da Piedade to Vila Real de Sto. António – Area C), being the benthic community structure imposed by these *a priori* partitions. Thus, a more comprehensive biodiversity assessment of the Portuguese continental shelf and particularly the identification and characterization of the benthic macrofauna communities is still to be performed.

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[15] http://www.ipma.pt/, 30.01.13

Aims of this thesis

The present work aims to contribute to:

- ✓ Characterize the sediments of the Portuguese continental shelf in terms of grain-size, total organic matter and bulk geochemistry and to identify some of the main factors explaining their distribution patterns;
- ✓ Identify and characterize the benthic macrofauna communities along the Portuguese continental shelf
- ✓ Analyze and discuss some of the major factors explaining the distribution of those communities, based on the hypothesis that they were established in shelf areas with no significant differences in terms of the selected abiotic factors (sediments, total organic matter, latitude, depth and hydrodynamics);
- ✓ Contribute with new insights to the diversity and ecology of some polychaete families;
- ✓ Discuss biogeographic issues related to the spatial distribution of species and communities.

Thesis structure

To achieve those goals the results and discussion are organized in two main chapters, covering the environmental characterization and the biological characterization (abundance and diversity patterns, distribution patterns of particular species, a comprehensive assessment of the soft-bottom benthic habitats and two cases studies of the shelf diversity within the Lumbrineridae and Pisionidae families).

The contents presented in the “Environmental characterization” chapter were published in: Martins R., Azevedo M.R., Mamede R., Sousa B., Freitas R., Rocha F., Quintino V., Rodrigues A.M. (2012a) Sedimentary and geochemical characterization and provenance of the Portuguese continental shelf soft-bottom sediments. *Journal of Marine Systems*, 91, 41–52.

The contents of the “Biological characterization” were submitted as follows:

- ✓ Martins, R., Quintino, V., Rodrigues, A.M. (*in press*) Diversity and spatial distribution patterns of the soft-bottom macrofauna communities on the Portuguese continental shelf. *Journal of Sea Research*.

- ✓ Martins R., Magalhães, L., Peter, A., San Martín G., Rodrigues A.M., Quintino V. (submitted a). Diversity, distribution and ecology of the Family Syllidae (Annelida) in the coasts of Portugal (Western Iberian Peninsula). *Hydrobiologia*.
- ✓ Martins, R., Sampaio, L., Quintino, V., Rodrigues, A.M. (submitted b) Soft-bottom Portuguese continental shelf polychaetes: diversity and distribution. *Journal of Marine Systems*.
- ✓ Martins, R., Sampaio, L., Freitas, R., Quintino, V., Rodrigues, A.M. (to be submitted) Diversity and distribution of benthic malacofauna on the Portuguese continental shelf. *Journal of Sea Research*.

The following articles correspond to new diversity insights within two polychaete families, presented here in chapter 3.8 as particular case studies of the shelf diversity:

- ✓ Martins, R., Carrera-Parra, L.F., Quintino, V., Rodrigues, A.M. (2012b) Lumbrineridae (Polychaeta) from the Portuguese continental shelf (NE Atlantic) with the description of four new species. *Zootaxa,* 3416, 1–21.
- ✓ Martins R., San Martín G., Rodrigues A.M., Quintino V. (2012c) On the diversity of the genus *Pisione* (Polychaeta, Pisionidae) along the Portuguese continental shelf, with a key to European species. *Zootaxa,* 3450, 12–22.

Chapter 2

Material and methods

2.1. *Study area and sampling*

The study area comprised the entire Portuguese continental shelf, from Caminha (41°51.8'N, 9°15.6'W) to Vila Real Santo António (36°56.1'N, 7°24.7'W) (Figure 2). A total of 145 sampling sites were positioned in a regular grid of perpendicular lines to the coastline, separated from each other nearly 10 Km (in the southwestern and southern shelf) or 15 Km (in the northwestern shelf; Figure 2) and stratified by depth (<50 m, 50 m, 75 m, 100 m, >100 m). Those sites were spread over the entire survey area, from the northern to the southeastern border and from 13 to 195 metres water depth, in order to cover as much as possible the whole range of potential benthic habitats. Sediments were collected with a 0.1 m^2 Smith-McIntyre grab (Figure 3) a grab with a reliable operation in a wide sediment types, easy to use and operate on board and widely used in several studies in Europe, simplifying the comparison of results (Eleftheriou and McIntyre, 2005). At each site, a total of two sediment samples was taken, one to study the macrofauna and the other to study the environmental descriptors (grain-size, total organic matter content and geochemistry analyses). Sediment samples were rejected depending on the sediment grab quantity or sedimentary differences between both replicates. Macrofaunal sediment samples were sieved on board over 1 mm mesh size (Figure 4) and the residue fixed in neutralized formalin (4%) stained with rose Bengal. The survey was carried out in 2007 and 2008, on board of the "Noruega" vessel of the Portuguese Fisheries Institute (IPMA).

2.2. *Laboratory analysis*

2.2.1. *Sediment grain-size analysis*

Grain size analysis was performed by wet and dry sieving, according to the methodology described by Quintino et al. (1989): *i*) chemical destruction of organic matter with H_2O_2; *ii*) measurement of the total sediment dry weight, followed by chemical dispersion with tetra-sodium pyrophosphate (30g/l) and wet sieving through a 63 μm mesh screen; *iii*) measurement of the second dry weight of the material left on the 63 μm mesh screen; *iv*) dry sieving of the sand fraction (particles with diameter from 63 μm to 2 mm) and the gravel fraction (particles with diameter above 2 mm), through a battery of sieves spaced at 1 ϕ size intervals ($\phi = -\log_2$ the particle diameter expressed in mm). Raw grain size data were expressed as weight percentages of the total sediment.

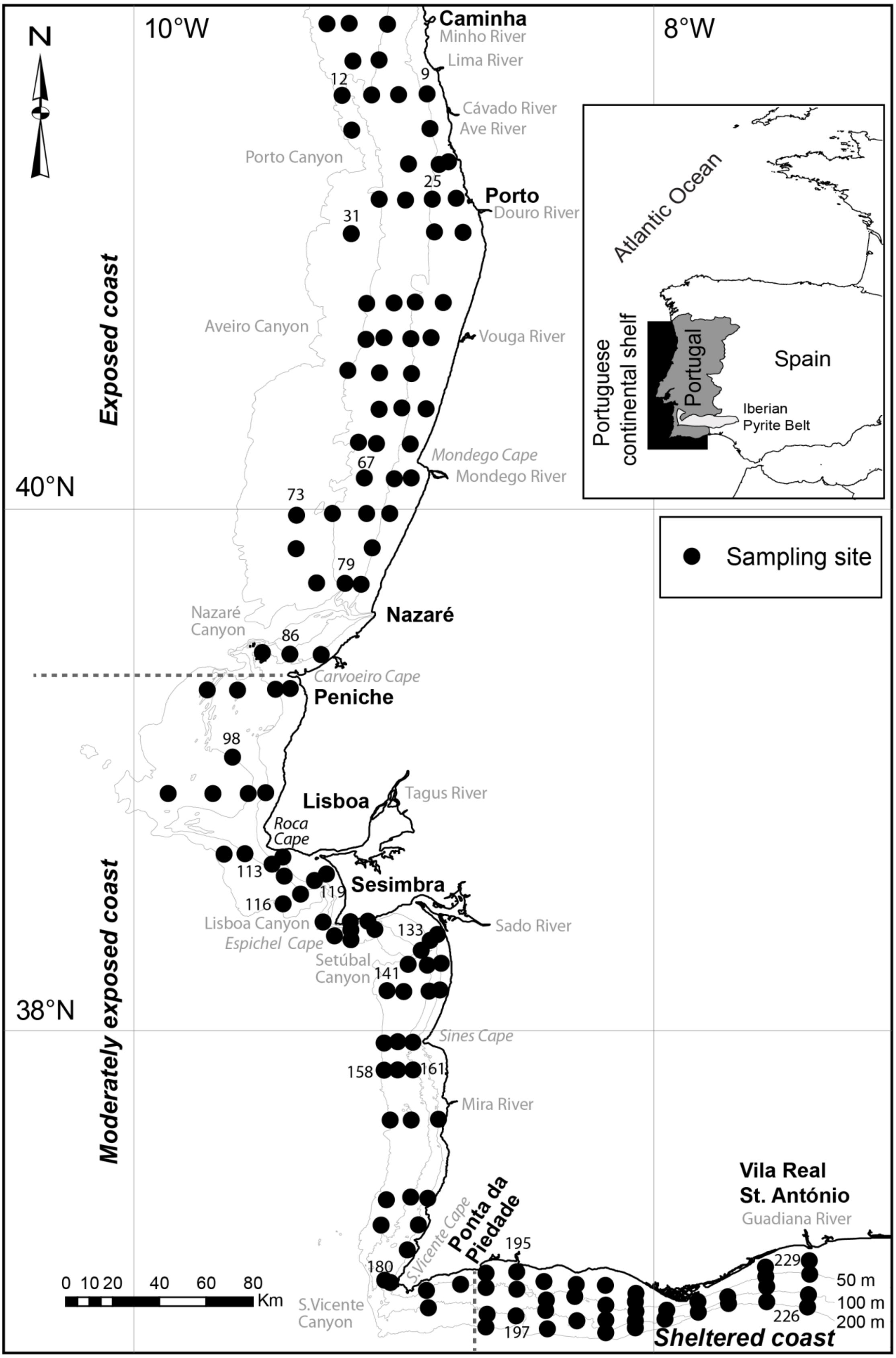

Figure 2 – Study area: the Portuguese continental shelf. Sampling sites are represented by black dots. Numbers indicate the samples selected for geochemical analyses.

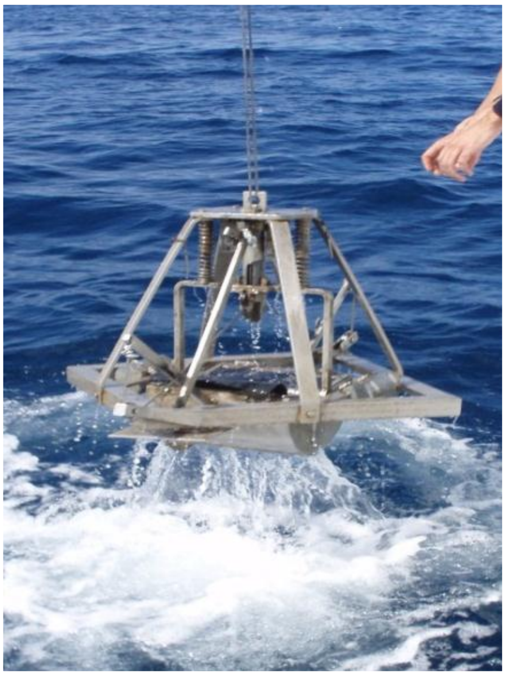

Figure 3 – Smith-McIntyre grab.

Figure 4 – Sieving of sediment over 1 mm mesh size, on board.

2.2.2. *Total organic matter analysis*

Total organic matter content (TOM) was performed by loss on ignition of 1 g of dried sediment at 450 ºC during 5 hours and expressed as a percentage of total sediment dry weight. At this temperature, there is minimal risk of volatizing inorganic carbon (Kristensen and Anderson, 1987).

2.2.3. *Geochemical analysis*

A subset of 21 samples was selected from the entire set of samples. The <2 mm sediment fraction of the samples was dried, ground in an agate mill and analyzed for major (Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, P) and trace (V, Cr, Ni, Cu, Zn, Ga, As, Pb, Rb, Sr, Ba and U) elements, using a Philips X-ray wavelength dispersive fluorescence spectrometer (model Panalytical Axios) in the Department of Geosciences at University of Aveiro (Portugal). Loss on ignition (LOI) was determined by heating 1 g of dry sample at 1350 ºC for 12 minutes. Detection limits are less than 0.01% for major elements and between 1-5 ppm for trace elements.

2.2.4. *Macrofauna*

The macrofauna samples were abundantly rinsed with water through a 0.5 mm mesh sieve under a fume hood and hand sorted. Macroinvertebrates were identified under a stereomicroscope to species level, whenever possible, following, the commonest references (e.g. Fauvel (1923, 1927), Campoy (1982), George and Hartmann-Schröder (1985), Pleijel and Dales (1991), Chambers and Muir (1997), San Martín (2003) and Viéitez et al. (2004), for annelids; Tebble (1976), Graham (1988), Thompson (1988) and Macedo et al. (1999) for molluscs; Chevreux and Fage, (1925), Bouvier (1940) for crustaceans; Southward and Campbell (2006) for echinoderms, among other references). Quality of the sorting process and taxonomic identification were internally guaranteed by experienced colleagues. Then the specimens were counted and transferred for long-term storage to 70% ethanol. The validity, authority and distribution of benthic species were confirmed in the World Register of Marine Species (WoRMS) (Appeltans et al., 2012)[16]. Within the manuscript only the species name is shown. A complete list of full species names with respective authority can be found in the annex 2.

The morphological characterization, diversity and distribution of two polychaetes Families (Lumbrineridae and Pisionidae) were deeply explored due to its abundance and

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[16] www.marinespecies.org, 25.10.12

biodiversity and presented as case studies of the diversity within this study. The specimens of the Family Lumbrineridae were identified and some of them were morphologically examined. In which concerns the description of the 4 new species of the Lumbrineridae family, a total of 184 specimens were used for a detailed morphological study. The descriptions of the new species were based on the type materials and followed the format of Carrera-Parra (2006b). The maxillary apparatus of each individual was extracted after an anterodorsal incision and mounted dorsally and ventrally on a slide to study the details of both the maxillae (M) and the mandible under an optical microscope. For each specimen, the length through chaetiger 10 (L10) and the width at chaetiger 10 excluding parapodia (W10) were determined. The terminology of the maxillary apparatus (Figure 5), the blade size of composite multidentate hooded hooks (CMHH) and the size of simple multidentate hooded hooks (SMHH) followed Carrera-Parra (2006a). Photographs of relevant morphological features were taken to illustrate the descriptions. The Lumbrineridae type specimens were deposited in the Muséum National d'Histoire Naturelle, Paris (MNHN), Museu Nacional de História Natural e da Ciência, Lisbon (MB), the Reference Collection of ECOSUR-Chetumal, Mexico (ECOSUR), and in the Collection of the Departamento de Biologia, Universidade de Aveiro (DBUA).

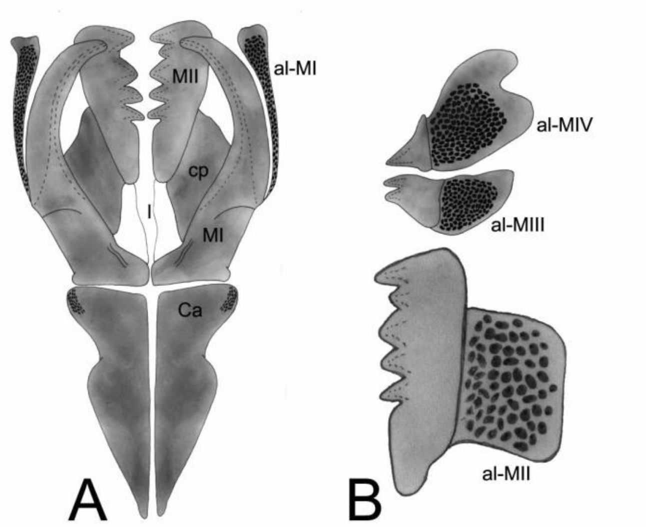


Figure 5 – Representation of a lumbrinerid maxillary apparatus. Legend: A – Carriers, MI and MII (dorsal view); B – MII, MIII and MIV (ventral view); ca – carriers, cp – connecting plate, al – attachment lamella, M – maxilla (Carrera-Para, 2006a).

Regarding to the study of the four *Pisione* species, a total of 75 specimens were used for a detailed morphological study. The measurement of total length, the width at chaetiger 10 (W10), the number of parapodia in complete specimens, the buccal aciculae shape, the length of the dorsal cirrus of parapodia 2 (CP2, mm) and 3 (CP3, mm), the shape of dorsal cirri, the number of teeth of the supra-acicular chaetae (nrT), the protruding length of the notoaciculae through the parapodia (P1, mm), the number and shape of the various types of compound chaetae (e.g. heterogomph, recurved or straight), the length of the longest blade (mm), the presence/absence of infra-acicular simple chaetae (IA), the number, location and shape of genital organs and the size of female gametes (µm). A set of *Pisione* specimens were deposited in the Museu Nacional de História Natural e da Ciência, Lisbon (MB). Additional material remains in the Department of Biology, University of Aveiro, Portugal.

2.3. *Data analysis*

2.3.1. *Grain-size sediments*

The amount of sediment in each grain size class was expressed, as a percentage of the whole sediment, dry weight, for each site. These results were used to calculate the median value, corresponding to the diameter that has half the grains finer and half coarser. No detailed grain size analysis was performed for the fines fraction (particles with diameter below 63 µm) and sediment samples with more than 50% fines content were classified as mud. The textural classification of the sediment samples was based in the Wentworth (1922) scale, using the median value, expressed in phi (Φ) units: mud (> 4 Φ), very fine sand (median between 3 – 4 Φ), fine sand (2 – 3 Φ), medium sand (1 – 2 Φ), coarse sand (0 – 1 Φ), very coarse sand ((-1) – 0 Φ) and fine gravel ((-2) – (-1) Φ). The relationships between depth, total organic matter, gravel (> 2 mm), sand (2 – 0.063 mm), fines (< 0.063 mm) and biogenic fraction (> 2 mm biogenic particles) contents were analysed with pairwise scatter plots between variables and with the associated Pearson correlations.

2.3.2. *Geochemistry*

The geochemical data matrix [element contents x sites] was simplified by eliminating collinear variables, highly correlated (Spearman correlation above 0.80), and analysed by classification and ordination methods, following the variables logarithmic transformation (those with disparate concentrations within sites) and normalization (to mean 1 and standard deviation 0). Classification analysis was performed by agglomerative hierarchical clustering, using the unweighted pair-group mean average (UPGMA) algorithm, following the calculation of the Euclidean distance between samples. Ordination was performed by Principal Components Analysis (PCA). The final biplot (sites and variables) included grain-size (based on the median values) and total organic matter data as supplementary variables in order to evaluate the correlation structure between these and the geochemical data.

The trace element enrichment factors (EF) relative to Upper Crust (UC) average values (Taylor and McLennan, 1985) were calculated using the expression:

$$EF = ([X]/[Y])_{sample} / ([X]/[Y])_{UC})$$

where X corresponds to the trace element concentration and Y to the proxy element concentration for samples and UC, respectively. The geochemical data were previously standardized in order to compensate for natural mineralogical and grain-size variability, (Loring, 1991). From the large number of conservative elements proposed in the literature (Al, Cs, Fe, Li), aluminium was chosen for standardization purposes due to its strong correlation with the clay mineralogy and clay sized particles (< 2 µm) (Brumsack, 2006).

2.3.3. *Macrofauna*

2.3.3.1. *Abundance and diversity description*

Abundance, species richness and diversity measurements were calculated per sampling site and mean values were obtained per sediment type, depth classes (<30 m, 30 – 60 m, 60 – 100 m and >100 m), hydrodynamic regime areas (sheltered=1; moderately exposed=2; exposed=3; according to the classification proposed by Bettencourt et al., 2004), latitudinal degree on the western shelf and longitudinal degree on the southern shelf, and major shelf areas (western, southern and entire shelf). *Alpha* diversity (α) or sample species richness corresponds to the total quantity of species per sampling unit (0.1 m^2). *Beta* or turnover diversity, which corresponds to the extent of biotic change or species replacement along an sedimentary, bathymetric or latitudinal gradient (Whitaker, 1960; Gray, 2000), was calculated for all the above mentioned categories, except for the single sampling site. It was obtained by dividing the mean *alpha* diversity per sample in a given category, by the total number of species found in that same category (Whittaker, 1960). As an example, *beta* diversity was calculated for the whole Portuguese shelf, β_{shelf}, as the quotient between the mean a*lpha* diversity of the entire set of samples (α_{shelf}) by the total number of species recorded in the shelf. Other diversity indices were also calculated per site, to complement and comprehend the spatial variation of the diversity along the Portuguese shelf, namely, Shannon-Wiener diversity (H´, $\log_2$), Margalef richness (d), Pielou evenness (J´), Simpson (1-λ') and Rarefaction indices (ES50).

2.3.3.2. *Lumbrineridae and Pisionidae morphological characterization*

Regarding to the Family Lumbrineridae, a data matrix of morphological descriptors for *Abyssoninoe, Gallardoneris*, *Lumbrineris*, *Lumbrinerides*, *Lumbrineriopsis* and *Ninoe* species was constructed on the basis of the presence/absence of the several categories identified for each descriptor: hooded hooks type (composite multidentate, simple multidentate, limbated simple multidentate, simple bidentate), aciculae color (yellow, reddish, black), aciculae type (straight, curved), 4 and 5 maxillae, MI attachment lamellae, MII ligament, MIII type (edentate, unidentate, unidentate followed by a knob, bidentate, multidentate), prominent projection in the basal part of MIII, MIV pigmentation, MIV types (edentate, unidentate, unidentate with well-developed plate, unidentate with pointed tooth, broad rectangular plate with a projection), anterior postchaetal lobe shape (conical, rounded, digitiform, digitiform wide basally, auricular), postchaetal branchiae. All characters had the same weighting in the analysis. Another data matrix was also prepared for the new species of *Lumbrineris* using the presence/absence of some relevant features for this genus (aciculae type, MIII type, MIV type, prominent projection in the basal part of MIII, anterior postchaetal lobe shape) as well as the width at chaetiger 10, the last chaetiger with composite multidentate hooded hooks, the first chaetiger where simple multidentate hooded hooks appear and the last chaetiger with ventral limbates. Both matrices were submitted to ordination analysis, using Principal Coordinates Analysis, upon the Jaccard distance matrix between samples (specimens) for the presence/absence matrix and upon the Euclidean distance matrix between samples, following the variables normalization for the *Lumbrineris* data matrix. In addition, the most correlated variables (Spearman rho > 0.8) were represented as vectors.

For the Family Pisionidae, a multivariate analysis of the morphological data was performed on the basis of a sub-set of descriptors, including W10 (mm), P1/W10, CP2/CP3, nrT (1 – unidentate; 2 – bidentate) and IA (0 – absent; 1 present). This data matrix was submitted to agglomerative hierarchical clustering, using the unweighted pair-group mean average algorithm (UPGMA) and ordination analysis, using Principal Coordinates Analysis (PCO), upon the Euclidean distance matrix between specimens, following the variables normalization.

2.3.3.3. *Benthic communities identification and characterization*

The data matrix with the macrofauna abundance per site was square root transformed and the Bray-Curtis similarity calculated between sites. The similarity matrix was analyzed using agglomerative hierarchical clustering, with the un-weighted pair-group mean average algorithm (UPGMA) and ordination analysis, with non-metric multidimensional scaling (NMDS). These techniques were used for the identification of the biological affinity groups, also named benthic assemblages thorough the text. The biological groups were characterized according to the mean abundance, species richness, *alpha* and *beta* diversity, Shannon-Wiener diversity ($\log_2$), Pielou evenness, Margalef richness, Simpson index, Rarefaction index, the sediment baseline data, the number of exclusive species and the characteristic species. The characteristic species of each assemblage were obtained following their constancy (C) and fidelity (F) in the assemblage. The constancy corresponds to a sampling frequency and is given by the number of sites where the species was sampled expressed as a percentage of the total number of sites in the assemblage (Dajoz, 1971). The fidelity corresponds to the quotient between the species constancy in a given assemblage and the sum of the constancies of the same species in all the assemblages where it exists (Retière, 1979). For constancy, species were classified into constant (C>50.0%), common (50.0≥C>25.0%), occasional (25.0≥C>12.5%) and rare (C≤12.5%), and for fidelity into elective (F>90.0%), preferential (90≥F>66.6%), indifferent (66.6≥F>33.3%), accessory (33.3≥F>10.0%) and accidental (F≤10.0%). The characteristic species per affinity group were selected following the highest product between the constancy and fidelity indices, which is a easy way to find the highest values of those measures cumulatively (e.g. Lourido et al., 2010). Using a one-way model in PERMANOVA+ (Anderson et al., 2008), the null hypotheses (H_0) of no significant differences among the biological affinity groups were tested for the following fixed factors: (a) sediment descriptors (median grain-size, gravel (> 2 mm), sand (2–0.063 mm), fines (< 0.063 mm) content; $H_0$1), total organic matter content ($H_0$2), depth ($H_0$3), hydrodynamic regime (sheltered=1; moderately exposed=2; exposed=3; $H_0$4) and latitude ($H_0$5). The significance in the main and pair-wise tests was obtained following unrestricted permutation of the raw data (9999 permutations) and the calculation of type III sums of squares. The null hypotheses were rejected at $p < 0.05$. The biological-environmental relationship was analyzed with the BIOENV procedure (BEST routine), using the Spearman correlation coefficient (Clarke and Gorley, 2006) and considering the environmental variables depth, median grain-size, gravel, sand, fines, biogenic fraction and TOM contents, hydrodynamic regime and latitude.

All the multivariate analyses were performed with PRIMER v.6 (Clarke and Gorley, 2006) and the hypothesis tests with the PERMANOVA+ add-on, permutational multivariate analysis of variance (Anderson et al., 2008). The software ArcGis 10 was used to represent abundance, diversity indices and affinity groups in a GIS environment. Additionally, the abundance of some selected species was spatially represented. The software Adobe Illustrator CS 5.0 was used to edit and improve the design of all figures.

Chapter 3

Results

A. Environmental characterization

The contents presented in this chapter are published in: Martins R., Azevedo M.R., Mamede R., Sousa B., Freitas R., Rocha F., Quintino V., Rodrigues A.M. (2012a) Sedimentary and geochemical characterization and provenance of the Portuguese continental shelf soft-bottom sediments. *Journal of Marine Systems*, 91, 41–52.

3.1. Grain-size distribution

The spatial distribution of the surface sediments and the fines content along the Portuguese continental shelf are shown in Figure 6 and Figure 7. The relation between environmental variables (depth, TOM, median grain-size, gravel, sand, fines and biogenic fraction contents) and their Pearson correlations are shown in Figure 8. Median grain-size showed high correlations with gravel and fines (Figure 8), which are co-related sedimentary variables, and moderate positive correlations with depth (rho=0.36, cf. Figure 8). The gravel distribution shows right-skewness reflecting the absence of gravel in several sites (Figure 8). Coarser deposits (ranging from gravel to coarse sand) occur mainly in the inner and mid-shelf of the northwestern sector, at depths between 20 and 80 m and immediately south of the Nazaré and Setúbal canyons (Figure 6). Fine and very fine sands (with fines content below 5%) are found along a continuous band in the near shore shelf; finer sands with fines content ranging mainly 5 and 25% dominate the outer shelf of the northwestern shelf (deeper than 80 m) and in the southwestern shelf; sandy sediments from the western part of the southern shelf are heterogeneous ranging mostly from medium to very fine sands with variable content in fines (5–49%) (Figure 6 and 7). Mud deposits were recognized in the shelf areas off the mouths of the Minho, Douro, Tagus (western coast) and Guadiana rivers (mud patch occupying most of the southern shelf), at water depths of nearly 100 m, 64–97 m, 87–137 m and 44–174 m, respectively (Figure 6). Most relevant sediment raw data is shown Annex 1.

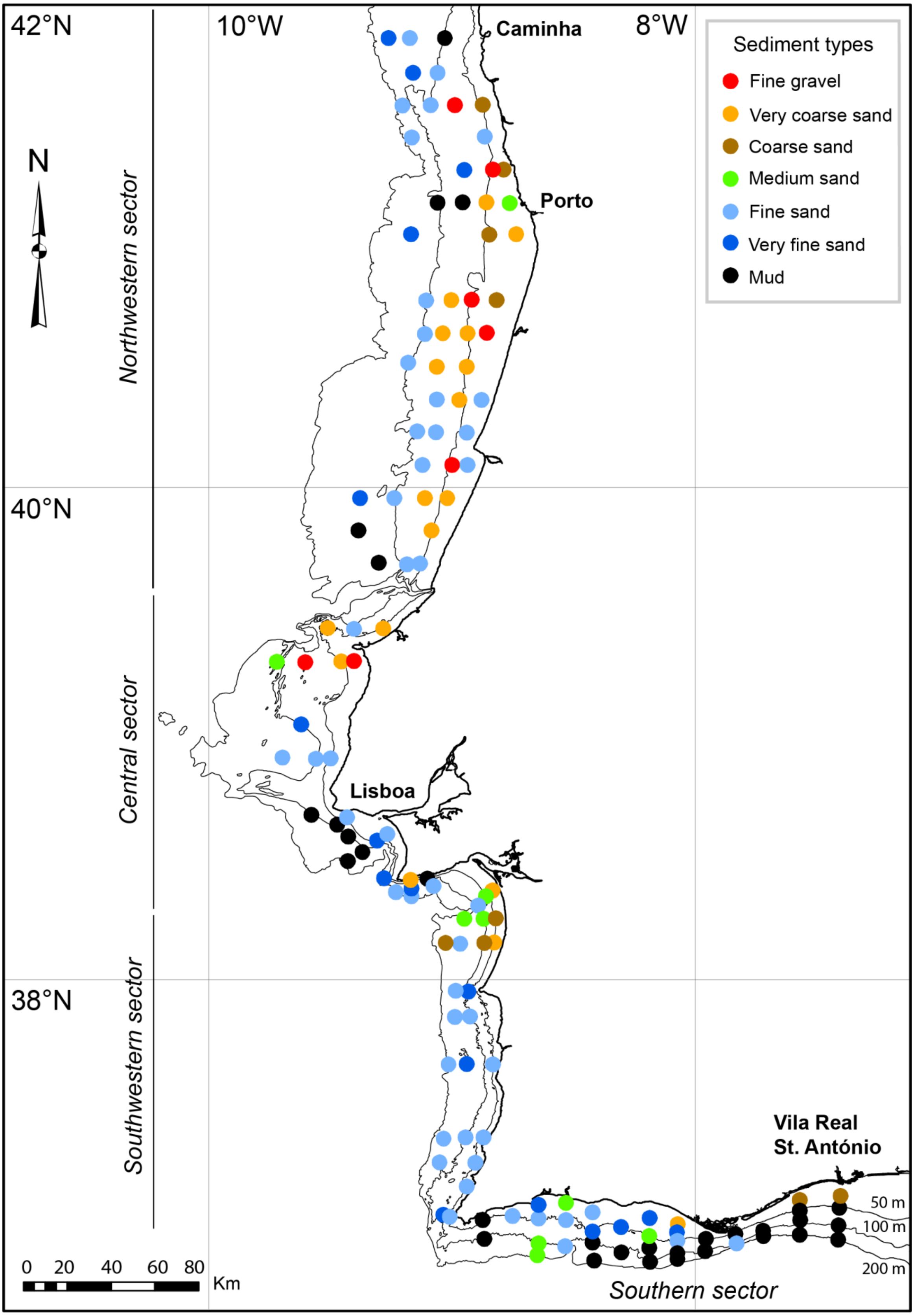


Figure 6 – Spatial distribution of sediment types according the median value in the Portuguese continental shelf.

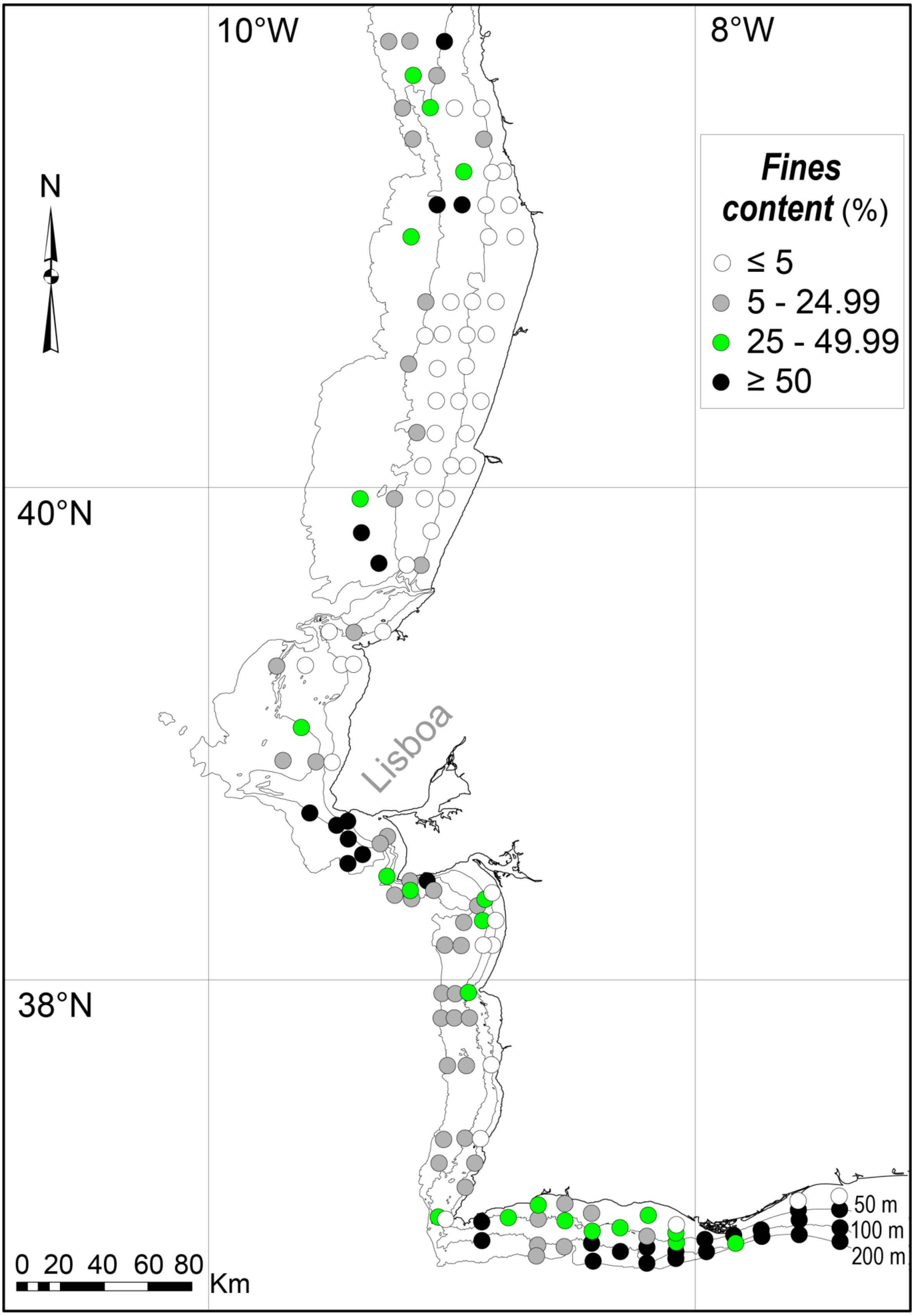


Figure 7 – Spatial distribution of fines content in the Portuguese continental shelf.

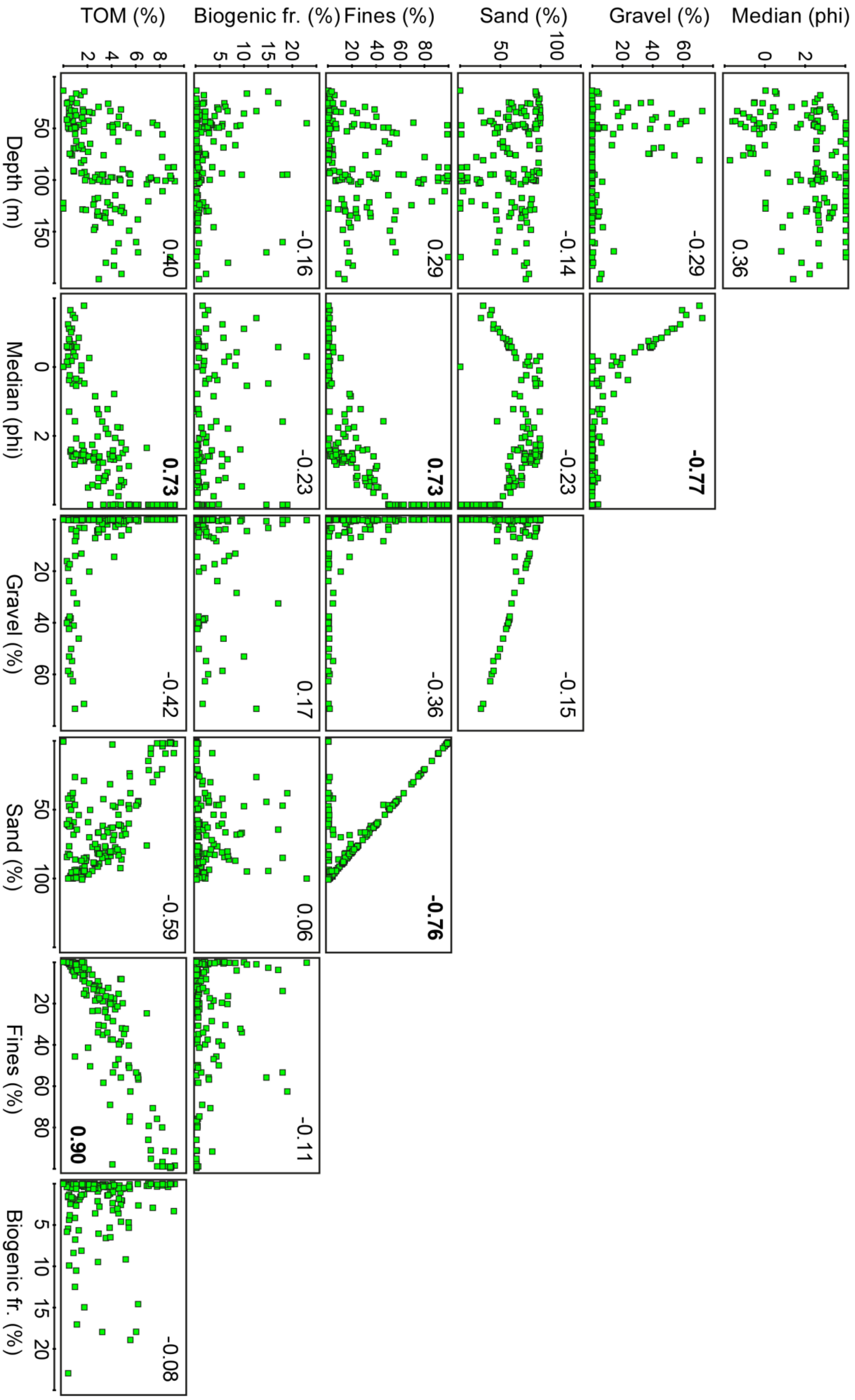


Figure 8 – Draftsman plot between environmental variables (Depth, TOM, median grain-size, gravel, sand, fines, biogenic fraction). Pearson correlation between each pair of variables is shown in the graph corner.

3.2. Total organic matter content

The spatial distribution of the total organic matter content (TOM) in the Portuguese continental shelf is shown in Figure 9. TOM patterns followed the surface sediments spatial distribution. A high correlation between TOM and both fines content and median grain-size were found (rho=0.90 and 0.73, respectively; Figure 8), which can be related to the dependence between each sediment parameter. Mud samples have the highest mean TOM values (6.71%) and gravel deposits the lowest (0.81%).

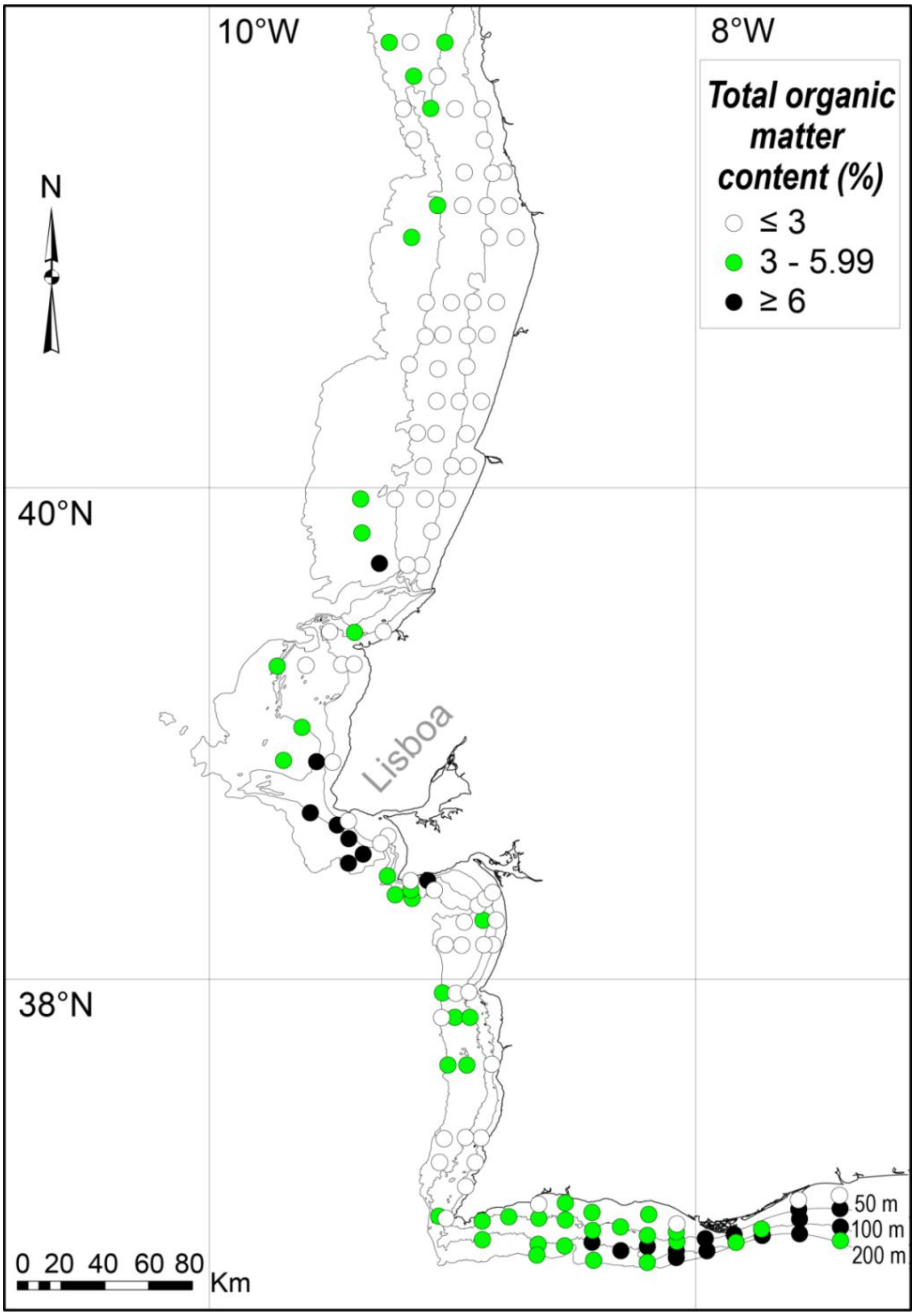


Figure 9 – Spatial distribution of total organic matter content in the Portuguese continental shelf.

3.3. Geochemistry

3.3.1. Geochemical composition of the bulk sediment fraction (< 2 mm)

A total of 21 superficial sediment samples were selected accordingly to the presence of the major Portuguese rivers, depth (nearshore and offshore) and the different granulometric types (excluding fine gravel) identified in the Portuguese continental shelf (cf. Figure 2 and 12). The < 2 mm fraction of those samples were analyzed for major (Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, P) and trace elements (V, Cr, Ni, Cu, Zn, Ga, As, Pb, Rb, Sr, Ba and U), corresponding to the mostly analysed elements. The results obtained are summarized in Table 1.

3.3.1.1. *Major elements*

The samples of Portuguese shelf sediments display a wide range of major element contents: SiO_2 (28.98–85.71%), CaO (2.13–30.95%) and Al_2O_3 (0.87–16.35%) are the most abundant, followed by Fe_2O_3 (0.93–9.62%), K_2O (0.38–3.18%), MgO (0.13–1.93%), Na_2O (0.01–1.19%), TiO_2 (0.06–0.81%), P_2O_5 (0.05–0.26%) and MnO (0.01–0.05%) (cf. Table 1). Loss on ignition varies between 3.03 and 28.97% (cf. Table 1) and tends to increase with increasing CaO contents. The highest SiO_2 values occur in the coarser sediments and in some fine sands located off the mouths of major rivers (Figure 10). The maximum CaO contents are found in fine and very fine sand deposits (CaO > 15%) and Al_2O_3 is clearly enriched in the three mud samples (6.53–16.35%), two from the Tagus mud patch and one from the southern shelf (Figure 10). K_2O, Na_2O and TiO_2 contents are relatively low and show a systematic increase with increasing Al_2O_3 contents, whilst Fe_2O_3(T), MnO and MgO display scattered distribution patterns.

3.3.1.2. *Trace elements*

The trace element compositions of the Portuguese shelf sediments are also highly variable (Table 1). Sr (81 to 1274 ppm) and, to a lesser extent, U (2–7 ppm) concentrations are particularly elevated in CaO-rich sediments. Ba (50–335 ppm) and Rb (16–155 ppm) show no obvious relation with grain size and are strongly enriched in the samples with higher K_2O contents. Cr (18–135 ppm), Zn (11–174 ppm), V (15–124 ppm), Pb (12–86 ppm), Cu (1–25 ppm), Ni (1–25 ppm) and Ga (1–20 ppm) tend to be concentrated in the mud samples from the Tagus and Guadiana shelves. However, Cr contents can also be high in the sandy deposits located off the mouths of the Douro, the Mondego and the Mira rivers (Figure 10). The maximum As values (14–51 ppm) are recorded in the shelf sediments from the southwestern and southern sectors, one coarse sand sample located off the mouth of the Cávado River and one sample from the Tagus mud patch (Figure 10).The calculation of trace element enrichment factors (EF) relative to the Upper Crust (UC) average values (Table 2) shows that the Portuguese shelf sediments are characterized by: (a) a pronounced enrichment in As; (b) highly variable EF values for Rb, U, Cr, Pb, Sr, Zn and V and (c) low enrichment or depletion in Ba, Cu and Ni. The highest EF values for Cr, Pb and As are found in samples from off estuarine areas (Ave, Cávado, Lima, Douro, Tagus, Sado and Guadiana). Sample 229, collected in the southern shelf sector, near the Guadiana estuary, records the maximum EF values for nearly all trace metals.

Table 1 – Geochemical composition of surface sediments from the Portuguese continental shelf.

Sites		**9**	**12**	**25**	**31**	**67**	**73**	**79**	**86**	**98**	**113**	**116**	**119**	**133**	**141**	**158**	**161**	**180**	**195**	**197**	**226**	**229**
SiO_2	(%)	66.4	78.6	85.7	30.0	83.8	39.9	83.5	29.0	38.4	54.2	56.5	79.3	71.7	72.6	36.6	50.5	32.9	47.8	51.3	33.4	79.1
Al_2O_3	(%)	3.0	5.3	4.3	4.5	5.5	6.9	5.9	5.0	5.3	16.4	9.7	6.5	2.1	4.2	3.8	3.3	3.6	4.7	3.6	6.5	0.9
Fe_2O_3 (T)	(%)	2.3	2.1	1.0	4.2	1.8	3.4	1.1	3.5	2.1	5.4	3.9	1.2	0.9	1.8	6.9	1.2	2.2	2.1	2.4	9.6	1.0
MnO	(%)	0.05	0.04	0.01	0.02	0.03	0.02	0.02	0.03	0.03	0.04	0.03	0.02	0.01	0.01	0.03	0.03	0.04	0.03	0.02	0.05	0.03
MgO	(%)	0.3	0.6	0.2	1.0	0.4	1.0	0.3	1.5	1.4	1.8	1.4	0.4	0.1	0.4	1.6	0.9	1.9	1.0	1.0	1.4	0.3
CaO	(%)	14.0	4.7	2.9	31.0	2.2	22.9	2.1	30.7	25.8	4.8	10.7	4.4	12.9	9.7	25.2	22.0	28.8	21.8	21.2	23.4	9.8
Na_2O	(%)	0.1	0.4	0.2	0.3	0.5	0.9	0.8	0.7	0.5	1.2	1.0	0.4	0.0	0.1	0.4	0.5	0.6	0.2	0.1	0.5	0.0
K_2O	(%)	1.5	2.0	2.2	1.6	2.1	2.0	2.4	1.5	1.5	3.2	2.7	2.3	1.1	1.9	2.1	1.1	0.8	1.1	1.3	1.9	0.4
TiO_2	(%)	0.1	0.7	0.1	0.3	0.6	0.4	0.4	0.2	0.4	0.8	0.6	0.4	0.1	0.2	0.3	0.2	0.2	0.3	0.2	0.4	0.1
P_2O_5	(%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.3	0.1
L.O.I.	(%)	12.2	5.5	3.4	27.2	3.0	22.5	3.5	27.8	24.4	12.2	13.5	5.0	11.0	9.1	23.0	20.2	29.0	21.0	18.8	22.6	8.7
Cr	(ppm)	17.9	41.8	74.9	70.8	57.2	45.8	26.1	36.6	40.8	72.5	135.1	22.9	30.1	34.9	71.2	26.3	33.3	38.3	38.1	73.2	20.0
Ga	(ppm)	3.0	5.7	4.0	5.6	5.6	8.6	5.8	6.7	5.8	20.0	11.5	6.6	1.8	4.4	5.3	3.8	4.5	5.4	4.1	8.6	1.0
As	(ppm)	45.4	6.7	5.5	11.0	5.9	7.2	3.3	11.4	8.3	17.1	6.1	6.8	13.0	4.0	15.3	3.6	11.9	14.2	6.3	50.9	23.0
Rb	(ppm)	67.5	76.3	88.9	64.5	76.2	85.6	90.6	65.7	66.7	155.1	114.0	102.8	39.3	68.0	63.1	45.3	35.6	48.1	48.6	65.7	16.4
Sr	(ppm)	514.0	146.4	133.1	611.6	81.3	552.3	87.5	1274.4	922.4	151.2	234.0	175.1	413.8	281.5	752.7	1096.1	1125.8	641.6	614.0	632.7	363.3
Ba	(ppm)	138.9	184.4	247.5	105.7	187.6	173.7	233.9	163.0	182.0	335.3	269.8	253.8	149.6	186.5	81.5	200.5	109.3	136.6	115.3	153.5	49.9
Zn	(ppm)	11.6	27.6	11.6	32.6	26.3	43.7	16.2	48.7	37.4	173.5	77.0	29.1	10.9	22.7	50.8	17.3	38.4	41.2	43.7	111.4	28.1
V	(ppm)	31.8	18.4	16.1	29.6	17.8	37.7	14.6	33.7	28.2	95.0	51.9	23.5	20.6	21.1	38.5	20.5	37.3	47.8	20.4	124.0	21.5
Pb	(ppm)	20.2	21.4	20.4	20.5	20.0	22.1	20.6	25.1	21.6	86.0	37.5	27.1	15.0	17.8	19.3	11.5	17.0	19.8	18.1	65.4	16.8
Ni	(ppm)	2.2	5.9	3.2	9.4	4.3	12.6	4.1	9.4	8.8	25.0	14.6	4.2	1.0	7.4	10.3	4.8	9.7	9.9	6.0	16.8	1.0
Cu	(ppm)	1.0	1.0	6.6	12.1	4.3	14.7	6.4	3.5	8.1	25.2	16.8	6.8	5.0	6.7	1.0	5.3	11.9	14.1	6.7	19.2	8.3
U	(ppm)	3.8	4.4	2.3	5.0	2.9	5.0	2.3	6.0	5.9	4.3	3.9	3.4	2.8	2.6	6.4	6.1	6.8	4.5	3.9	4.1	2.6

Table 2 – Trace elements enrichment factors (EF) for Portuguese continental shelf sediments. Shaded cells represent elemental enrichment (EF > 5).

	Elements										
Sites	**Cr**	**U**	**As**	**Rb**	**Sr**	**Ba**	**Zn**	**V**	**Pb**	**Ni**	**Cu**
9	2.6	6.8	151.8	3.1	7.4	1.0	0.8	2.7	6.8	0.6	0.2
12	3.4	4.5	12.8	2.0	1.2	0.8	1.1	0.9	4.1	0.8	0.1
25	7.6	2.9	13.0	2.9	1.3	1.3	0.6	1.0	4.8	0.6	0.9
31	6.9	6.1	25.0	2.0	6.0	0.5	1.6	1.7	4.7	1.6	1.6
67	4.5	2.9	10.9	1.9	0.6	0.7	1.0	0.8	3.7	0.6	0.5
73	2.9	3.9	10.5	1.7	3.5	0.5	1.4	1.4	3.2	1.4	1.3
79	1.9	2.1	5.7	2.1	0.6	0.9	0.6	0.6	3.6	0.5	0.7
86	3.2	6.5	23.2	1.8	11.1	0.7	2.1	1.7	5.1	1.4	0.4
98	3.3	6.0	15.8	1.7	7.5	0.7	1.5	1.3	4.1	1.3	0.9
113	1.9	1.4	10.6	1.3	0.4	0.4	2.3	1.5	5.3	1.2	0.9
116	6.1	2.2	6.4	1.6	1.1	0.6	1.7	1.4	3.9	1.1	1.1
119	1.5	2.8	10.6	2.2	1.2	0.8	1.0	0.9	4.2	0.5	0.6
133	6.2	7.2	62.4	2.6	8.5	1.5	1.1	2.5	7.2	0.4	1.4
141	3.6	3.4	9.7	2.2	2.9	1.0	1.2	1.3	4.3	1.3	1.0
158	8.2	9.2	41.0	2.3	8.6	0.5	2.9	2.6	5.2	2.1	0.2
161	3.4	9.9	11.0	1.9	14.3	1.3	1.1	1.6	3.5	1.1	1.0
180	4.1	10.3	33.8	1.4	13.7	0.7	2.3	2.6	4.8	2.1	2.0
195	3.6	5.2	30.7	1.4	6.0	0.6	1.9	2.6	4.3	1.6	1.8
197	4.6	5.9	17.8	1.9	7.4	0.7	2.6	1.4	5.1	1.3	1.1
226	4.9	3.4	79.0	1.4	4.2	0.5	3.7	4.8	10.1	2.0	1.8
229	10.0	16.2	267.9	2.6	18.1	1.2	6.9	6.3	19.6	0.9	5.8

3.3.2. Spearman correlations

The Spearman correlation values (rho) between major and trace elements, TOM and grain-size data (sand and fines fractions) are displayed in Table 3. SiO_2 shows a moderate level of positive correlation with K_2O and the sand fraction contents (rho = 0.38 and 0.36, respectively) and a strong negative correlation with CaO (rho = -0.96), TOM (rho = -0.72), mud fraction contents (rho = -0.56) and most trace metals. CaO is positively correlated with MgO, Sr and U (rho = 0.63, 0.92 and 0.80, respectively). Positive correlations are also found between Al_2O_3 and TiO_2, K_2O, Na_2O, Fe_2O_3(T), TOM and mud particle contents. Fe_2O_3(T) and MnO show a high to moderate level of positive correlation against P_2O_5, MgO, TOM and mud particle contents. Finally, the trace elements Ga, Pb, Ni, Zn, Cu and Cr define good positive correlations with Al_2O_3, Fe_2O_3(T) and MnO, whilst Rb and Ba are positively correlated with SiO_2, Al_2O_3 and K_2O (cf. Table 3).

Table 3 – Spearman correlation matrix (T: total organic matter; median: M; sand: 2 mm – 0.063 mm fraction; fines: <0.063 mm fraction).

	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	Cr	Ga	As	Rb	Sr	Ba	Zn	V	Pb	Ni	Cu	U	Fines	Sand	M	T
SiO_2	1																									
Al_2O_3	0.01	1																								
Fe_2O_3	-0.71	0.42	1																							
MnO	-0.33	0.13	0.48	1																						
MgO	-0.78	0.38	0.80	0.49	1																					
CaO	-0.96	-0.21	0.57	0.23	0.63	1																				
Na_2O	-0.29	0.72	0.43	0.30	0.63	0.11	1																			
K_2O	0.38	0.74	0.22	-0.10	0.02	-0.53	0.46	1																		
TiO_2	0.00	0.87	0.43	0.32	0.47	-0.19	0.67	0.63	1																	
P_2O_5	-0.53	0.50	0.89	0.64	0.70	0.37	0.44	0.28	0.57	1																
Cr	-0.20	0.55	0.56	0.07	0.45	0.09	0.34	0.49	0.51	0.54	1															
Ga	-0.26	0.95	0.59	0.23	0.58	0.05	0.80	0.62	0.83	0.60	0.52	1														
As	-0.44	-0.15	0.44	0.55	0.33	0.43	-0.18	-0.33	-0.11	0.47	-0.01	-0.01	1													
Rb	0.42	0.79	0.13	-0.07	-0.05	-0.56	0.48	0.92	0.62	0.23	0.37	0.66	-0.36	1												
Sr	-0.87	-0.35	0.38	0.25	0.57	0.92	0.06	-0.66	-0.31	0.23	-0.12	-0.10	0.37	-0.66	1											
Ba	0.49	0.63	-0.18	-0.13	-0.13	-0.61	0.50	0.71	0.47	-0.07	0.22	0.48	-0.56	0.82	-0.56	1										
Zn	-0.62	0.52	0.83	0.40	0.89	0.45	0.53	0.17	0.53	0.74	0.54	0.68	0.39	0.10	0.37	-0.08	1									
V	-0.66	0.32	0.76	0.50	0.72	0.55	0.35	0.00	0.26	0.77	0.35	0.49	0.68	-0.01	0.46	-0.18	0.78	1								
Pb	-0.12	0.88	0.53	0.26	0.38	-0.05	0.60	0.66	0.70	0.56	0.49	0.90	0.11	0.75	-0.22	0.50	0.54	0.43	1							
Ni	-0.67	0.58	0.84	0.36	0.88	0.48	0.60	0.23	0.56	0.81	0.65	0.71	0.24	0.18	0.36	0.04	0.89	0.80	0.51	1						
Cu	-0.27	0.47	0.34	0.06	0.42	0.17	0.34	0.05	0.32	0.27	0.37	0.47	0.21	0.14	0.06	0.11	0.56	0.58	0.39	0.59	1					
U	-0.85	0.01	0.58	0.44	0.80	0.80	0.42	-0.29	0.21	0.53	0.17	0.24	0.27	-0.33	0.79	-0.32	0.53	0.51	0.04	0.60	0.07	1				
Fines	-0.56	0.43	0.59	0.05	0.62	0.44	0.40	0.16	0.35	0.49	0.56	0.57	0.27	0.11	0.26	0.05	0.64	0.63	0.44	0.73	0.57	0.36	1			
Sand	0.38	-0.29	-0.43	0.08	-0.40	-0.32	-0.19	-0.16	-0.12	-0.32	-0.62	-0.37	-0.28	-0.13	-0.11	-0.06	-0.46	-0.52	-0.37	-0.55	-0.58	-0.13	-0.90	1		
M	-0.47	0.66	0.64	0.29	0.73	0.31	0.74	0.33	0.70	0.57	0.46	0.76	0.09	0.29	0.18	0.21	0.71	0.55	0.58	0.74	0.61	0.47	0.71	-0.48	1	
T	-0.72	0.46	0.82	0.40	0.89	0.57	0.54	0.06	0.43	0.72	0.54	0.63	0.37	0.04	0.48	-0.06	0.92	0.84	0.46	0.93	0.59	0.62	0.72	-0.56	0.69	1

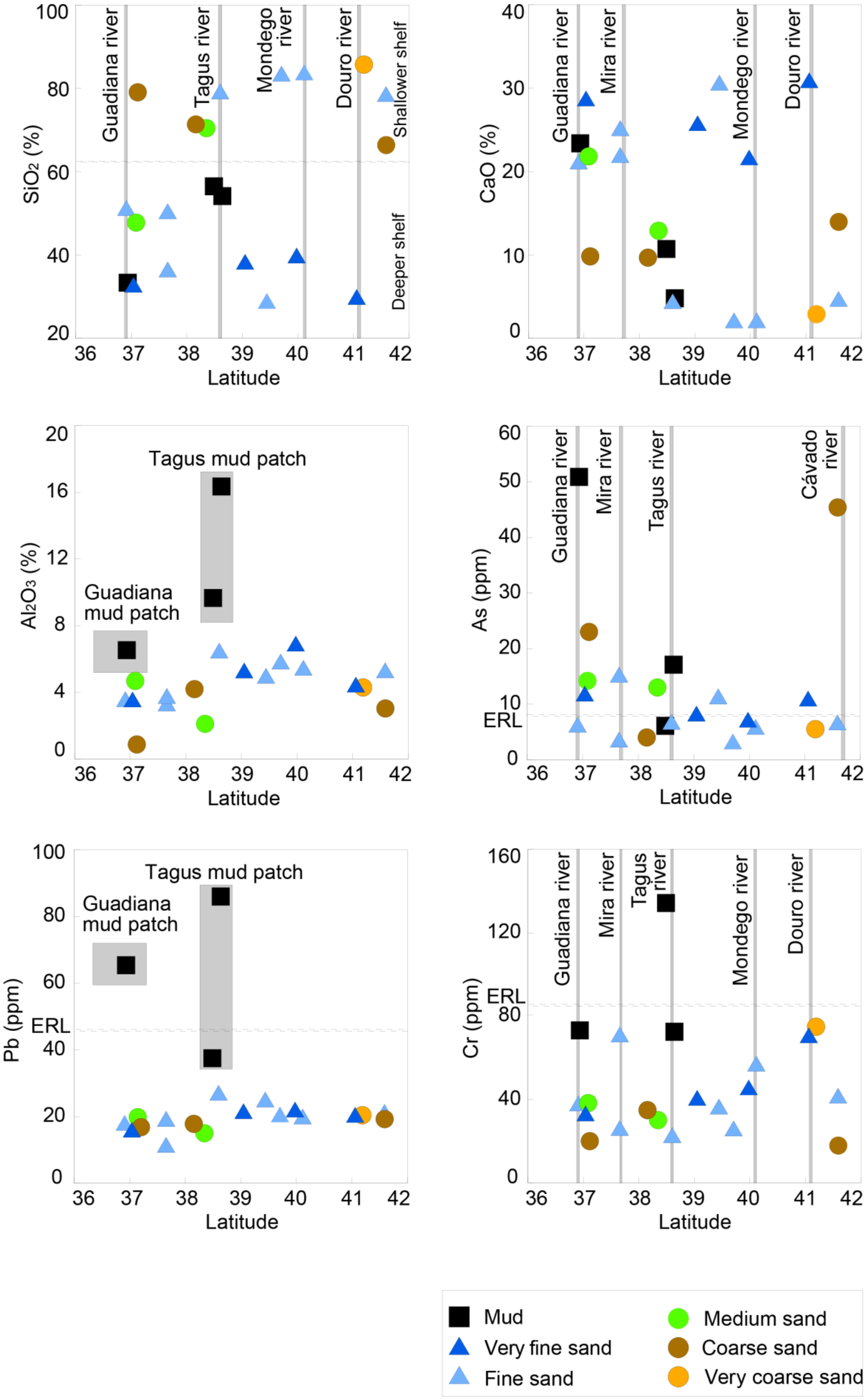


Figure 10 – Plots showing the variation between selected major and minor elements contents of sediment and the sample geographical location. The position of relevant rivers or mud patches and the effects range low threshold (ERL) is also indicated.

3.3.3. *Multivariate analysis*

The results of cluster and ordination analysis for major and trace element data are shown in Figure 11. Minimization of collinearity effects was achieved by selecting only one variable within each subset of highly correlated variables (rho > 0.80), since the chosen variable conveys essentially all the information contained in the others. Reduction of the initial variable data set involved the selection of Al_2O_3 (TiO_2, Ga, and Pb removed), K_2O (Rb removed), Fe_2O_3 (MgO, P_2O_5, Zn and Ni eliminated) and CaO (Sr and U excluded). Grain-size and TOM were added as supplementary variables and do not affect the analysis. Axis 1 accounts for 37.2% of the total variance and is characterized by high positive loads for the majority of major and trace elements (excluding SiO_2, CaO and As) and high negative loads for SiO_2. TOM plots concordantly with the positive segment of this axis. Axis 1 discriminates well the mud and very fine sand deposits from the coarser sediments (fine, medium and coarse sands). Axis 2 is responsible for 29.8% of the total variance and has high positive loads for SiO_2, K_2O, Al_2O_3, Na_2O and Ba and negative loads for CaO and As. It divides the sandy deposits into two main groups: (a) sand sediments showing a marked enrichment in SiO_2, K_2O, Al_2O_3, Na_2O and Ba (b) sand deposits with high CaO contents. Axis 3 describes 12.1% of the total variance and shows high positive loadings for MnO, As, SiO_2 and Fe_2O_3(T). Samples located off the mouth of the Cávado and Guadiana rivers plot as a discrete cluster of data points in the extreme positive end of axis 3, suggesting that these rivers act as an important source of As. Based on the results of multivariate analysis, it was possible to subdivide the Portuguese shelf sediments into four main groups: A, B, C and D (Figure 11 and Figure 12; Table 4). Group A includes the three mud samples collected off the mouths of the Tagus and Guadiana rivers, which are characterized by strong trace metal enrichments and high concentrations of TOM (cf. Table 4; Figure 12). Group B comprises the carbonate-rich sands with high CaO, Sr and U contents and an average amount of mud sized particles of 25.47% (cf. Table 4). This group is found in the deeper parts of the northwestern coast shelf and also in shallower environments in the central, southwestern and southern sectors (Figure 12). Group C corresponds to sand sediments of variable grain-size (from fine to very coarse sand), displaying very high concentrations of SiO_2 and moderate abundances of Al_2O_3, K_2O and TiO_2. Their low contents of organic matter and mud sized particles are consistent with the observed trace metal depletion (cf. Table 4). Some of these deposits occur in the middle shelf of the northwestern sector (Figure 12). Group D consists of two coarse sand samples, enriched in SiO_2, MnO and As (cf. Table 4), located off important estuarine systems (Figure 12).

Table 4 – Major and minor elements and baseline sedimentary descriptors mean values in the geochemical affinity groups (TOM: total organic matter; gravel: >2 mm fraction; sand: 2 mm – 0.063 mm fraction; mud: <0.063 mm fraction).

			A	B	C	D
Major elements	**SiO_2**	**(%)**	48.00	42.79	80.60	72.73
	Al_2O_3		10.85	4.27	5.27	1.95
	Fe_2O_3 (T)		6.29	2.89	1.50	1.63
	MnO		0.04	0.03	0.02	0.04
	MgO		1.52	1.14	0.40	0.31
	CaO		12.96	24.21	4.33	11.88
	Na_2O		0.88	0.40	0.38	0.88
	K_2O		2.59	1.42	2.14	0.95
	TiO_2		0.58	0.25	0.38	0.07
	P_2O_5		0.19	0.12	0.10	0.09
Minor elements	**U**	**(ppm)**	4	5	3	3
	Zr		145	78	200	16
	Cr		94	43	43	19
	Ga		13	5	5	2
	As		25	10	5	34
	Br		74	41	16	4
	Rb		112	56	84	42
	Sr		339	800	151	439
	Ba		253	142	216	94
	Zn		121	36	22	20
	V		90	31	19	27
	Pb		63	19	21	19
	Ni		19	8	5	2
	Cu		20	8	5	5
Sediment	**TOM**	**(%)**	6.79	3.42	1.47	1.54
	Sand		31.83	73.12	87.01	94.77
	Mud		68.07	25.47	7.26	1.88

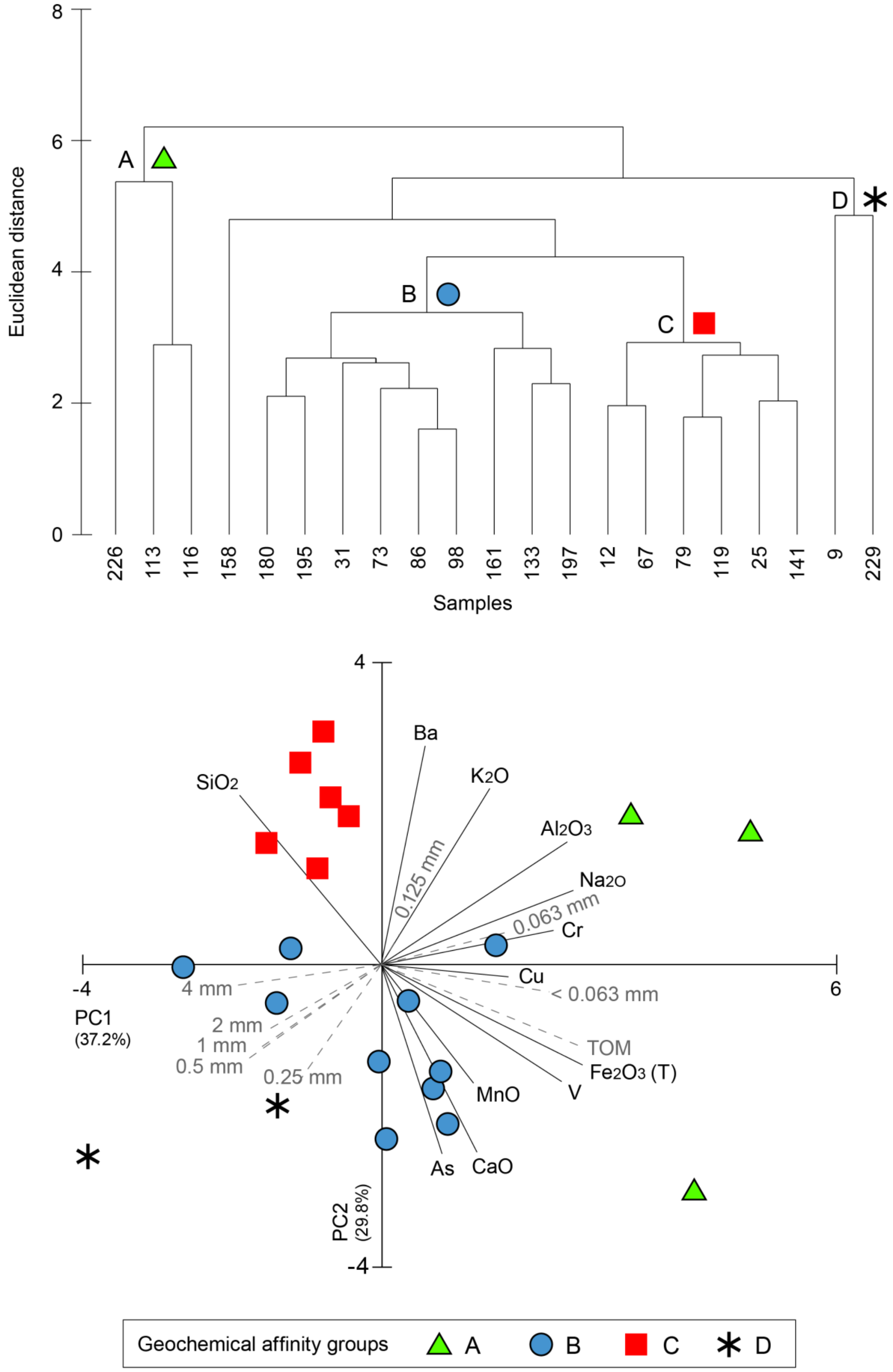


Figure 11 – Major and minor elements classification and ordination analysis identifying the geochemical groups (A, B, C, D). Baseline sediment variables (grain-size classes and total organic matter – TOM) are superimposed as supplementary variables (dashed vectors)

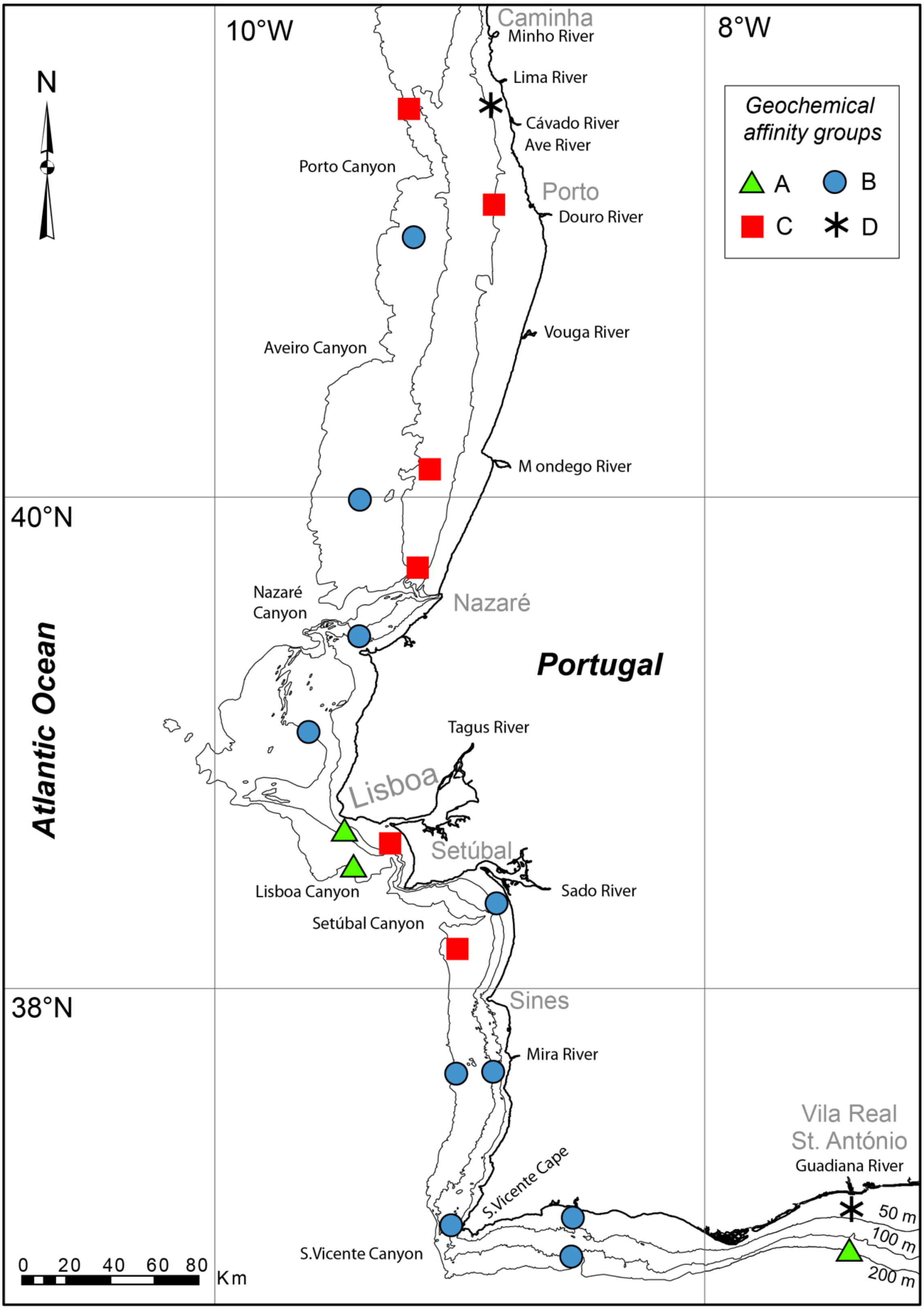


Figure 12 – Spatial distribution of samples according its geochemistry affinity groups (A, B, C, D) in the Portuguese continental shelf.

B. Biological characterization

3.4. Macrofauna abundance patterns

A total of 737 species were identified from a set of 30008 individuals (full list of species, total abundance and number of presences can be found in Annex 2). The most abundant phyla were the Annelida, Mollusca and Arthropoda (Subphylum Crustacea) (20241, 2544 and 2236 individuals, respectively; cf. Figure 13). The most abundant taxa were the polychaetes, bivalves, nematodes, nemerteans and amphipods (19731, 1996, 1709, 1611 and 1413 specimens, respectively). The spatial representation of the abundance per sampling site is shown in Figure 14–A. The abundance of the macrofauna ranged from 7 to 1307 specimens per site (0.1 m^{-2}). Mean abundance reached 207 specimens per site. Abundance decreased from coarser sediments to muddy sediments, with increasing depth, from the most exposed to the sheltered shelf and from the northernmost latitude to the southernmost coast. Considering this, the highest abundance of benthic fauna were obtained in gravel (479.0 ind. 0.1 m^{-2}), in the inner (<30 m water depth; 300.9 ind. 0.1 m^{-2}) and in the exposed shelf area (261.6 ind. 0.1 m^{-2}) and in the northern latitudinal degrees (>200 ind. 0.1 m^{-2}). By contrast, lower abundances were found in the majority of the 31 muddy sites (79.1 ind. 0.1 m^{-2} , among 31 sites), in the deepest shelf (> 100 m water depth; 134.1 ind. 0.1 m^{-2}), in the southern sheltered shelf (151.2 ind. 0.1 m^{-2}) and in the southwestern shelf (latitudinal range 37ºN – 37.99ºN; 137.5 ind. 0.1 m^{-2}).

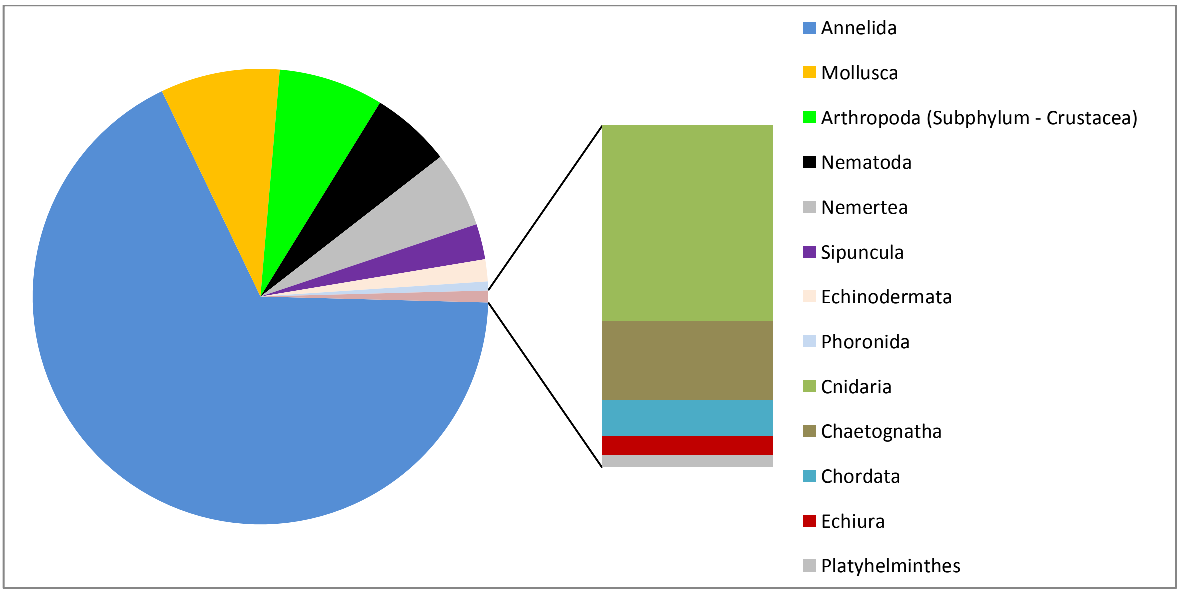


Figure 13 – Total abundance of the benthic macrofauna per Phylum.

The most abundant taxa (N>500 ind.) were Nematoda n.i. (1709 ind.; 5.7% of the total abundance A_T), Nemertea n.i. (1611 ind.; A_T = 5.4%), *Mediomastus fragilis* (967 ind.; A_T =

3.2%), *Polygordius appendiculatus* (890 ind.; A_T = 3.0%), *Ampharete finmarchica* (800 ind.; A_T = 2.7%), *Prionospio fallax* (684 ind.; A_T = 2.3%), *Spio filicornis* (560 ind.; A_T = 1.9%), *Protodorvillea kefersteini* (557 ind.; A_T = 1.9%), *Ampelisca* sp. (549 ind.; A_T = 1.8%), and Oligochaeta n.i (510 ind.; A_T = 1.7%). Those are the global results; however some differences were found analyzing the three major faunal groups separately. Regarding to the annelid polychaetes (19731 specimens), the most abundant families were the spionids (2927 ind.), syllids (1459 ind.), capitellids (1363 ind.), cirratulids (1341 ind.) and ampharetids (1338 ind.). Abundance of polychaetes ranged from 0 (one muddy site) to 620 (one site in very coarse sand) specimens per site (0.1 m^{-2}) (Figure 15–A). The most abundant species were *Mediomastus fragilis*, *Polygordius appendiculatus*, *Ampharete finmarchica*, *Prionospio fallax, Spio filicornis*, *Protodorvillea kefersteini* and *Eunice vittata*. Overall, polychaetes abundance followed the general macrofauna patterns, decreasing from coarser to muddy sediments, with increasing depth, from the exposed to the sheltered shelf and from the northern latitude to the southernmost coast.

Among the molluscs, a total of 2544 specimens were analysed corresponding to 170 species, 2 Aplacophora, 2 Scaphopoda, 8 Polyplacophora, 53 Gastropoda and 105 Bivalvia. Abundance ranged from 1 to 172 specimens per site (0.1 m^{-2}). From the 145 sites only thirteen sites were characterized by a total absence of molluscs. The lowest abundance values were found in the sheltered, muddy and deeper sites whereas the highest values were obtained in coarser sediments of the near and mid exposed western shelf (Figure 16–A). The most abundant species (N>100 ind./0.1 m^2) were *Abra alba*, *Thracia villosiuscula*, *Thyasira flexuosa*, *Kurtiella bidentata* and *Corbula gibba*.

A total of 2236 crustaceans were identified corresponding to 195 species. The Families Ampeliscidae (634 ind.), Cirolanidae (146 ind.) and Apseudidae (133 ind.) were the most abundant, among the 78 families recorded in this study area. The most abundant species (N>50 ind.) were *Ampelisca* sp., *Apseudes* sp. 2, *Ampelisca brevicornis*, *Campylaspis* cf. *glabra* and *Othomaera othonis.* Fourteen sites were characterized by a total absence of crustaceans. Mean abundance reached 15 specimens per site, and decreased with increasing depth, from the sheltered shelf to the most exposed shelf and from the southern to the northern latitudinal degrees (Figure 17 – A). No clear abundance pattern was found among sediment types (higher mean abundance was found in gravel (31.0 ind. 0.1 m^{-2}) and very fine sand (22.7 ind. 0.1 m^{-2}) while lower values were found in coarse sands (8.1 ind. 0.1 m^{-2}) and muds (10.3 ind. 0.1 m^{-2})).

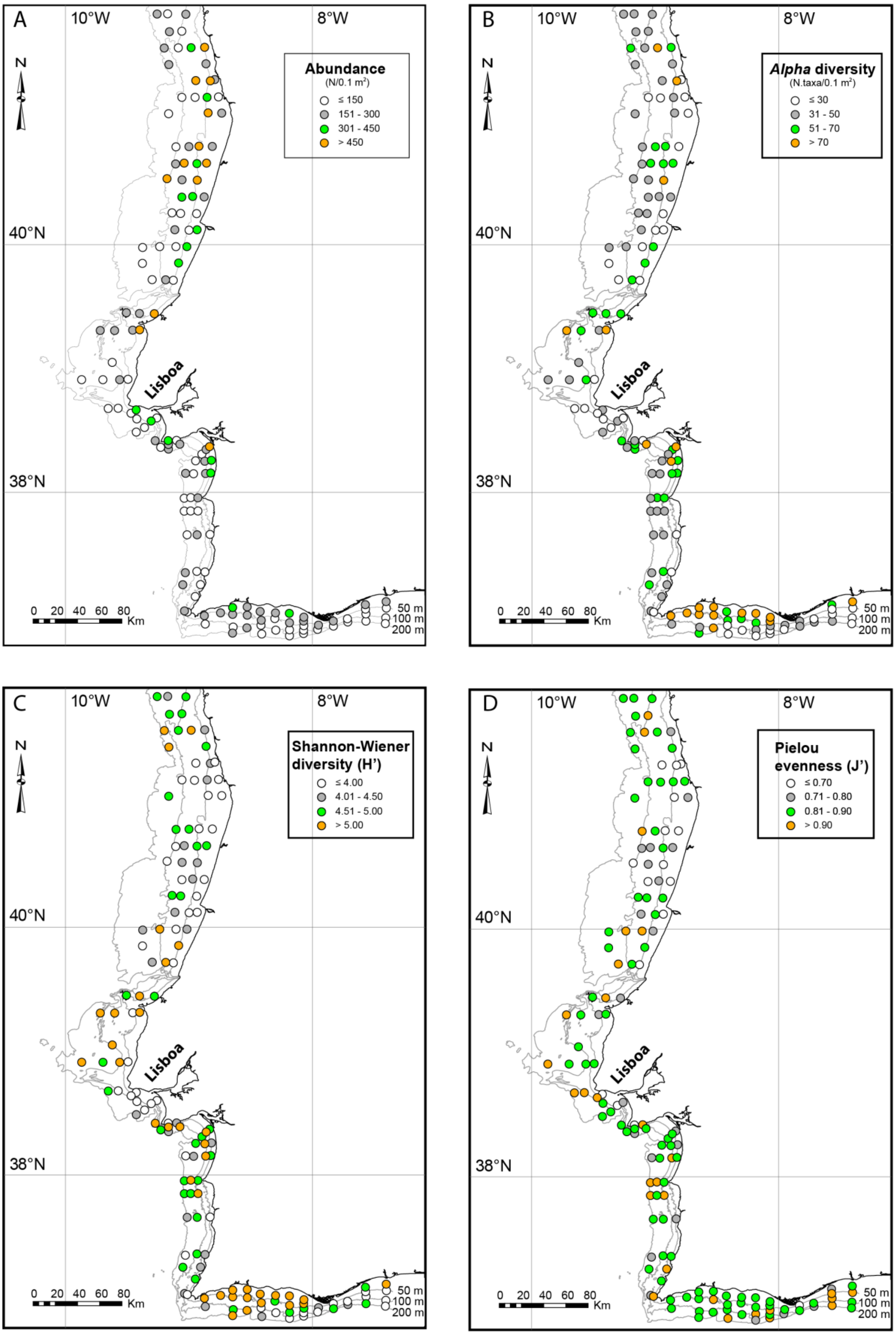


Figure 14 – Spatial distribution of benthic macrofauna abundance (A) and alpha diversity (B), Shannon-Wiener diversity (C) and Pielou evenness (D) in the Portuguese continental shelf.

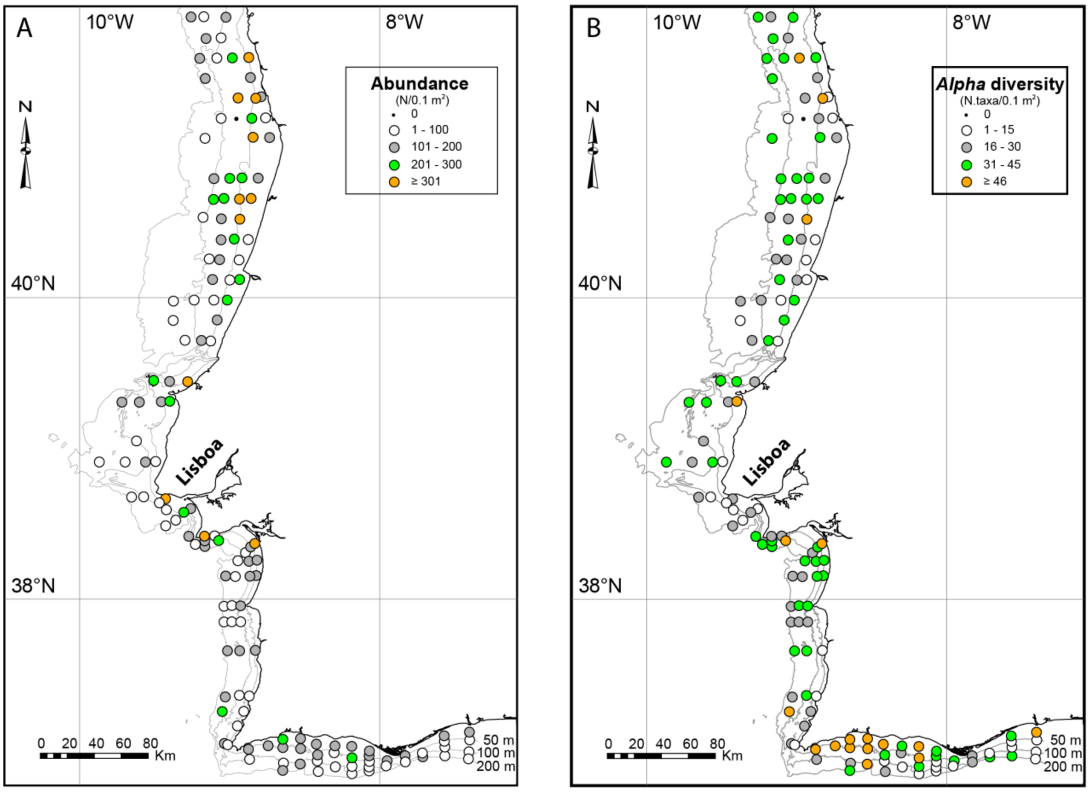


Figure 15 – Spatial distribution of polychaetes abundance (A) and *alpha* diversity (B), in the Portuguese shelf.

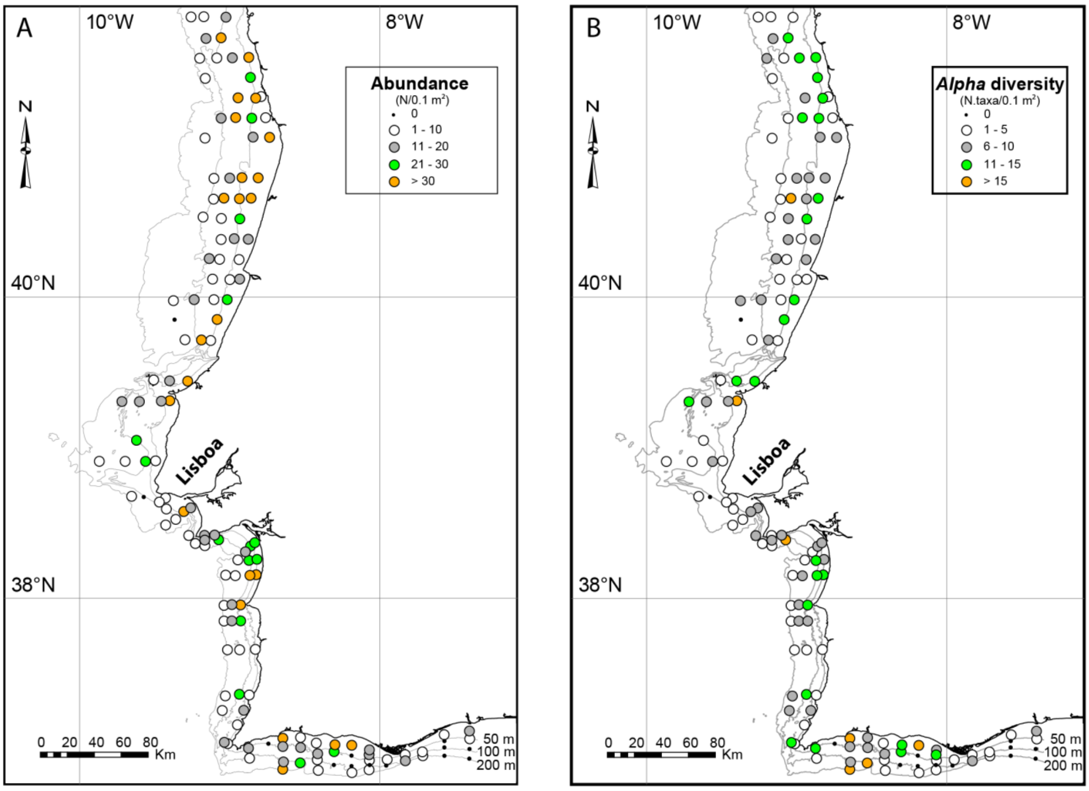


Figure 16 – Spatial distribution of molluscs abundance (A) and *alpha* diversity (B), in the Portuguese continental shelf.

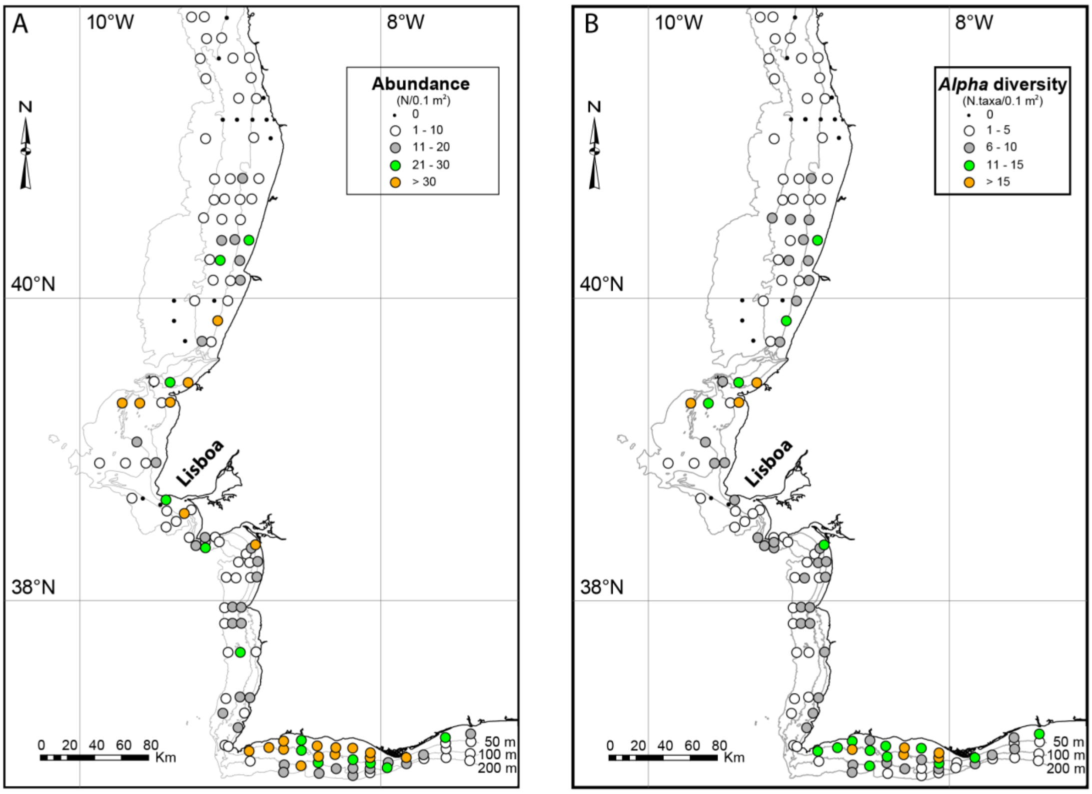


Figure 17 – Spatial distribution of crustaceans abundance (A) and *alpha* diversity (B), in the Portuguese continental shelf.

3.5. Species richness and diversity patterns

A total of 737 species were recorded. Polychaetes, bivalves, amphipods, gastropods and decapods presented the highest species richness values (319, 105, 99, 53 and 38 species, respectively). The most frequent taxa were Nemertea n.i. (F=72.4%, 105 sites), *Ampharete finmarchica* (F=64.8%, 94 sites), *Ampelisca* sp. (F=53.8%, 78 sites), *Lumbrineris lusitanica* (F=46.9%, 68 sites), *Aponuphis bilineata* (F=44.8%, 65 sites), *Spiophanes kroyeri* (F=44.1%, 64 sites) and *Notomastus latericeus* (F=42.8%, 62 sites).

The *alpha* diversity ranged from 3 to 96 spp. 0.10 m^{-2}; 17 sites had less than 20 spp. while 21 sites had more than 70 (cf. Figure 14 – B). The mean *alpha* diversity was 45.8 spp. 0.1 m^{-2}. Highest mean *alpha* diversity were found in gravel (66.0 spp. 0.1 m^{-2}), in the inner (below 30 m; 54.1 spp. 0.1 m^{-2}), in the sheltered (47.2 spp. 0.1 m^{-2}) and in the western part of the southern shelf (longitude 8º – 8.99º W; 56.3 spp. 0.1 m^{-2}). The lower values of mean *alpha* diversity were found in mud (25.3 spp. 0.1 m^{-2}), regarding to sediment types, in very deep bottoms (above 100 m; 41.0 spp. 0.1 m^{-2}), according to depth classes, in the most exposed shelf (43.6 spp. 0.1 m^{-2}) in terms of hydrodynamic areas, and in the eastern part of the southern shelf (33.2 spp. 0.1 m^{-2}) analyzing longitude and latitude degrees.

The highest *beta* diversity values were found in mud (β = 10.1) regarding to sediment types, between 60 – 100 m (β = 10.9) in terms of depth classes and in the moderately exposed coast (β = 10.8) according to the hydrodynamic regime areas. Regarding to latitude, the highest *beta* diversity values were found in the latitudinal range 38º N–38.99º N (β = 8.4) and in the longitudinal range 8º W–8.99º W (β = 7.3), in terms of longitude. The lowest values were found in gravel (β = 3.5), in terms of sediment types, below 30 m (β = 6.2), in terms of depth, and in the sheltered coast (β = 9.6), in terms of hydrodynamics. A slightly decrease of *beta* diversity was noticed with increasing latitude, being this pattern more clear if only the northwestern part of the shelf was considered (slope = 0.80). The *beta* diversity for the western part of the shelf, for the southern and for the entire shelf was respectively 13.6, 9.5 and 16.1. The highest values of the diversity indices (Shannon-Wiener, H' > 5; Figure 14 – C; Margalef richness, d > 9, Simpson > 0.9 and Rarefaction, ES50 > 25) were found mainly in the western part of the southern shelf sector, in the southwestern shelf, south of the Setubal canyon and off Sesimbra (Espichel Cape), off Peniche (Carvoeiro Cape) and in the northernmost shelf sector. The lowest diversity values were recorded in muds and in several fine sands along the near shore shelf. The highest values of Pielou's evenness (J > 0.9; Figure 14 – D) were obtained mainly in muds and finer sands at greater depths. The highest diversity areas mentioned before presented moderate equitability. The diversity indices decreased with increasing latitude, such as for the Rarefaction index (slope = -0.73) or Margalef index (slope = -0.27) or Shannon-Wiener index (slope = -0.10).

Like the abundance data, the overall diversity results did not fully overlap the results gained from the isolated analysis of three major faunal groups, particularly regarding to crustaceans, as follows.

Among the 319 polychaete species recorded in this study, a total of 49 families were found, being the highest number of species found within the Syllidae, Spionidae, Cirratulidae, Paraonidae and Maldanidae presented (36, 23, 19, 16 and 16 species, respectively). The most frequent species, occurring at least in 60 sites, were *Ampharete finmarchica, Lumbrineris lusitanica*, *Aponuphis bilineata, Spiophanes kroyeri* and *Notomastus latericeus*. The *alpha* diversity, ranged from 1 to 65 spp. 0.1 m^{-2} (Figure 15–B). Higher values of *alpha* diversity were found mainly in five areas: western part of the southern shelf sector, coarser sediments of the southwestern shelf, off Sesimbra, off

Peniche and northernmost shelf sector. Low or very low *alpha* diversity values were recorded in muds and in the near shore shelf sand.

The most frequent mollusc species, occurring at least in 20 sites, were *Abra alba*, *Corbula gibba*, *Thracia villosiuscula, Saccella commutata*, *Tellina compressa*, *Thyasira flexuosa*, *Angulus pygmaeus*, *Fustiaria rubescens, Gouldia minima*, *Dosinia lupinus* and *Tellimya ferruginosa*. The *alpha* diversity values, per each sampling site, ranged from 1 species (in seven sites) to 21 spp. 0.10 m^{-2} (in one site) (Figure 16–B). Lower values of *alpha* diversity were found in mud and deeper bottoms and higher values were recorded in gravel, shallow depths and in the exposed shelf.

Regarding to crustaceans, the most frequent species, occurring at least in 20 sites, were *Ampelisca* sp., *Ampelisca brevicornis*, *Lembos* sp., *Harpinia antennaria* and *Diastylis bradyi*. The number of species per site, ranged from 1 (in 10 sites) to 30 spp. 0.10 m^{-2} (in one site), excluding 14 sites with total absence of crustaceans (Figure 17–B). Higher *alpha* diversity values were found in medium and very fine sands, in the inner shelf and in the southern sheltered shelf as well as off Peniche. Lower values of *alpha* diversity were found in mud and coarse sand, in deep bottoms, in the exposed shelf, but also all over the western shelf sector (when compared with the southern shelf sector).

3.6. Distribution patterns of particular species

The spatial distribution patterns of some species are here presented to obtain a better comprehension of the species diversity and the Portuguese shelf benthic communities. The spatial distribution of the abundance of some selected species is shown in Figure 18 to Figure 23.

Several species showed in this study broad spatial distributions being present along the entire shelf. Among these more cosmopolitan species some can be highlighted:

a) The polychaetes *Ampharete finmarchica* (Figure 18–A)*, Monticellina heterochaeta* (Figure 18–B), *Prionospio fallax* (Figure 18–C), *Aphelochaeta* sp.1 (Figure 19–B)*, Lumbrineris lusitanica* (Figure 20–C), *Galathowenia oculata, Terebellides stroemii* and the molluscs *Thyasira flexuosa* (Figure 21–A), *Abra alba* (Figure 21–B)*, Corbula gibba* (Figure 21–C) and *Kurtiella bidentata* or the sipunculid *Golfingia (Golfingia) elongata* dominated the finer sands, most of them in the deep shelf.

b) The polychaetes *Magelona filiformis* and *Magelona johnstoni* (Figure 19–A) or the decapod *Diogenes pugilator*, the molluscs *Nassarius reticulatus* (Figure 22–B) or *Angulus fabula*, the amphipods *Urothoe pulchella* (Figure 23–B), *Pontocrates* *altamarinus* or *Megaluropus agilis* were more abundant in fine sands of the near shore shelf.

c) Nemerteans, nematodes, polychaetes (e.g. *Protodorvillea kefersteini* (Figure 18–D), *Spio filicornis*, *Polygordius appendiculatus, Sphaerosyllis bulbosa*, *Lumbrineriopsis paradoxa*, all *Pisione* species or several syllids), bivalves (e.g. *Angulus pygmaeus*, *Thracia villosiuscula* (Figure 21–D), *Limatula subovata* or *Glycymeris glycymeris* (Figure 22–A) or the sipunculid *Aspidosiphon (Aspidosiphon) muelleri muelleri* (Figure 23–D) were some of the most abundant and dominant taxa in coarser sediments of the western shelf.

d) The amphipod *Harpinia antennaria* or the polychaetes *Sternaspis scutata* and *Ninoe armoricana* presented their highest abundances in muds.

e) The bivalves *Spisula subtruncata*, *Chamelea striatula*, *Clausinella fasciata*, *Spisula elliptica*, *Chamelea gallina*, the gastropod *Euspira pulchella*, the polychaetes *Aricidea (Allia) roberti* and *Aricidea (Aricidea) wassi* or the anthozoa *Edwardsia claparedii* presented higher abundances in the northwestern shelf.

f) The scaphopod *Fustiaria rubescens*, the bivalves *Saccella commutata* (Figure 22–C) and *Palliolum incomparabile* and the Aplocophora sp. 1 polychaetes *Pterolysippe vanelli, Sarsonuphis bihanica* were mostly collected in the southwestern deepest shelf.

g) The polychaetes *Eunice vittata*, the crustacean *Ampelisca* sp. (Figure 23–A) or the sipunculids *Golfingia (Golfingia) vulgaris vulgaris* and *Onchnesoma steenstrupii steenstrupii* were highly abundant in both southern and southwestern shelf sectors.

h) The polychaetes *Heteromastus filiformis* (Figure 19–C) and *Gallardoneris iberica* (Figure 20–A), or the molluscs *Leptochiton cancellatus* (Figure 22–D) and *Laevicardium crassum* reached higher abundances in the southern shelf.

However, several other species were exclusively found:

a) *In the northwestern shelf* (between the northern Portuguese border and the Nazaré Canyon), where can be highlighted, for instance, the polychaetes *Phyllodoce rosea*, *Microspio mecznikowianus*, *Prionospio aluta* or *Glycera oxycephala*, the crustaceans *Nebalia* cf. *strausi*, *Schistomysis* cf. *ornata* or *Pagurus excavatus*, the bivalve *Spisula elliptica* or the gastropod *Caecum subannulatum*.

b) *Off Peniche* (e.g. the polychaete *Lacydonia Miranda,* the cumacean *Campylaspis* cf. *glabra*; the crustaceans Euphausiacea *Iathrippa bisbidens*, *Jaera (Jaera)* cf. *albifrons* or *Eurydice naylori*).

c) *In the western shelf*. The southern distribution limit of the species were located in the vicinity of some of the western canyons, namely the Lisbon canyon (e.g. *Caulleriella zetlandica*, *Sthenelais limicola*, *Phaxas pellucidus*, *Mactra stultorum* or *Pharus legumen*), Setúbal Canyon (e.g. *Streptodonta pterochaeta*, *Syllis licheri*, *Mesochaetopterus saggitarius*, *Modiolus barbatus*, *Abra prismatica*) or São Vicente Canyon (e.g. *Tellimya ferruginosa*, *Cylichna cylindracea*, *Chamelea striatula*, *Eunice harassii*, *Magelona johnstoni* (Figure 19–A), *Glycera mimica*, *Echinocyamus pusillus* (Figure 23–C), *Amphiura chiajei*) or in the vicinity of capes, such as the *Carvoeiro Cape*, off Peniche (e.g. *Malmgreniella* cf. *mcintoshi*, *Gari tellinella*, *Anomia ephippium* and *Scrobicularia plana*) or Sines cape (e.g. *Aricidea (Acmira) assimilis*).

d) In both *southwestern and southern shelf sectors* (being most abundant in the later sector). The species *Anapagurus pusillus*, *Paralacydonia paradoxa*, *Lumbrineris luciliae* (Figure 20–B), *Syllidia armata*, *Haplosyllis spongicola, Sphaerosyllis taylori*, among several others, exhibited their northern limits near the Nazaré Canyon. This work sets the northern limit of *Lumbrineris pinaster* (Figure 20–D) in the Tagus mud patch. The Setúbal Canyon was the setentrional limit of *Calyptraea chinensis*, *Retusa truncata, Eulima glabra*, *Yoldiella philippiana*, *Tellina serrata*, *Bathyarca pectunculoides*, *Arcopagia crassa*, *Nematonereis unicornis* or *Urothoe elegans*, among several others.

e) *In the southern shelf*. The most abundant southern exclusive species (at least 5 specimens recorded in total) were the polychaetes *Parapionosyllis brevicirra*, *Schistomeringos rudolphii*, *Euchone rubrocincta* (Figure 19–D) and *Paradoneis armata*, the Euphausiacea *Conilera cylindracea* and *Cirolana cranchi*, the amphipods *Microdeutopus versiculatus*, *Medicorophium minimum* and *Ericthonius punctatus*, the decapod *Liocarcinus navigator* and the bivalves *Pitar rudis* and *Montacuta phascolionis*.

A total of 125 species (51 crustaceans, 38 molluscs, 35 polychaetes and 1 echinoderm) were found exclusively in the southern shelf, while 276 species were uniquely recorded in the western shelf (90 polychaetes, 68 crustaceans, 56 bivalves, 29 echinoderms, 25 gastropods, among other taxa).

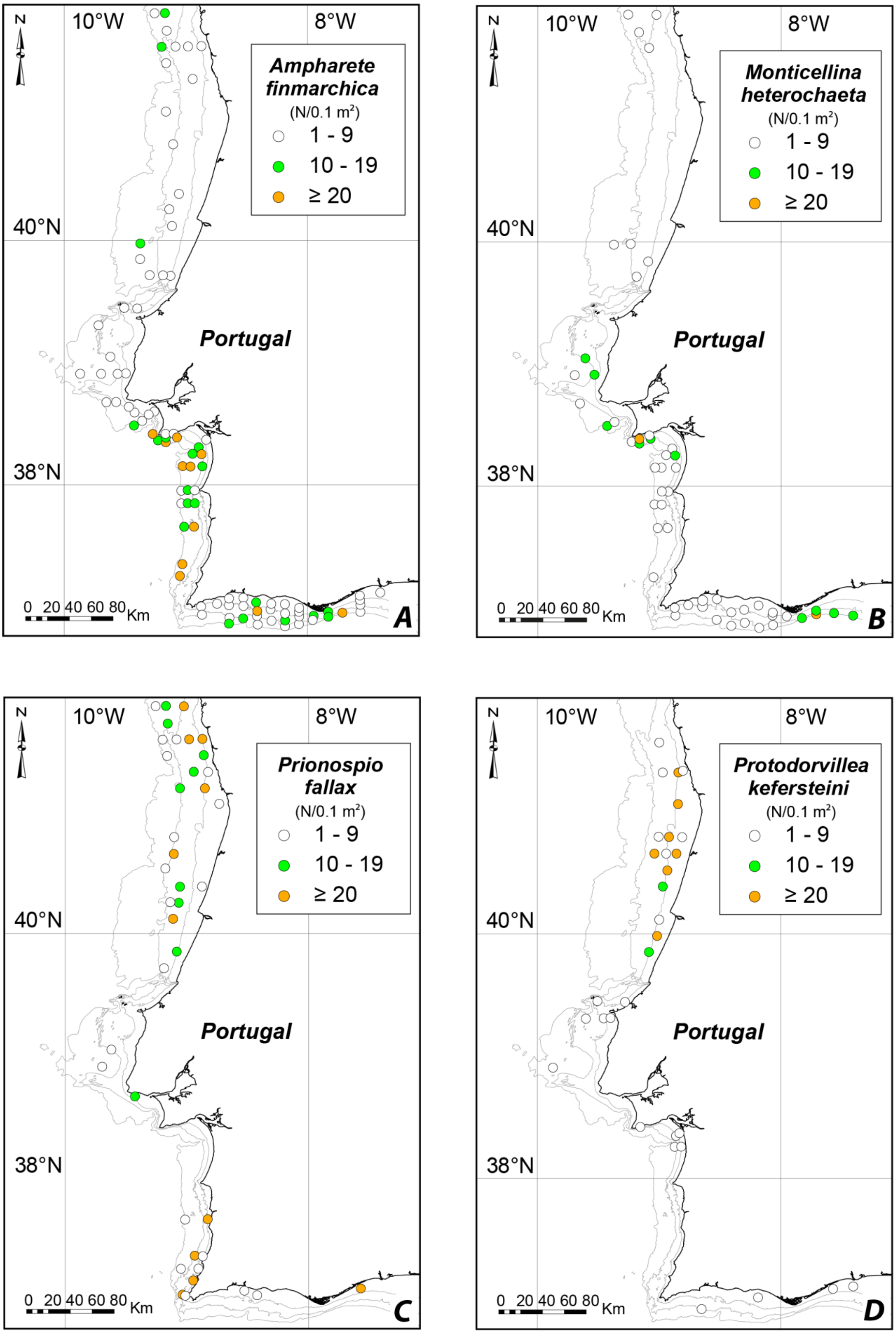


Figure 18 – Abundance spatial distribution patterns of some selected polychaete species: *Ampharete finmarchica* (A), *Monticellina heterochaeta* (B), *Prionospio fallax* (C) and *Protodorvillea kefersteini* (D).

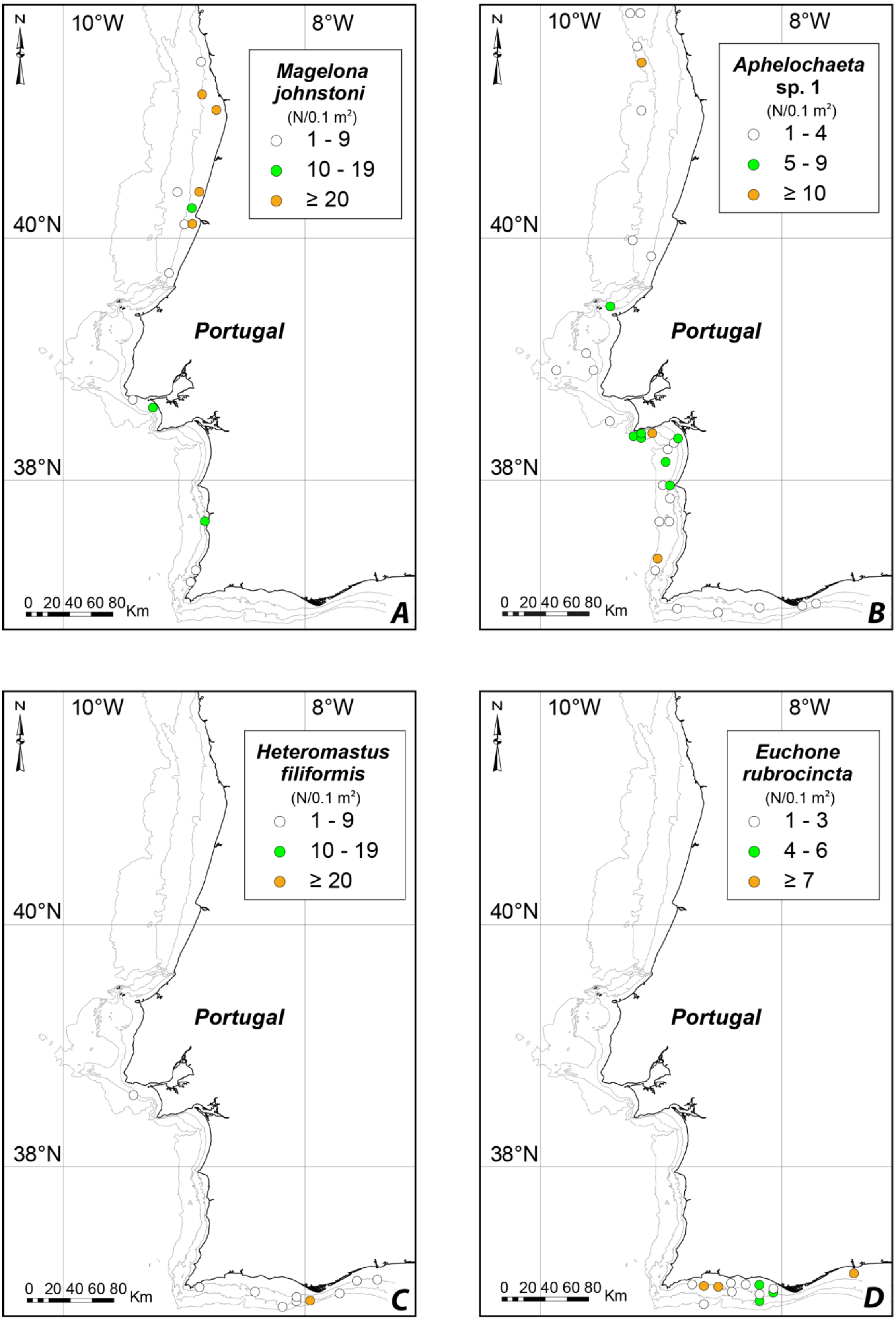


Figure 19 – Abundance spatial distribution patterns of some selected polychaete species: *Magelona johnstoni* (A), *Aphelochaeta* sp. 1 (B), *Heteromastus filiformis* (C) and *Euchone rubrocincta* (D).

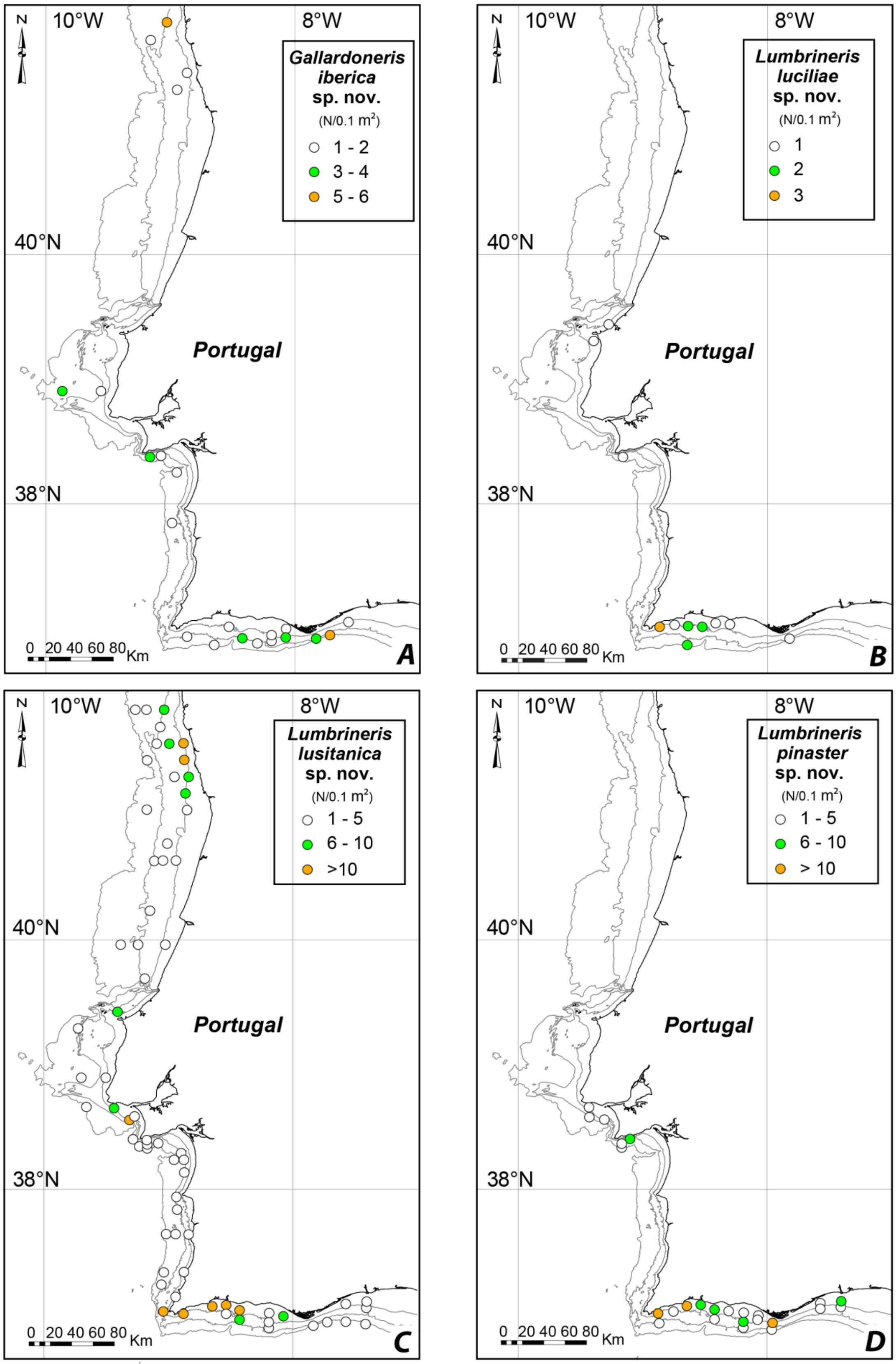


Figure 20 – Abundance spatial distribution patterns of the new Lumbrineridae (Polychaeta) species: *Gallardoneris iberica* **sp. nov.** (A), *Lumbrineris luciliae* **sp. nov.** (B), *L. lusitanica* **sp. nov.** (C), *L. pinaster* **sp. nov.** (D).

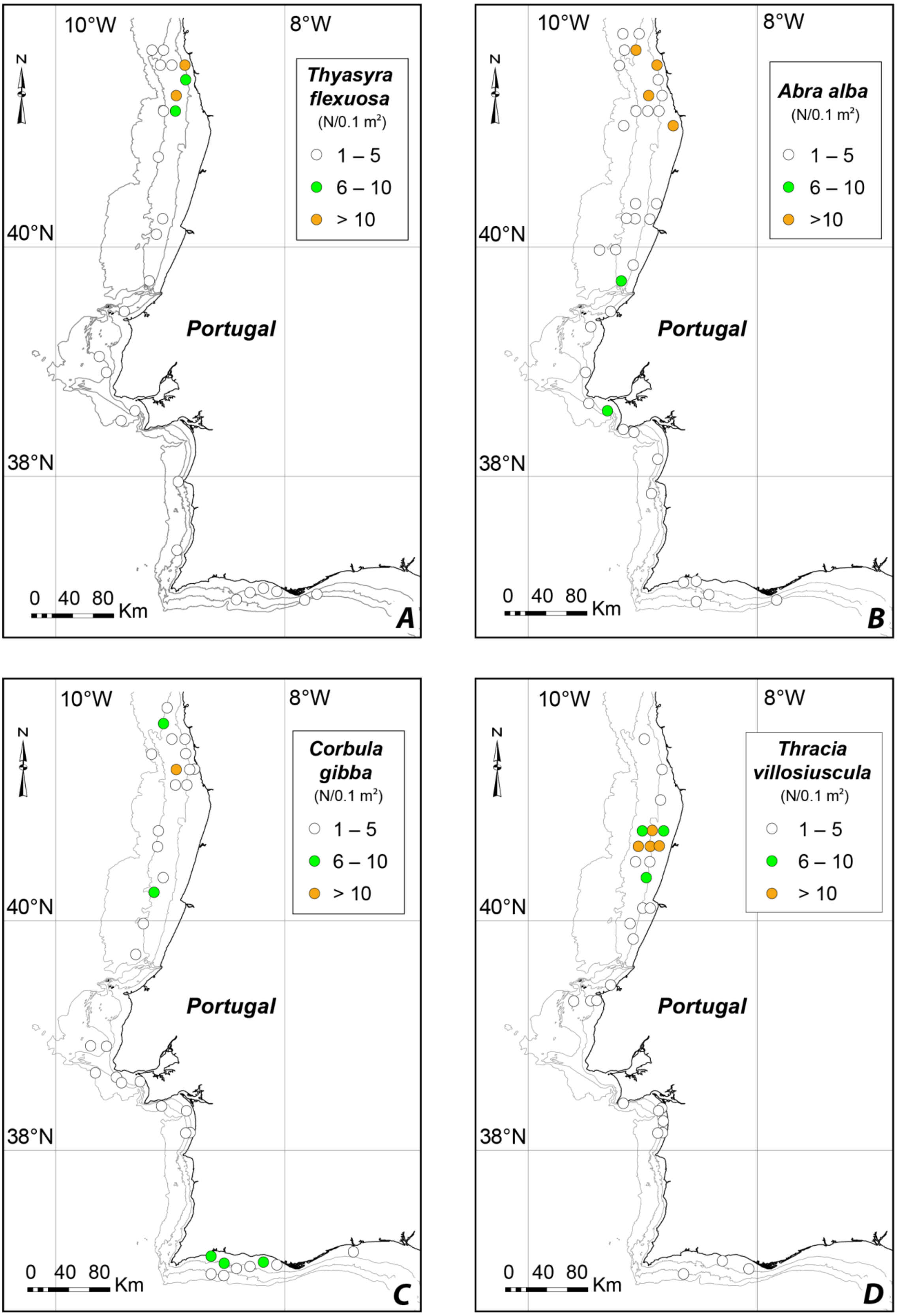


Figure 21 – Abundance spatial distribution patterns of some selected molluscs species: *Thyasira flexuosa* (A), *Abra alba* (B), *Corbula gibba* (C) and *Thracia villosiuscula* (D).

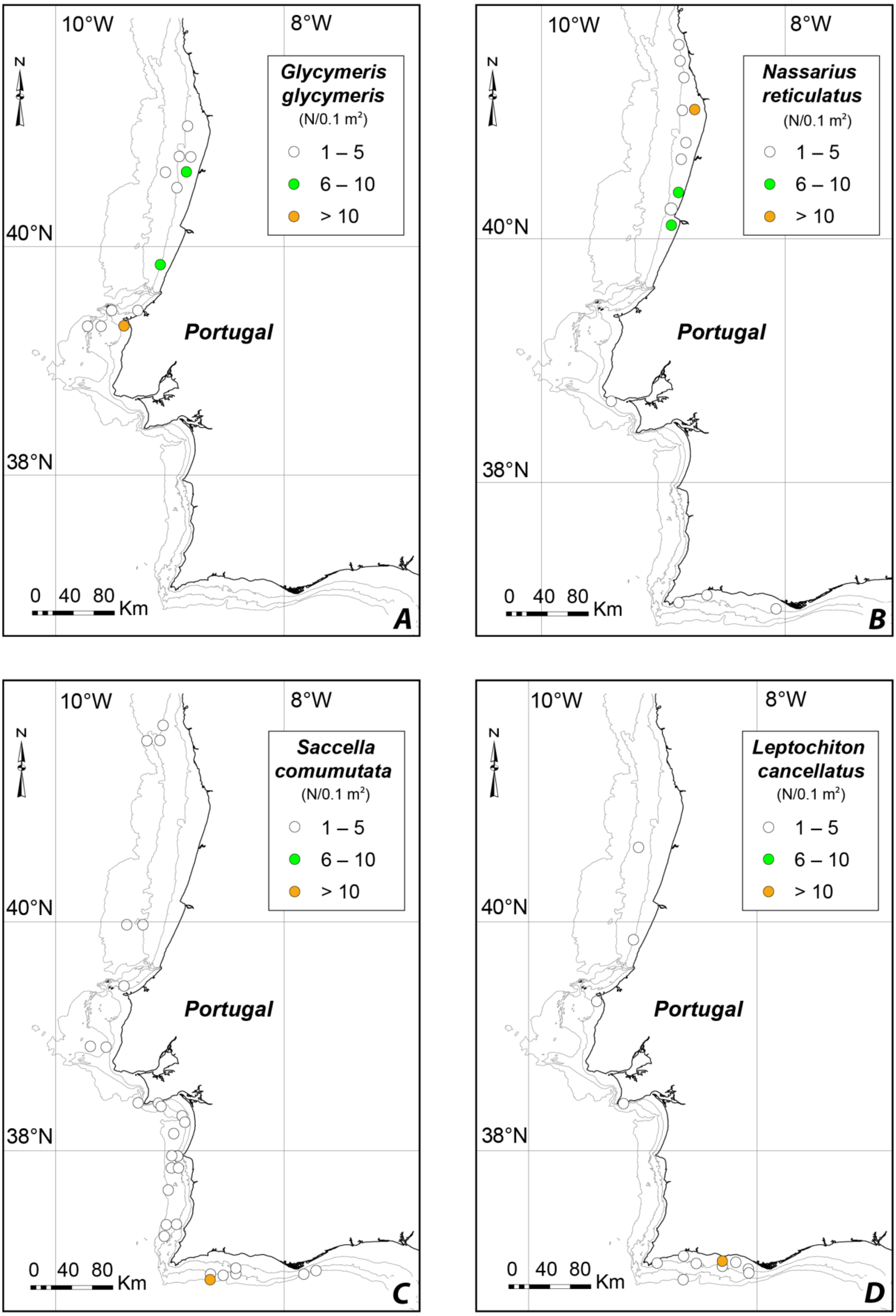


Figure 22 – Abundance spatial distribution patterns of some selected molluscs species: *Glycymeris glycymeris* (A), *Nassarius reticulatus* (B), *Saccella commutata* (C) and *Leptochiton cancellatus* (D).

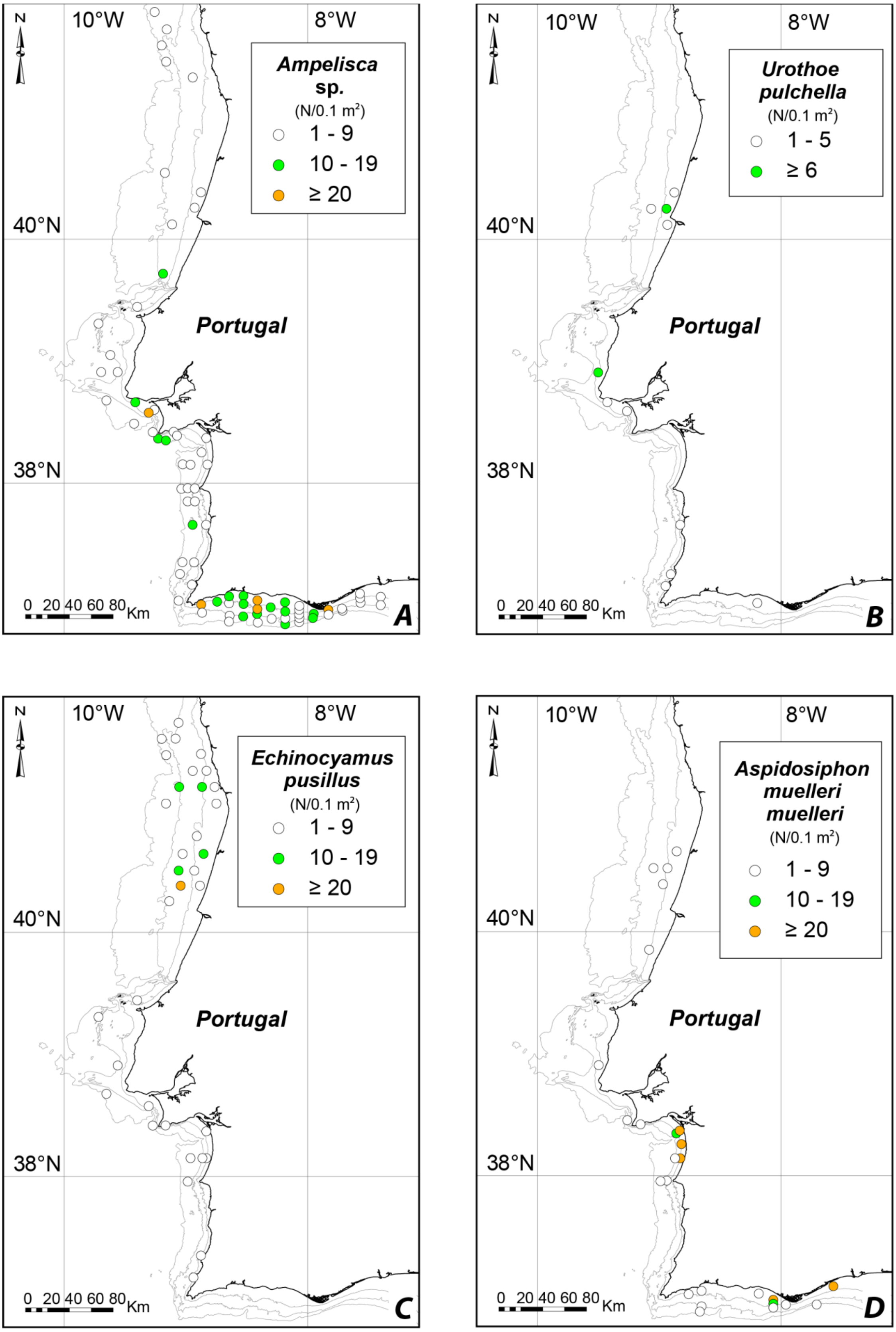


Figure 23 – Abundance spatial distribution patterns of some selected species: crustacean *Ampelisca* sp. (A), crustacean *Urothoe pulchella* (B), echinoderm *Echinocyamus pusillus* (C) and sipunculid *Aspidosiphon muelleri muelleri* (D).

3.7. Identification and characterization of benthic habitats

The multivariate analysis based on the benthic macrofauna abundance data is shown in Figure 24 and the spatial representation of the affinity groups in Figure 25. Six affinity groups were identified, A, B, C1, C2, C3 and D (Figure 24 and Figure 25). Their overall characterization is shown in Table 5 and the species succession in Table 6.

The PCO axis 1 (cf. Figure 24 – B) accounts for 13.8% of the total variation and opposes the sites of groups C2, C3 and D, and the majority of C1 to the sites of group A. The environmental variables superimposed on the analysis show that these opposing groups of sites correspond to a sedimentary partition, separating the shallower sites with high gravel and sand contents, on the negative pole, from the deeper sites with finer sediments on the positive pole of the axis. Median, gravel content, total organic matter, depth and fines content were high correlated with axis 1 (Pearson rho = 0.79, -0.66, 0.64, 0.61, and 0.52, respectively). Axis 2 gathered 8.5 % of the total variation and isolates the sites from group B and part of C1 on the positive pole. The superimposed environmental descriptors indicate that axis 2 corresponds to a partition based mainly in the hydrodynamic regime, latitude and sand content (Pearson rho = 0.50, 0.46, and 0.34 respectively). It isolates the sandy sites located in the northern exposed coast on the positive pole from sites of southern and more sheltered shelf areas. In Figure 24 – C is shown the ordination of the groups by NMDS, to which the most correlated species (Spearman rho > 0.45) were superimposed and represented as vectors. Several species were highly correlated with group A (bottom left side of Figure 24 – C), such as *Pisione remota, Glycera lapidum, Syllis pontxioi* or *Angulus pygmaeus*. The species *Magelona filiformis* and *Magelona johnstoni* were most correlated with Group B, positioned in the top left side of the representation. The species *Spiophanes bombyx* and *Prionospio fallax* were associated to the group C1 although some of these species were also common with the assemblage B. The species represented in the right side, *Labioleanira yhleni* and *Nephtys incisa* were associated to the group D, while *Ampharete finmarchica* and *Monticellina heterochaeta* were mostly associated to C2. The species *Eunice vittata* were correlated with group C3.

Group A included 31 sites, located mainly on coarse sediments of the near and mid-western shelf (Figure 25), characterized by the highest gravel content and by low content in fines and TOM (Table 5). The mean faunal abundance was highest in this group (398 ind. 0.1 m^{-2}) and the diversity measurements were high overall compared to other groups (Table 5). From a total of 440 species here sampled, 128 were exclusive or presented high fidelity (cf. Table 5). *Protodorvillea kefersteini, Pisione remota* and *Goniadella gracilis* were the most characteristic species, while the most abundant taxa were Nematoda n.i.

(53 ind. 0.1m^{-2}) and *Polygordius appendiculatus* (28 ind. 0.1 m^{-2}) and *Mediomastus fragilis* (22 ind. 0.1 m^{-2}) (Table 6).

Group B gathered 13 sites from the western near shore shelf (Figure 25). Sediments comprised predominantly fine sands, with very low fines, gravel, biogenic fraction and TOM content (Table 5). The macrofauna abundance, species richness and diversity presented here some of lowest values. The low evenness and *beta* diversity values indicate that the community was dominated by a specific set of species which did not vary greatly between sites. These characteristic species were *Magelona johnstoni, Urothoe pulchella, Spiophanes bombyx, Angulus fabula, Sigalion mathildae* and *Magelona filiformis*. The number of exclusive species was low (25 species) (cf. Table 5).

Group C1 assembled 29 sites from the northwestern outer shelf (Figure 25), mainly composed by fine and very fine sands with high content of sand and moderate content of fines, gravel, and TOM (Table 5). The mean abundance was high and the mean *alpha* diversity and total species richness were moderate, compared to other groups. All the diversity parameters in C1 were slightly lower comparing to the muddy sand groups C2 and C3 (Table 5). Some of the most characteristic species were *Tellina compressa, Prionospio fallax, Chaetozone gibber* and *Abra alba*. A total of 30 species were exclusively found in group C1 (cf. Table 5).

Group C2 included 32 sites, from deep areas (mean depth of 132.2 m; cf. Table 5) and mostly from the southwestern shelf (20 sites; Figure 25). Sediments were dominantly fine and very fine sands, with high content of sand, and moderate content of fines and TOM (Table 5). Mean abundance, mean *alpha* diversity and total species richness was moderate while diversity measurements were moderately high (cf. Table 5). Polychaetes, such as *Galathowenia oculata, Lumbrinerides amoureuxi* and *Pterolysippe vanelli*, dominated the list of the most characteristic species of this assemblage, including also the bivalve *Saccella commutata*. This group presented 47 exclusive species (cf. Table 5).

Group C3 comprised a set of 15 sites exclusively found in the southern shelf (Figure 25), composed by fine and medium sands and mud. Sand, fines, TOM and biogenic fraction content were moderate (Table 5). Mean abundance and total species richness were high. Mean *alpha* diversity and several other diversity measurements (H’, d, 1-λ’ and ES50) showed the highest values in this group (Table 5). The most characteristic species were polychaetes, namely *Euchone rubrocincta*, *Nematonereis unicornis, Panthalis oerstedi* and *Cirrophorus branchiatus* (cf. Table 5). A total of 56 species were exclusive, within the 347 sampled in C3 (cf. Table 5).

Group D corresponded to 21 sites, mostly muds (19/21), sampled in the three largest shelf mud patches: Guadiana (southeastern shelf), Tagus (off Lisbon) and immediately north of the Nazaré (northwestern shelf) (Figure 25). These sediments were characterized by very high fines content and TOM and low content of sand, gravel and biogenic fraction content (Table 5). Abundance and diversity values were very low, excluding *beta* diversity and evenness values, showing a high species turnover within the group. The most characteristic species were *Sternaspis scutata, Heteromastus filiformis* and *Psammogammarus caecus*. Nineteen species were exclusively recorded (cf. Table 5).

On the basis of the biological affinity group, the null hypothesis of no significant differences between sediments grain-size data, TOM, depth, hydrodynamic regime and latitude (cf. Table 7) were all rejected at $p < 0.0001$. Most of the pairwise comparisons between groups for grain-size, also rejected the null hypothesis at $p < 0.01$, except between groups C1 – C2 and C2 – C3, indicating that no sedimentary significant differences were found between those groups (cf. Table 8). Most pairwise comparisons also rejected the null hypothesis at $p < 0.01$ for TOM, except between A – B and C2 – C3 (cf. Table 8). According to depth, most of the pairwise comparisons also rejected the null hypothesis at $p < 0.01$, except between A – C3, B – C3 and C1 – D (cf. Table 8). Most of the pairwise comparisons, on the basis of the hydrodynamic regime also rejected the null hypothesis at $p < 0.01$, except between A – B and C3 – D (cf. Table 8). Regarding latitude, most pairwise comparisons also rejected the null hypothesis at $p < 0.01$, except between A – B and C2 – D (cf. Table 8). These results showed that grain-size, TOM, depth, hydrodynamic regime and latitude contributed to the definition of the six biological affinity groups. Group A and D differed from the others mainly due to sediments (coarse and muddy sediments, respectively). Group B was established mainly based in the sediments (fine sands with low gravel, fines and TOM content). Depth, hydrodynamics and latitude were the main factors related to groups C1 (northwestern very exposed shelf), C2 (moderately exposed, southwestern and deeper shelf) and C3 (sheltered and southern shelf) given that no significant sedimentary differences were found among the three muddy sand groups.

The global test of the BIOENV analysis showed that the combination of variables which best relates to the biological data were depth, hydrodynamic regime, grain-size median, gravel, fines and TOM content (rho = 0.554). At rho = 0.550, the set of variables also included latitude and sand content.

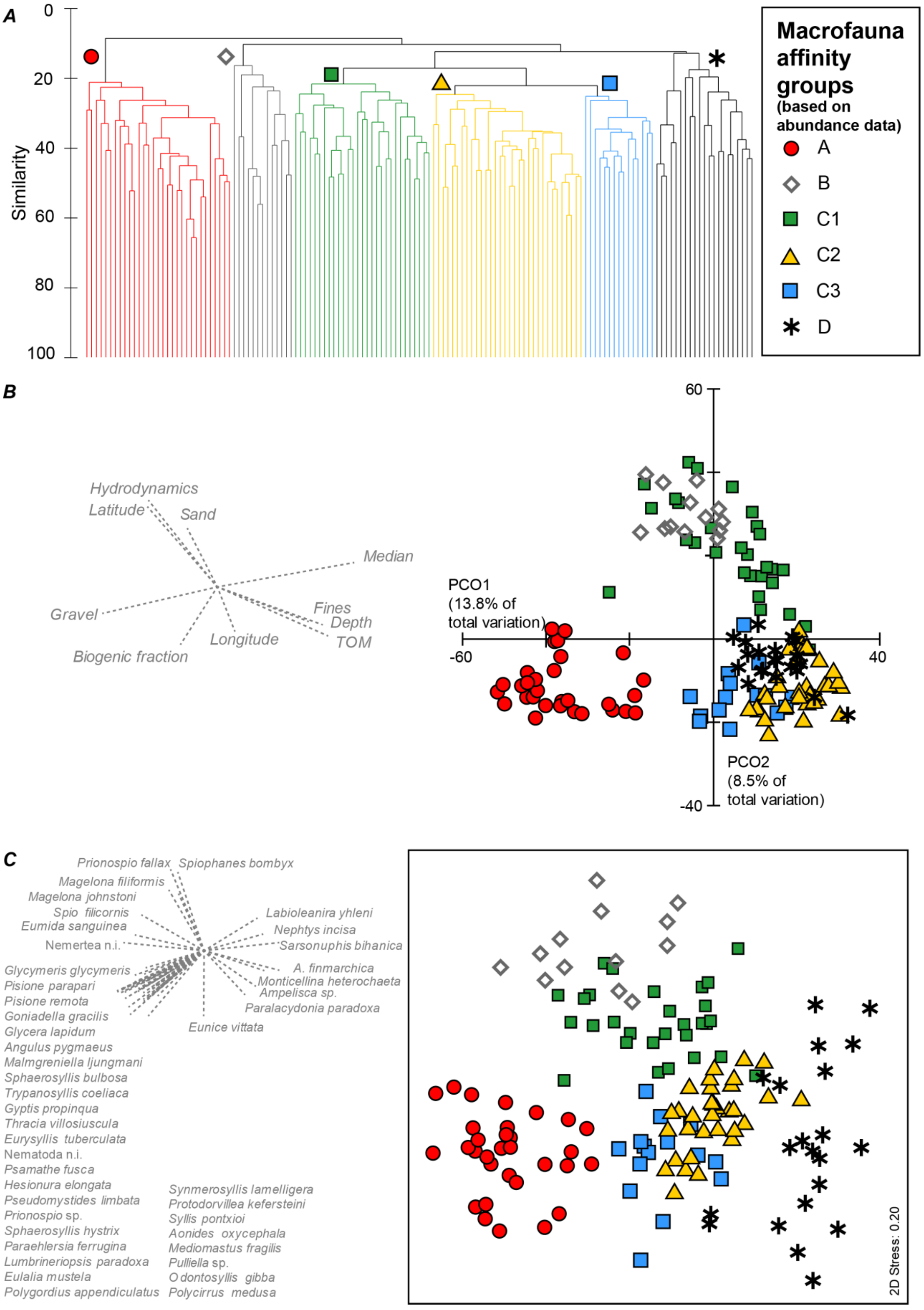


Figure 24 – Classification (A) and ordination diagrams (PCO, B; nMDS, C) based on the abundance benthic macrofauna data. Pearson correlation vectors of environmental data are provided as supplementary variables in diagram B. The species with the highest Spearman correlation (rho > 0.45) are shown in diagram C.

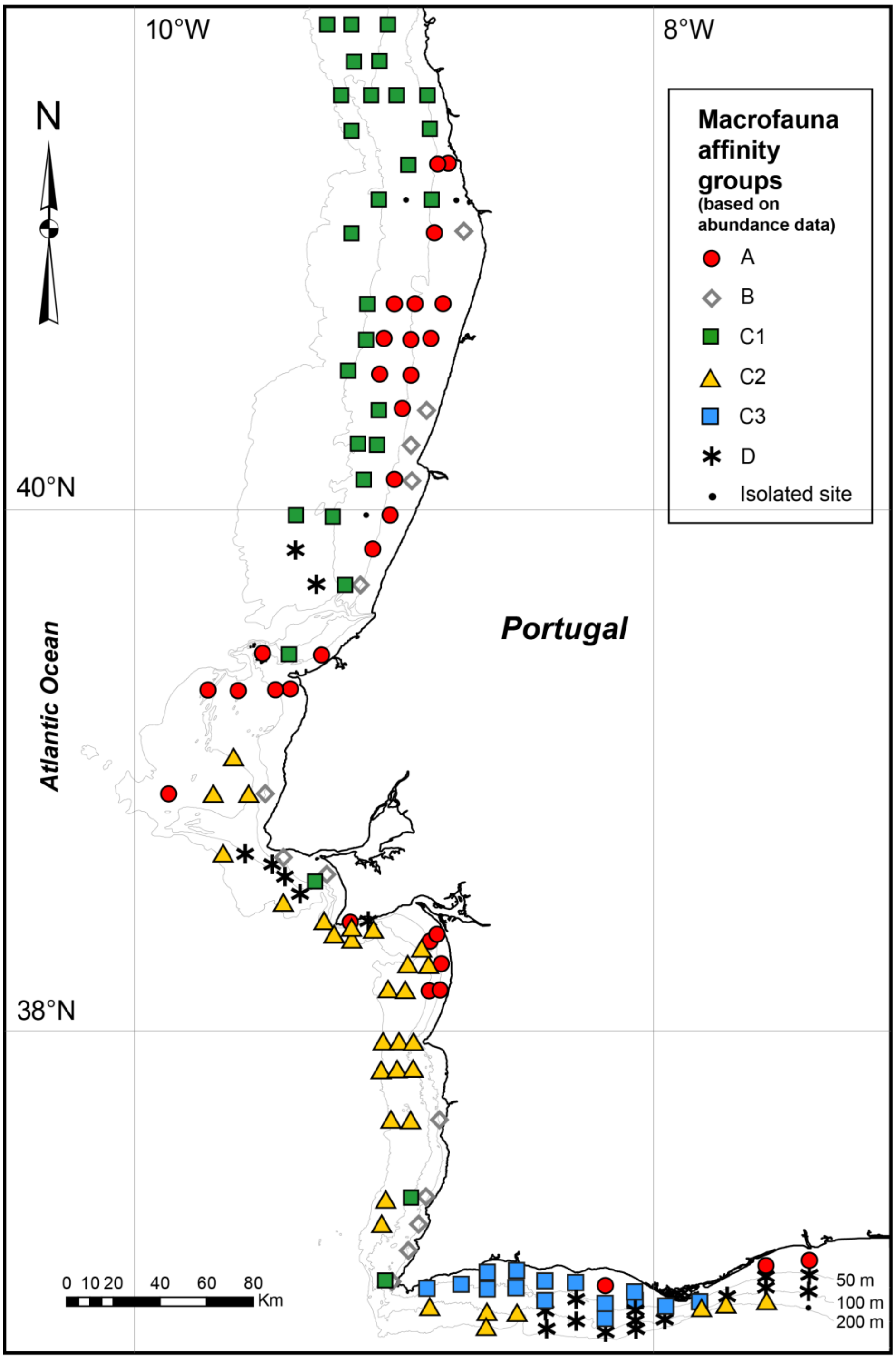


Figure 25 – Spatial distribution of the soft-bottom benthic habitats along the Portuguese continental shelf (macrofauna affinity groups obtained based on the abundance macrofauna data). A – Coarse sediments with *Protodorvillea kefersteini, Pisione remota,* and *Angulus pygmaeus*; B – Near shore hydrodynamic exposed fine sands with *Magelona johnstoni, Urothoe pulchella* and *Angulus fabula*; C1 – *Abra alba* community in northwestern deep muddy sands; C2 – *Galathowenia oculata* and *Lumbrinerides amoureuxi* in southwestern very deep muddy sands; C3 – *Euchone rubrocincta* and *Nematonereis unicornis* in muddy sands of the southern and sheltered shelf; D – Muds of *Sternaspis scutata*, *Heteromastus filiformis* and *Psammogammarus caecus.*

Table 5 – Characterization of the benthic assemblages identified in the Portuguese continental shelf. Mean values are reported to the unit sampling area (0.1 m^2). The top 15 characteristic species in each group were defined according the highest product between the constancy and fidelity indices. The 5 most abundant species were defined according the highest mean abundance (per site) among all groups. Sediment types: G = gravel, VCS = very coarse sand, CS = coarse sand, MS = medium sand, FS = fine sand, VFS = very fine sand, M = mud; TOM = Total organic matter content; Constancy: Cn = constant, C = common, O = occasional, R = rare; Fidelity: E = elective, P = preferential, I = indifferent, A = accessory; * = exclusive species in each group.

Affinity groups	**A**	**B**	**C1**	**C2**	**C3**	**D**
Nr. of sampling sites	31	13	29	32	15	21
Main sediment type	Coarse sediments	Fine sand	Muddy sands	Muddy sands	Muddy sands	Muds
Sediment types	VCS (14/31), CS (7/31), G (6/31), MS (2/31), VFS (1/31), no data (1/31)	FS (12/13), VCS (1/13)	FS (17/29), VFS (7/29), M (2/29), VCS (1/29), CS (1/29), G (1/29)	FS (15/32), MS (6/32), VFS (5/32), M (4/32), CS (1/32), no data (1/32)	FS (4/15), M (4/15), VFS (3/15), MS (2/15), VCS (1/15), maërl (1/15)	M (19/21), VFS (1/21), FS (1/21)
Gravel content (mean; %)	27.2	3.0	3.2	1.9	2.7	0.2
Sand content (mean; %)	68.8	93.8	76.8	72.1	60.5	16.6
Fines content (mean; %)	3.9	3.2	20.1	26.0	36.9	83.2
Biogenic fraction (mean; %)	4.5	0.3	0.7	2.9	4.5	1.6
TOM content (mean; %)	1.1	1.2	2.4	4.0	4.6	7.3
Depth (mean; m)	50.7	35.2	91.2	132.2	42.6	95.8
Abundance (mean)	397.7	139.7	213.4	157.6	229.1	48.4
Total species richness	440	151	294	345	347	183
Mean *alpha* diversity (ind. 0.1 m^{-2})	60.3	28.3	45.4	49.7	68.4	20.5
***Beta* diversity** (within group)	7.3	5.3	6.5	6.9	5.1	8.9
Shannon-Wiener (mean; H’)	4.5	3.6	4.5	4.8	5.2	3.7
Margalef (mean; d)	10.1	5.8	8.6	9.7	12.4	5.0
Simpson (mean; 1-λ’)	0.89	0.83	0.90	0.94	0.95	0.91
Rarefaction (mean; ES50)	22.7	18.3	23.8	25.9	28.4	18.1
Pielou’s evenness (mean; J’)	0.76	0.75	0.82	0.85	0.86	0.88
Nr. of exclusive species	128	25	30	47	56	19

Table 5 (cont.) – Characterization of the benthic assemblages identified in the Portuguese continental shelf. Mean values are reported to the unit sampling area (0.1 m2). The top 15 characteristic species in each group were defined according the highest product between the constancy and fidelity indices. The 5 most abundant species were defined according the highest mean abundance (per site) among all groups. Sediment types: G = gravel, VCS = very coarse sand, CS = coarse sand, MS = medium sand, FS = fine sand, VFS = very fine sand, M = mud; TOM = Total organic matter content; Constancy: Cn = constant, C = common, O = occasional, R = rare; Fidelity: E = elective, P = preferential, I = indifferent, A = accessory; * = exclusive species in each group.

Affinity groups	**A**	**B**	**C1**	**C2**	**C3**	**D**
Characteristic species (with Constancy and Fidelity indications)	*Protodorvillea kefersteini* (Cn/P) *Pisione remota* (Cn/E)* *Goniadella gracilis* (Cn/P) *Angulus pygmaeus* (Cn/E) *Glycera lapidum* (Cn/P) *Sphaerosyllis bulbosa* (Cn/P) *Polygordius appendiculatus* (Cn/P) *Thracia villosiuscula* (Cn/P) *Pulliella* sp. (Cn/E)* *Syllis pontxioi* (Cn/P) *Hesionura elongata* (Cn/E) *Malmgreniella ljungmani* (Cn/I) *Pisione parapari* (C/E)* *Prionospio* sp. (Cn/P) *Gyptis propinqua* (C/P)	*Magelona johnstoni* (Cn/P) *Urothoe pulchella* (Cn/P) *Spiophanes bombyx* (Cn/I) *Angulus fabula* (Cn/P) *Sigalion mathildae* (Cn/P) *Magelona filiformis* (Cn/I) *Hippomedon denticulatus* (C/P) *Megaluropus agilis* (C/P) *Leucothoe incisa* (C/P) *Pharus legumen* (C/E)* *Glycera convoluta* (C/P) *Prionospio fallax* (Cn/I) *S. typicus* (C/I) *Chaetozone carpenteri* (C/I) *Bathyporeia elegans* (O/I)	*Tellina compressa (Cn/I)* *Prionospio fallax* (Cn/I) *Chaetozone gibber* (C/P) *Phaxas pellucidus* (C/I) *Spiophanes bombyx* (Cn/I) *Thyasira flexuosa* (Cn/I) *Pionospio aluta* (C/E)* *Abra alba* (Cn/I) *Aricidea pseudoarticulata* (C/I) *Aricidea catherinae* (C/I) *Phyllodoce rosea* (O/E)* *Pseudopolydora antennata* (Cn/I) *Poecilochaetus serpens* (Cn/I) *Spio filicornis* (Cn/I) *Nephtys hombergii* (C/I)	*Galathowenia oculata* (Cn/I) *Lumbrinerides amoureuxi* (C/E)* *Saccella commutata* (Cn/I) *Paralacydonia paradoxa* (Cn/I) *Pterolysippe vanelli* (Cn/I) *Sarsonuphis bihanica* (Cn/I) *Aphelochaeta* sp.1 (Cn/I) *Monticellina heterochaeta* (Cn/I) Aplacophora sp.1 (C/P) *Isolda pulchella* (C/I) *Eunice vittata* (Cn/I) *Terebellides stroemii* (Cn/I) *Ampharete finmarchica* (Cn/A) *Chirimia biceps* (C/I) *Leiocapitella dollfusi* (O/P)	*Euchone rubrocincta* (Cn/P) *Nematonereis unicornis* (Cn/P) *Prionospio multibranchiata* (Cn/P) *Panthalis oerstedi* (Cn/P) *Cirrophorus branchiatus* (Cn/P) *Lumbrineris pinaster* (Cn/I) *Lygdamis muratus* (Cn/I) *Paralacydonia paradoxa* (Cn/I) *Eunice vittata* (Cn/I) *Schistomeringos rudolphi* (C/E)* *Parapionosyllis brevicirra* (Cn/P) *Harmothoe antilopes* (Cn/P) *Polydora flava* (Cn/I) *Notomastus latericeus* (Cn/I)	*Sternaspis scutata* (C/E) *Heteromastus filiformis* (C/P) *Psammogammarus caecus* (C/I) *Sarsonuphis bihanica* (Cn/I) *Nephtys incisa* (C/I) *Ampharete finmarchica* (Cn/A) *Harpinia antennaria* (C/I) *Chaetozone* sp.2 (C/A) *Ninoe armoricana* (C/I) *Glycera unicornis* (Cn/A) *Ampelisca* sp. (Cn/A) *Labioleanira yhleni* (C/I) *Athanas nitescens* (O/P) *Alpheus* cf. *glaber* (O/P) *Paraprionospio pinnata* (C/A)
Most abundant species	Nematoda n.i. *Polygordius appendiculatus* *Mediomastus fragilis* *Protodorvillea kefersteini* *Spio filicornis*	*Magelona johnstoni* *Chaetozone carpenteri* *Edwardsia claparedii* *Magelona filiformis* *Glycera convoluta*	Nemertea n.i. *Prionospio fallax* *Caulleriella alata* *Aponuphis grubii* *Spiophanes bombyx*	*Ampharete finmarchica* *Pterolysippe. vanelli* *Sarsonuphis bihanica* *Monticellina heterochaeta* *Galathowenia oculata*	*Ampelisca* sp. *Eunice vittata* *Paralacydonia paradoxa* *Notomastus latericeus* *Lumbrineris lusitanica*	*Nephtys incisa* *Heteromastus filiformis* *Harpinia antennaria* Sipuncula n.i. *Labioleanira yhleni*

Table 6 – Mean species abundance (ind./0.1 m^2) per affinity group. The 20 species with the highest mean abundance per group are listed (light grey). The 5 exclusive species with the highest abundance in the groups are also highlighted (dark grey). * = mean abundance below 0.05 ind/ 0.1 m^{-2}.

Taxa	A	B	C1	C2	C3	D
Pisione remota (Southern, 1914)	9.9					
Pisione parapari Moreira, Quintas and Troncoso, 2000	6.5					
Pulliela sp.	2.5					
Caecum sp.	2.5					
Limatula subovata (Monterosato, 1875)	1.8					
Nematoda n.i.	53.1	0.2	0.8	0.6	1.2	0.1
Polygordius appendiculatus Fraipont, 1887	28.1		0.3	0.2	0.1	
Mediomastus fragilis Rasmussen, 1973	22.2	0.9	7.4	0.7	1.5	0.3
Protodorvillea kefersteini (McIntosh, 1869)	17.6		0.3	0.1		
Spio filicornis (Müller, 1776)	15.3	0.8	2.5	0.1		
Aspidosiphon (Aspidosiphon) muelleri muelleri Diesing, 1851	13.7	0.2		0.3	2.8	0.3
Oligochaeta n.i.	12.5		2.9	0.6	1.1	0.1
Sphaerosyllis bulbosa Southern, 1914	9.3		0.1		1.1	*
Aonides oxycephala (Sars, 1862)	7.2		0.1	0.1	0.7	
Malmgreniella ljungmani (Malmgren, 1867)	6.8				0.9	*
Glycera lapidum Quatrefages, 1865	6.3		0.3	0.1	0.1	
Goniadella gracilis Verril, 1873	4.7		0.4	*		
Aponuphis bilineata (Baird, 1870)	4.5	3.2	1.2	3.2	1.2	*
Thracia villosiuscula (MacGillivray, 1827)	4.4	0.2	*		0.2	
Gyptis propinqua Marion, 1875	4.1				0.1	
Psamathe fusca Johnston, 1836	3.8		0.2	0.1	0.1	
Pseudomystides limbata Sain-Joseph, 1888	3.4			0.1	0.1	
Hesionura elongata (Southern, 1914)	3.3		*			
Trypanosyllis coeliaca Claparède, 1868	3.1		*		0.3	*
Angulus pygmaeus (Lovén, 1846)	3.0			*		
Diogenes pugilator (Roux, 1829)		0.5				
Mactra sp.		0.3				
Pharus legumen (Linnaeus, 1758)		0.3				
Diopatra micrura Pires, Paxton, Quintino and Rodrigues, 2010		0.2				
Pontocrates altamarinus (Bate and Westwood, 1862)		0.2				
Magelona johnstoni Fiege, Licher and Mackie, 2000	*	29.6	1.4			
Chaetozone carpenteri McIntosh, 1911	0.3	23.8	0.9	0.1	0.2	0.2
Edwardsia claparedii (Panceri, 1869)	0.1	4.8	0.5	*	0.1	0.1
Magelona filiformis Wilson, 1959	*	4.5	1.6			
Glycera convoluta Keferstein, 1862		3.5	0.4			
Urothoe pulchella (Costa, 1853)		2.1	0.1		0.1	
Sigalion mathildae Audouin and Milne Edwards in Cuvier, 1830	0.1	1.6	0.1	0.1		
Nassarius reticulatus (Linnaeus, 1758)	0.2	1.4	0.1		0.2	
Spisula subtruncata (da Costa, 1778)	*	1.2	0.6		0.2	
Scoloplos typicus (Eisig, 1914)	0.1	0.8	0.2		0.1	*
Megaluropus agilis Hoeck, 1889		0.7			0.1	
Anthozoa n.i.		0.7	*	*	0.1	
Angulus fabula (Gmelin, 1791)		0.7	0.6	*		
Hippomedon denticulatus (Bate, 1857)	0.1	0.6		*		*
Leucothoe incisa (Robertson, 1892)	0.3	0.6	*			
Urothoe grimaldii Chevreux, 1895		0.5	*			
Nephtys cirrosa (Ehlers, 1868)	0.1	0.5			0.4	*
Tellimya ferruginosa (Montagu, 1808)	0.1	0.5	0.3	0.1		0.1
Podarkeopsis capensis (Day 1963)	0.1	0.4	0.2	*	0.1	*
Venus casina Linnaeus, 1758	0.1	0.4	*			

(cont).

Table 6 (cont.) – Mean species abundance (ind./0.1 m^2) per affinity group. The 20 species with the highest mean abundance per group are listed (light grey). The 5 exclusive species with the highest abundance in the groups are also highlighted (dark grey). * = mean abundance below 0.05 ind/ 0.1 m^{-2}.

Taxa	A	B	C1	C2	C3	D
Prionospio aluta Maciolek, 1985			1.9			
Melinna cristata (M. Sars, 1851)			0.7			
Phyllodoce rosea McIntosh, 1877			0.7			
Aricidea simonae Laubier and Ramos, 1974			0.1			
Chaetozone sp.1			0.1			
Nemertea n.i.	16.6	10.8	25.4	2.9	6.4	1.3
Prionospio fallax Söderström, 1920	1.8	6.1	18.4	0.4	0.2	
Caulleriella alata (Southern, 1914)	0.5		7.0	0.1	0.8	
Aponuphis grubii (Marenzeller, 1886)		1.4	6.4	0.1	2.5	
Spiophanes bombyx (Claparède, 1870)	0.7	5.5	5.7	0.1	0.1	0.1
Lagis koreni Malmgren, 1866	0.1	0.5	4.1	0.1	0.2	
Thyasira flexuosa (Montagu, 1803)	*		4.0	0.3	0.1	0.1
Spiophanes kroyeri Grube, 1860	0.3	1.9	3.6	1.6	0.7	0.2
Prionospio ehlersi Fauvel, 1928		0.3	3.6	0.3	0.1	0.2
Echinocyamus pusillus (O.F. Müller, 1776)	1.7	0.5	3.3	0.2		
Abra alba (W. Wood, 1802)	0.3	3.1	3.1	0.1	0.3	0.1
Prionospio steenstrupi Malmgren, 1867		0.2	3.1	0.7	0.1	0.1
Myriochele danielsseni Hansen, 1878	0.4		2.7	1.3	0.5	
Tellina compressa Brocchi, 1814			2.2	0.8	0.1	0.1
Nephtys hombergii Savigny in Lamarck, 1818		0.1	2.2	0.6	0.5	*
Owenia fusiformis delle Chiaje, 1844	0.1		2.1	0.1	1.3	
Corbula gibba (Olivi, 1792)	0.7	0.2	2.1	0.2	1.3	0.3
Nephtys kersivalensis McIntosh, 1908	0.8	0.6	1.9	0.6	0.9	
Aricidea (Allia) roberti Hartley, 1984	0.2	0.2	1.7	0.4	0.1	0.1
Aricidea (Aricidea) pseudoarticulata Hobson, 1972			1.7	0.2	0.1	
Kurtiella bidentata (Montagu, 1803)	0.9		1.7		0.9	*
Lumbrinerides amoureuxi Miura, 1981				0.9		
Bathyarca pectunculoides (Scacchi, 1835)				0.3		
Ebalia nux A. Milne-Edwards, 1883				0.2		
Ringicula auriculata (Ménard de la Groye, 1811)				0.2		
Yoldiella philippiana (Nyst, 1845)				0.2		
Ampharete finmarchica (M. Sars, 1864)	0.6	0.3	2.6	16.2	8.0	3.1
Pterolysippe vanelli (Fauvel, 1936) sensu Eliason, 1955, emend	0.1	0.1	1.2	7.8	1.3	
Sarsonuphis bihanica (Intes and le Loeuff, 1975)	*		0.7	7.7	5.9	2.5
Monticellina heterochaeta Laubier, 1961	1.5		0.7	7.1	1.0	1.9
Galathowenia oculata (Zachs, 1923)	0.2	0.3	3.6	6.3	0.8	0.4
Isolda pulchella Müller in Grube, 1858			0.7	4.2	1.0	
Pseudopolydora antennata (Claparède, 1869)		0.1	2.7	3.1		*
Terebellides stroemii Sars, 1835	0.5		0.6	2.9	0.7	0.2
Chirimia biceps (M. Sars, 1861)			*	2.8	0.1	1.0
Aphelochaeta sp.1	0.2		0.9	2.3	0.2	0.1
Potamilla torelli (Malmgren, 1866)	0.4		0.4	1.7	0.8	
Onchnesoma steenstrupii steenstrupii Koren and Danielssen, 1876	*		0.1	1.7	0.6	0.2
Saccella commutata (Philippi, 1844)			0.4	1.6	0.1	0.1
Paraprionospio pinnata (Ehlers, 1901)	0.1	0.1	0.5	1.2	1.1	0.6
Golfingia (Golfingia) elongata (Keferstein, 1862a)	0.3	0.4	0.7	1.0	0.1	0.3
Ophiura albida Forbes, 1839	0.5	0.7	0.4	1.0		0.8
Magelona wilsoni Glémarec, 1966			0.1	0.9	0.3	*
Aplacophora sp.1	0.1		0.1	0.9		*
Phyllodoce maculata (Linnaeus, 1767)	0.1	0.1		0.7	0.1	
Glycera alba (O.F. Müller, 1776)	0.1		0.6	0.7	0.2	

(cont).

Table 6 (cont.) – Mean species abundance (ind./0.1 m^2) per affinity group. The 20 species with the highest mean abundance per group are listed (light grey). The 5 exclusive species with the highest abundance in the groups are also highlighted (dark grey). * = mean abundance below 0.05 ind/ 0.1 m^{-2}.

Taxa	A	B	C1	C2	C3	D
Microdeutopus versiculatus (Bate, 1856)					0.9	
Cirolana cranchi Leach, 1818					0.9	
Schistomeringos rudolphii (delle Chiaje, 1828)					0.7	
Lumbrineris sp.					0.7	
Paradoneis armata Glemarec, 1966					0.7	
Ampelisca sp.	1.0	1.5	2.3	3.7	13.3	5.5
Eunice vittata (Delle Chiaje, 1828)	2.2	0.1	0.1	5.8	12.6	0.2
Paralacydonia paradoxa Fauvel, 1913	0.1		0.2	6.2	11.5	0.8
Notomastus latericeus Sars, 1851	1.8	0.2	0.6	1.2	9.8	0.1
Lumbrineris lusitanica (Martins, Carrera-Parra, Quintino and Rodrigues, 2012)	1.1	0.9	5.8	1.3	7.3	0.2
Lumbrineris pinaster (Martins, Carrera-Parra, Quintino and Rodrigues, 2012)	0.4	0.3	*	0.2	5.7	1.0
Lygdamis muratus (Allen, 1904)	0.4	0.4	0.3	0.1	5.1	
Phoronida n.i.	0.1	0.7	2.9	0.5	4.6	0.4
Syllis garciai (Campoy, 1982)	3.8			0.3	4.3	0.7
Parapionosyllis brevicirra San Martin, 1984	0.1			0.2	3.6	0.3
Magelona alleni Wilson, 1958		0.3	2.0	*	3.1	0.1
Apseudes sp. 2	1.1			0.1	2.7	0.9
Prionospio multibranchiata Berkeley, 1927	*		0.6	1.2	2.7	0.1
Euchone rubrocincta (Sars, 1862)	0.4			*	2.5	
Aponuphis brementi (Fauvel, 1916)			1.3	1.7	2.4	*
Syllis mercedesae Lucas, San Martín, Parapar, 2012	0.7			0.3	2.4	0.2
Euclymene cf. *droebachiensis* (M. Sars in G.O. Sars, 1871)	0.5	0.1	0.3	0.2	2.2	0.1
Paramphitrite tetrabranchia Holthe, 1976	0.3		0.2	0.5	2.1	
Jasmineira elegans Saint-Joseph, 1894	1.3		1.5	1.1	1.9	
Paradoneis lyra (Southern, 1914)	1.4		0.9	0.5	1.9	0.2
Ecrobia truncata (Vanatta, 1924)						0.3
Ericthonius punctatus (Bate, 1857)						0.2
Gammarella fucicola (Leach, 1814)						0.1
Megamphopus brevidactylus Myers, 1976						0.1
Nassarius ovoideus (Locard, 1886)						0.1
Nephtys incisa Malmgren, 1865			*	0.9	0.1	1.5
Heteromastus filiformis (Claparède, 1864)				*	0.4	1.2
Harpinia antennaria Meinert, 1890	*		0.1	0.5	0.2	1.0
Sipuncula n.i.	0.1		0.1	0.2	0.3	0.9
Labioleanira yhleni (Malmgren, 1867)		0.1	0.5	0.5	0.1	0.9
Glycera unicornis Savigny in Lamarck, 1818	*	0.4	0.3	0.6	0.7	0.8
Sternaspis scutata Ranzani, 1817			0.2			0.7
Ninoe armoricana (Glémarec, 1968)			0.1	0.1	0.1	0.6
Psammogammarus caecus Karaman, 1955	0.5			*		0.6
Monticellina sp.	0.1		0.2	0.3		0.3
Athanas nitescens (Leach, 1813 [in Leach, 1813-1814])					0.1	0.3
Nassarius elatus (Gould, 1845)				0.1		0.3
Medicorophium minimum (Schiecke, 1978)	*				0.1	0.2
Goneplax rhomboides (Linnaeus, 1758)					0.1	0.1
Alpheus cf. *glaber* (Olivi, 1792)				*		0.1
Echinocardium cordatum (Pennant, 1777)	0.1			0.1		0.1
Hydrobia acuta neglecta Muus, 1963	*				0.1	0.1
Leptopentacta cf. *tergestina* (M. Sars, 1857)				*		*
Astarte sulcata (da Costa, 1778)	*					*
Ophiodromus flexuosus (Delle Chiaje, 1827)			*			*

Table 7 – Results of PERMANOVA main test between biological affinity groups based on median grain-size, gravel, sand and fines content.

Descriptor	Source	df	SS	MS	Pseudo-F	*p*
Median grain-size	Affinity groups	5	312.60	62.52	34.20	0.0001
	Residual	135	246.83	1.83		
	Total	140	559.43			
TOM	Affinity groups	5	97.04	19.41	59.45	0.0001
	Residual	135	44.08	0.33		
	Total	140	141.11			
Depth	Affinity groups	5	91.34	18.28	50.91	0.0001
	Residual	135	48.46	0.36		
	Total	140	139.84			
Hydrodynamic regime	Affinity groups	5	80.65	16.13	37.91	0.0001
	Residual	135	57.44	0.43		
	Total	140	138.08			
Latitude	Affinity groups	5	81.22	16.24	38.73	0.0001
	Residual	135	56.62	0.42		
	Total	140	137.84			

Table 8 – Values for the *t*-statistic and associated significance in the pair-wise tests between biological affinity groups, for the environmental descriptors that rejected the main test null hypothesis (sediments grain-size, TOM, depth, hydrodynamic regime and latitude). Significance values: * p < 0.05; ** p < 0.01; (ns) = non-significant.

	Sediments	*TOM*	*Depth*	*Hydrodynamics*	*Latitude*
A *vs.* B	4.1817**	0.4025(ns)	2.1417*	0.3210(ns)	1.7202(ns)
A *vs.* C1	5.3302**	4.5023**	6.1347**	3.2421**	3.3441**
A *vs.* C2	6.1310**	8.6952**	11.6360**	4.5986**	6.3887**
A vs. C3	4.5289**	6.9202**	1.1466(ns)	7.0822**	7.6299**
A *vs.* D	9.9024**	15.8890**	5.9509**	5.3580**	5.8049**
B *vs.* C1	1.9046*	3.4013**	7.2587**	4.0395**	4.2125**
B *vs.* C2	3.2392**	6.5440**	11.0450**	4.0450**	2.8608**
B *vs.* C3	3.4122**	5.2155**	1.3486(ns)	7.6771**	4.8841**
B *vs.* D	12.0920**	12.3410**	6.9635**	4.3839**	2.8425**
C1 *vs.* C2	0.9449(ns)	4.0648**	5.5955**	11.8080**	10.6720**
C1 *vs.* C3	1.8012*	3.6766**	6.4984**	17.0840**	11.0090**
C1 *vs.* D	8.5599**	11.4200**	0.5783(ns)	10.3190**	9.0519**
C2 *vs.* C3	1.4443(ns)	0.8770(ns)	10.6560**	5.6638**	5.2361**
C2 *vs.* D	9.7996**	7.8846**	4.3022**	2.6076*	1.3224(ns)
C3 *vs.* D	5.5861**	4.6567**	6.2869**	1.5441(ns)	2.2740*

3.8. Case studies of the shelf diversity

3.8.1. Diversity of the Family Lumbrineridae

Herein, it is presented the diversity of the Family Lumbrineridae in the Portuguese shelf and the description of three new species belonging to the genus *Lumbrineris* and one new species of *Gallardoneris*, which is also the first record of this genus in the Atlantic Ocean. A taxonomic key to lumbrinerid species from Iberian waters is included. A total of 1943 lumbrinerids were recorded from 222 sampling sites along the Portuguese continental shelf within various projects (Acoshelf and MeshAtlantic). The diversity of lumbrinerids in the study area includes the species *Abyssoninoe hibernica, Gallardoneris iberica* **sp. nov.**, *Lumbrinerides amoureuxi*, *Lumbrineriopsis paradoxa*, *Lumbrineris futilis*, *Lumbrineris latreilli*, *Lumbrineris luciliae* **sp. nov.**, *Lumbrineris lusitanica* **sp. nov.**, *Lumbrineris pinaster* **sp. nov.**, *Lumbrineris* sp., *Ninoe armoricana, Scoletoma fragilis*, *Scoletoma* sp. 1 and *Scoletoma* sp. 2. A comparison of morphological descriptors and intraspecific variability of the most important morphological features measured in all species recorded in the studied area is reported in Table 9. A systematization of the environmental characteristics of the sampling sites where Lumbrineridae species were sampled is presented in Table 10.

The contents of this subchapter are published in Zootaxa as Martins, R., Carrera-Parra, L.F., Quintino, V., Rodrigues, A.M. (2012b) Lumbrineridae (Polychaeta) from the Portuguese continental shelf (NE Atlantic) with the description of four new species. *Zootaxa*, 3416, 1–21.

Systematics

Class Polychaeta Grube, 1850

Family Lumbrineridae Schmarda, 1861

Genus *Gallardoneris* Carrera-Parra, 2006

***Gallardoneris iberica* sp. nov.**

Figure 26

Material examined. *Type material*: Holotype (MNHN TYPE 1538) northwestern Portuguese continental shelf, site MESH 3B, 39º48.584′ N 9º13.773′ W, June 2010, in fine sand, 100.5 m. *Paratypes*: MB29–000226, 1 specimen, same data as holotype. DBUA 01315.01, 1 specimen, same data as holotype. ECOSUR0128, 1 specimen, site PC128. MB29–000227, 1 specimen, site MESH 2E. MB29–000228, 2 specimens, site MESH 7E. DBUA 01315.02, 1 specimen, site MESH 7E. *Additional material*: see Martins et al. (2012b).

Description. Holotype complete, with 101 chaetigers, LT=16.0 mm, W10=0.3 mm, L10=1.7 mm. Prostomium conical, slightly longer than wide, with a pair of nuchal organs, ventrally with short buccal lips. Peristomium about 2/3 of the prostomium length, with two rings of similar size (Figure 26–A). All parapodia well developed, first six smaller than following ones. Prechaetal lobe in parapodia 1–5 inconspicuous, in parapodia 6–14 ovoid, from parapodium 15 digitiform; smaller than postchaetal lobe in anterior parapodia, of similar size in median parapodia (15–81), longer than postchaetal from parapodium 82. Postchaetal lobe in parapodia 1–18 auricular, from parapodium 19 digitiform (Figure 26–B–D). Short rounded dorsal cirri in all parapodia. Composite multidentate hooded hooks (CMHH) in chaetigers 1–7, with 2–3 per parapodium, with short blade, with up to 7 teeth, proximal tooth largest (Figure 26–E). Simple multidentate hooded hooks from chaetiger 8, with short hood, with up to 7 teeth, proximal tooth largest, preacicular hook as large as postacicular hook (Figure 26–F). Dorsal limbate chaetae in chaetigers 1–26, ventral limbates in chaetigers 1–7. Aciculae yellow, aristate, one in anterior parapodia and up to two in posterior parapodia. Pygidium with terminal anus, without anal cirri. Mandible completely fused. Maxillary apparatus with four pairs of maxillae; maxillary carriers as long as MI, almost triangular, joined along base of MI (Figure 26–G). MI forceps-like with wide recurved base, without attachment lamella. MII stout, as long as MI, with ligament, with three teeth, without attachment lamella. MIII edentate (Figure 26–H). MIV edentate plate, with whitish central area (Figure 26–I).

Variations. Material examined varied in L10 from 1.2 to 2.3 mm, in W10 from 0.2 to 0.5 mm and also varied in the following features: the last composite multidentate hooded hooks were found from chaetigers 6 to 9; the first simple multidentate hooded hooks appeared from chaetigers 7 to 10; the end of dorsal and ventral limbate ranged from chaetigers 25 to 35 and from 7 to 13 respectively (cf. Table 9).

Reproduction. Mature specimens were found in June and October. The female gametes are globular with a diameter ranging from 129 µm to 188 µm. The gametes were located from parapodia 23 until last segment in incomplete specimens examined (Paratypes DBUA 01315.01, MB29–000226). The male gametes of *Gallardoneris iberica* **sp. nov.** are located posteriorly to chaetiger 18 in an incomplete specimen (Paratype MB29–000227). The male gametes have a long tail and a subspherical nucleus with diameter between 2.3 and 3.0 µm.

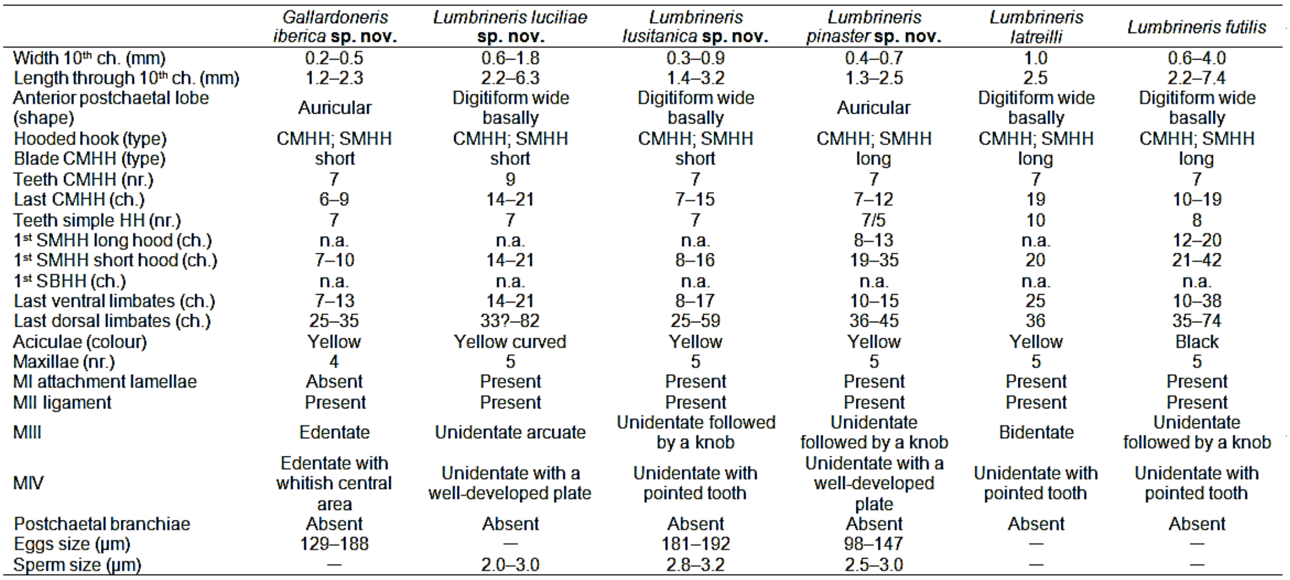
Type locality. Portuguese continental shelf.

Etymology. The name of the species refers to the type locality, the Iberian Peninsula.

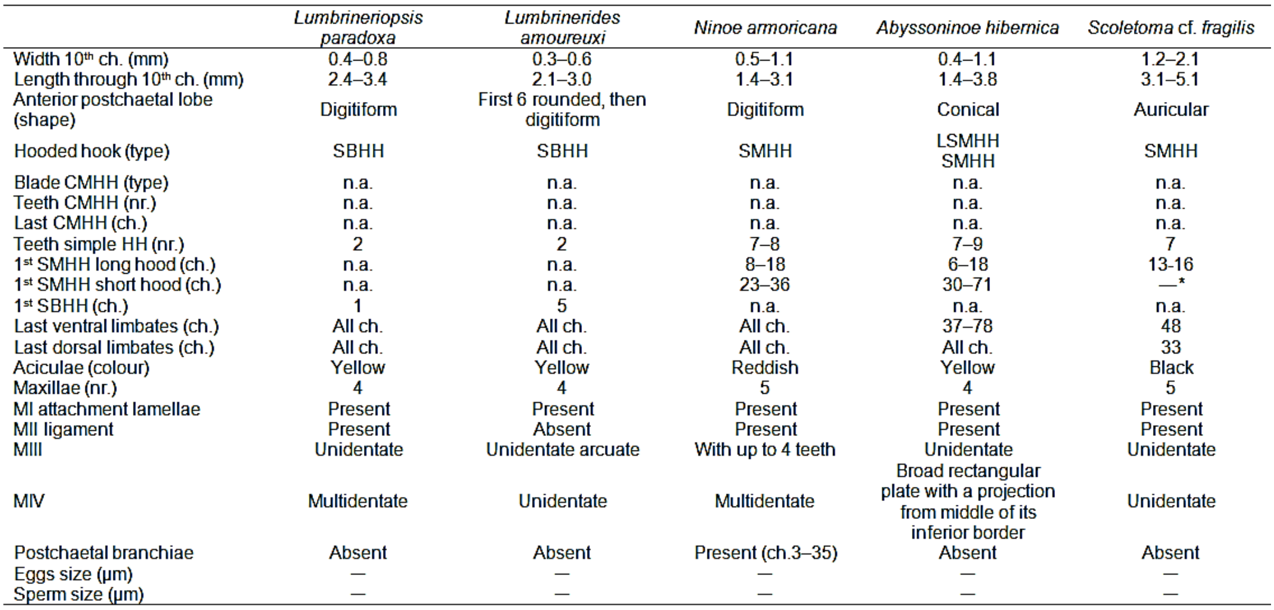
Distribution and habitat. *Gallardoneris iberica* **sp. nov.** was found in the Portuguese continental shelf at depths ranging from 18 to 180 m (cf. Table 10). The specimens inhabit mainly finer sediments with high content of fines, biogenic fraction and TOM (Table 10). Highest abundances were found in the southern shelf sites (Figure 20–A). The Galician shelf and the Gulf of Cádiz shelf (northwestern and southern Iberia) present extensive mud patches being a continuity of the muddy areas recorded in the shelf off the rivers Minho and Guadiana (Dias et al., 2002; Gonzalez et al., 2004; Martins et al., 2012a). These sediments seem to be preferred by this species and therefore it is expected to be found in those shelf areas.

Remarks. *Gallardoneris iberica* **sp. nov.** is the first record of this genus in the Atlantic Ocean and can be distinguished from the other two known *Gallardoneris* species by the distribution of the CMHH and the SMHH and the shape of the parapodial lobes.

Table 9 – Comparison of morphological descriptors and intraspecific variability of the morphological characters assessed on species found in the Portuguese continental shelf.Legend: nr. = number; ch. = chaetiger; all ch. = feature present in all chaetigers; CMHH = composite multidentate hooded hooks; SMHH = simple multidentate hooded hooks; SBHH = simple bidentate hooded hooks; LSMHH = limbated simple multidentate hooded hooks; * — incomplete specimens. n.a. = not applicable; “—” = no available data.



	Gallardoneris iberica **sp. nov.**	*Lumbrineris luciliae* **sp. nov.**	*Lumbrineris lusitanica* **sp. nov.**	*Lumbrineris pinaster* **sp. nov.**	*Lumbrineris latreilli*	*Lumbrineris futilis*
Width 10th ch. (mm)	0.2–0.5	0.6–1.8	0.3–0.9	0.4–0.7	1.0	0.6–4.0
Length through 10th ch. (mm)	1.2–2.3	2.2–6.3	1.4–3.2	1.3–2.5	2.5	2.2–7.4
Anterior postchaetal lobe (shape)	Auricular	Digitiform wide basally	Digitiform wide basally	Auricular	Digitiform wide basally	Digitiform wide basally
Hooded hook (type)	CMHH; SMHH	CMHH; SMHH	CMHH; SMHH	CMHH; SMHH	CMHH; SMHH	CMHH; SMHH
Blade CMHH (type)	short	short	short	long	long	long
Teeth CMHH (nr.)	7	9	7	7	7	7
Last CMHH (ch.)	6–9	14–21	7–15	7–12	19	10–19
Teeth simple HH (nr.)	7	7	7	7/5	10	8
1st SMHH long hood (ch.)	n.a.	n.a.	n.a.	8–13	n.a.	12–20
1st SMHH short hood (ch.)	7–10	14–21	8–16	19–35	20	21–42
1st SBHH (ch.)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Last ventral limbates (ch.)	7–13	14–21	8–17	10–15	25	10–38
Last dorsal limbates (ch.)	25–35	33?–82	25–59	36–45	36	35–74
Aciculae (colour)	Yellow	Yellow curved	Yellow	Yellow	Yellow	Black
Maxillae (nr.)	4	5	5	5	5	5
MI attachment lamellae	Absent	Present	Present	Present	Present	Present
MII ligament	Present	Present	Present	Present	Present	Present
MIII	Edentate	Unidentate arcuate	Unidentate followed by a knob	Unidentate followed by a knob	Bidentate	Unidentate followed by a knob
MIV	Edentate with whitish central area	Unidentate with a well-developed plate	Unidentate with pointed tooth	Unidentate with a well-developed plate	Unidentate with pointed tooth	Unidentate with pointed tooth
Postchaetal branchiae	Absent	Absent	Absent	Absent	Absent	Absent
Eggs size (μm)	129–188	—	181–192	98–147	—	—
Sperm size (μm)	—	2.0–3.0	2.8–3.2	2.5–3.0	—	—



	Lumbrineriopsis paradoxa	*Lumbrinerides amoureuxi*	*Ninoe armoricana*	*Abyssoninoe hibernica*	*Scoletoma* cf. *fragilis*
Width 10th ch. (mm)	0.4–0.8	0.3–0.6	0.5–1.1	0.4–1.1	1.2–2.1
Length through 10th ch. (mm)	2.4–3.4	2.1–3.0	1.4–3.1	1.4–3.8	3.1–5.1
Anterior postchaetal lobe (shape)	Digitiform	First 6 rounded, then digitiform	Digitiform	Conical	Auricular
Hooded hook (type)	SBHH	SBHH	SMHH	LSMHH SMHH	SMHH
Blade CMHH (type)	n.a.	n.a.	n.a.	n.a.	n.a.
Teeth CMHH (nr.)	n.a.	n.a.	n.a.	n.a.	n.a.
Last CMHH (ch.)	n.a.	n.a.	n.a.	n.a.	n.a.
Teeth simple HH (nr.)	2	2	7–8	7–9	7
1st SMHH long hood (ch.)	n.a.	n.a.	8–18	6–18	13-16
1st SMHH short hood (ch.)	n.a.	n.a.	23–36	30–71	—*
1st SBHH (ch.)	1	5	n.a.	n.a.	n.a.
Last ventral limbates (ch.)	All ch.	All ch.	All ch.	37–78	48
Last dorsal limbates (ch.)	All ch.	All ch.	All ch.	All ch.	33
Aciculae (colour)	Yellow	Yellow	Reddish	Yellow	Black
Maxillae (nr.)	4	4	5	4	5
MI attachment lamellae	Present	Present	Present	Present	Present
MII ligament	Present	Absent	Present	Present	Present
MIII	Unidentate	Unidentate arcuate	With up to 4 teeth	Unidentate	Unidentate
MIV	Multidentate	Unidentate	Multidentate	Broad rectangular plate with a projection from middle of its inferior border	Unidentate
Postchaetal branchiae	Absent	Absent	Present (ch.3–35)	Absent	Absent
Eggs size (μm)	—	—	—	—	—
Sperm size (μm)	—	—	—	—	—

Table 10 – Environmental characterization of the sites where Lumbrineridae species occurred along the Portuguese continental shelf (SD = standard deviation).

	Gallardoneris iberica **sp. nov.**	*Lumbrineris luciliae* **sp. nov.**	*Lumbrineris lusitanica* **sp. nov.**	*Lumbrineris pinaster* **sp. nov.**	*Lumbrineris latreilli*	*Lumbrineris futilis*	*Lumbrineriopsis paradoxa*	*Lumbrinerides amoureuxi*	*Ninoe armoricana*	*Abyssoninoe hibernica*	*Scoletoma* cf. *fragilis*
Depth (range, m)	18.0–179.3	32.7–179.3	13.8–190.0	11.0–160.5	28.7	25.6–128.3	7.0–126.9	67.9–195.0	92.9–138.5	16.0–190.0	28.9–125.5
Depth (mean ± SD, m)	98.3±38.7	81.6±50.9	75.1±42.1	48.1±30.9	28.7	60.1±32.3	50.5±26.0	119.9±35.2	114.7±14.8	43.2±100.1	77.9±45.9
Gravel content (mean ± SD, %)	1.8±6.9	6.2±19.3	7.1±15.5	2.8 ±6.2	3.73	20.4±29.0	23.9±20.1	4.9±11.9	0.2±0.5	2.2±6.6	13.2±22.9
Sand content (mean ± SD, %)	55.3±24.8	64.9±22.2	77.5±19.3	57.6±29.7	65.85	68.4±25.0	72.2±19.5	73.2±11.5	48.3±24.3	58.9±25.9	66.9±20.6
Fines content (mean ± SD, %)	43.0±26.3	28.9±20.5	15.4±17.8	39.7±32.1	30.43	11.2±13.8	3.8±10.4	21.7±12.1	51.6±24.4	39.0±27.3	19.9±20.5
Biogenic content (mean ± SD, %)	5.3±11.8	8.0±6.5	3.8±8.3	6.4±6.9	6.02	5.2±7.3	5.7±11.2	5.6±2.7	2.4±4.8	2.6±4.0	3.0±4.0
TOM content (mean ±SD, %)	4.7±1.6	3.8±1.7	2.6±1.6	4.7±1.91	2.93	2.1±1.4	1.2±1.1	3.4±0.6	5.6±1.6	4.6±1.9	2.7±2.2
Main sediment types	Mud, very fine sand, fine sand	Several types of sediments but mostly fine sand and mud	All type of sediments but mostly finer sands	Mud, very fine sand, fine sand, coarse sand	Very fine sand	Fine gravel, fine sand	Coarser sediments	Fine sand, medium sand, very fine sand	Mud, very fine sand, fine sand	Mud, very fine sand, fine sand	Very fine and medium sand and fine gravel
Occurrence	Portuguese shelf	Mainly southern Portuguese shelf	Portuguese shelf	Southern Portuguese shelf; off Tagus Estuary	Southern Portuguese shelf	Portuguese shelf	Portuguese shelf	Mainly SW Portuguese shelf	Portuguese shelf	Portuguese shelf	NW Portuguese shelf

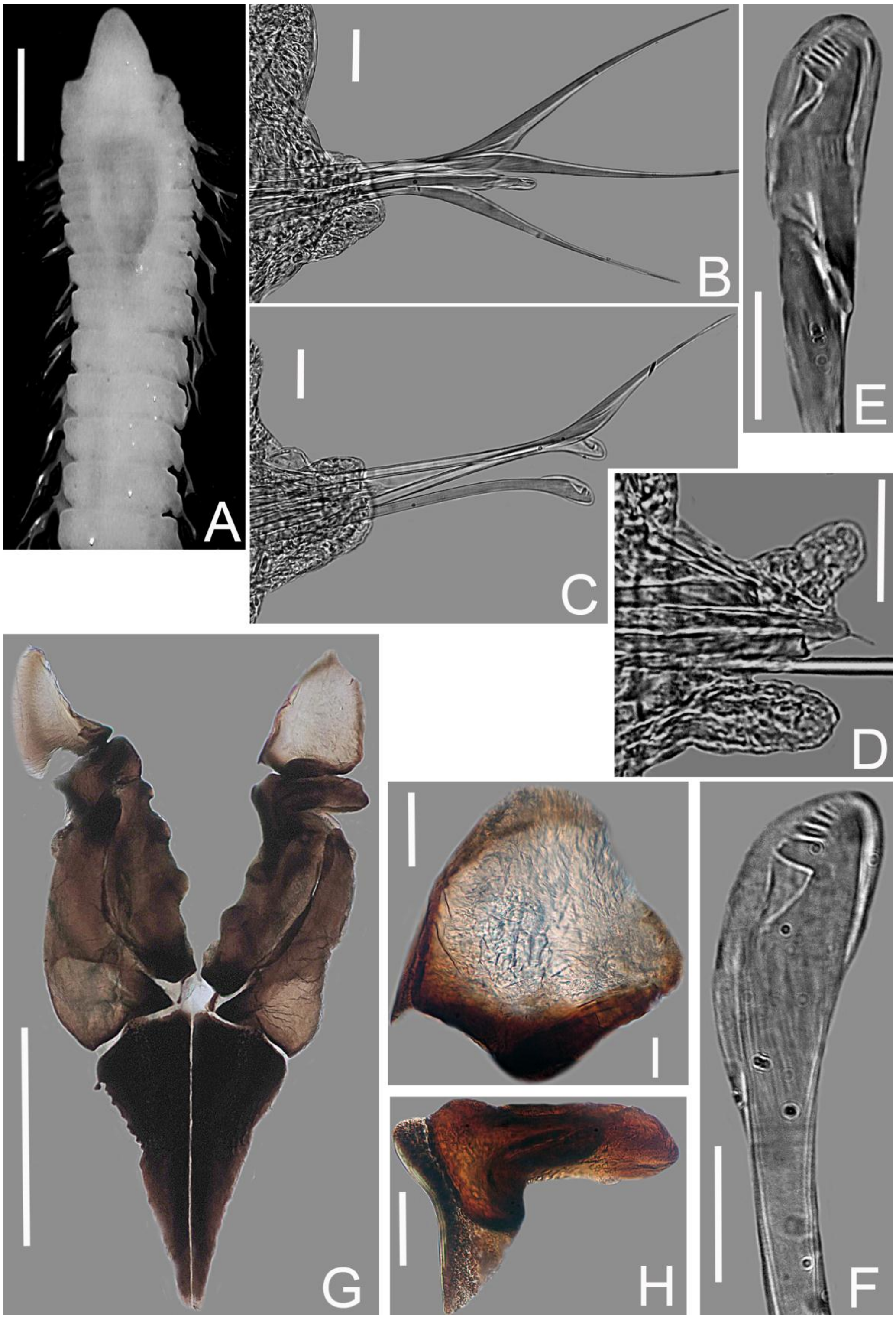


Figure 26 – *Gallardoneris iberica* **sp. nov.** Paratype (ECOSUR0128). Legend: A, anterior end, dorsal view; B, parapodium 4, frontal view; C, parapodium 16, frontal view; D, parapodium 88, frontal view; E, composite multidentate hooded hook, from parapodium 4; F, simple multidentate hooded hooks, from parapodium 16; G, maxillary apparatus, dorsal view; H, maxillae III; I, maxillae IV. Scale bars: A, 0.3 mm; B, C, D, 0.025 mm; E, F, 0.012 mm; G, 2.5 mm; H, I, 0.5 mm.

Genus *Lumbrineris* de Blainville, 1828

Lumbrineris luciliae sp. nov.

Figure 27

Material examined. *Type material*: Holotype (MNHN TYPE 1539) southern Portuguese continental shelf, site PC201, 37º02.860′ N 8º25.285′ W, April 2008, in fine sand, 32.7 m. *Paratypes:* MB29–000229, 1 specimen, site PC125. ECOSUR0129, 1 specimen, site PC191. DBUA 01317.01, 1 specimen, site MESH 3D. *Additional material:* see Martins et al. (2012b).

Description. Holotype mature male complete with 121 chaetigers (last 17 chaetigers regenerating), LT=52.0 mm, L10=4.7 mm , W10=1.8 mm. Prostomium subconical, as long as wide, with a pair of nuchal organs, ventrally with short buccal lips. Peristomium with two rings, anterior ring twice as long as second one (Figure 27–A). All parapodia well developed, first six smaller than following ones. Prechaetal lobe in first parapodia inconspicuous, in chaetigers 2–10 as a small globular protuberance, conical in posterior chaetigers; always smaller than postchaetal lobe. Postchaetal lobe digitiform in parapodia 1, digitiform wide basally from parapodia 2 to 28; in posterior chaetigers digitiform; larger in anterior and posterior parapodia; always longer than prechaetal lobe (Figure 27–B–D). Short rounded dorsal cirri in all parapodia. Composite multidentate hooded hooks in chaetigers 1–21, 3–8 per parapodium, with short blade, with up to 9 teeth, all of similar size (Figure 27–E). Simple multidentate hooded hooks from chaetiger 21, with short hood, with up to 7 teeth, proximal tooth largest ; preacicular hook with a section that is twice as large as the postacicular hook (Figure 27–F). Dorsal limbate chaetae in chaetigers 1–82, ventral limbate chaetae in chaetigers 1–21. Aciculae yellow, aristate, distally curved in median and posterior parapodia (Figure 27–G), up to five in anterior parapodia and two in posterior parapodia. Pygidium with terminal anus, with two pairs of anal cirri of similar size. Mandible divided for about half its length. Maxillary apparatus with five pairs of maxillae; maxillary carriers as long as MI. MI forceps-like with attachment lamella well developed. MII as long as MI, with wide connecting plates slightly developed; with four teeth of similar size. MIII arcuate, unidentate. MIV unidentate, with well-developed plate. MV free, prominent, lateral to MIV and MIII (Figure 27–H).

Variations. The specimens examined ranged in L10 from 2.2 to 6.3 mm, in W10 from 0.6 to 1.8 mm and varied in the following features: the last appearance of the composite multidentate hooded hooks and ventral limbates and the first simple multidentate hooded hooks ranged from chaetigers 14 to 21 (cf. Table 9).

Reproduction. One mature male was found (Holotype MNHN TYPE 1539) in April; the sperm cells have a long tail and a head with a subspherical nucleus, which diameter ranging from 2 to 3 µm.

Type locality. Southern Portuguese continental shelf.

Etymology. This species is named in honor of Lucília Gonçalves, mother of the first author.

Distribution and habitat. *Lumbrineris luciliae* **sp. nov.** occurred in several sediment types from gravel to mud, characterized by high sand and biogenic contents, on average, 65% and 8% respectively (cf. Table 10). The species is distributed on the whole Portuguese continental shelf, but mainly in the southern shelf, at water depths ranging from 33 to 179 m (cf. Table 10). Highest abundances were found in the western part of the southern shelf (Figure 20–B). The species seems to occur mainly in biogenically enriched sediments. The biogenic fraction of the sediment is mainly composed of skeletal remains of molluscs, echinoderms or other fauna. Those mixed sediments may play some role in the creation of a favorable predator habitat and/or a protective habitat to these specimens, which are bigger than the other new species.

Remarks. *Lumbrineris luciliae* **sp. nov.** has an arcuate, unidentate MIII and MIV unidentate with well-developed plate, digitiform wide basally postchaetal lobes in anterior parapodia, composite multidentate hooded hooks with short blade, simple multidentate hooded hooks of two sizes, preacicular hook twice as big as postacicular hook, and distally curved aciculae in median and posterior parapodia.

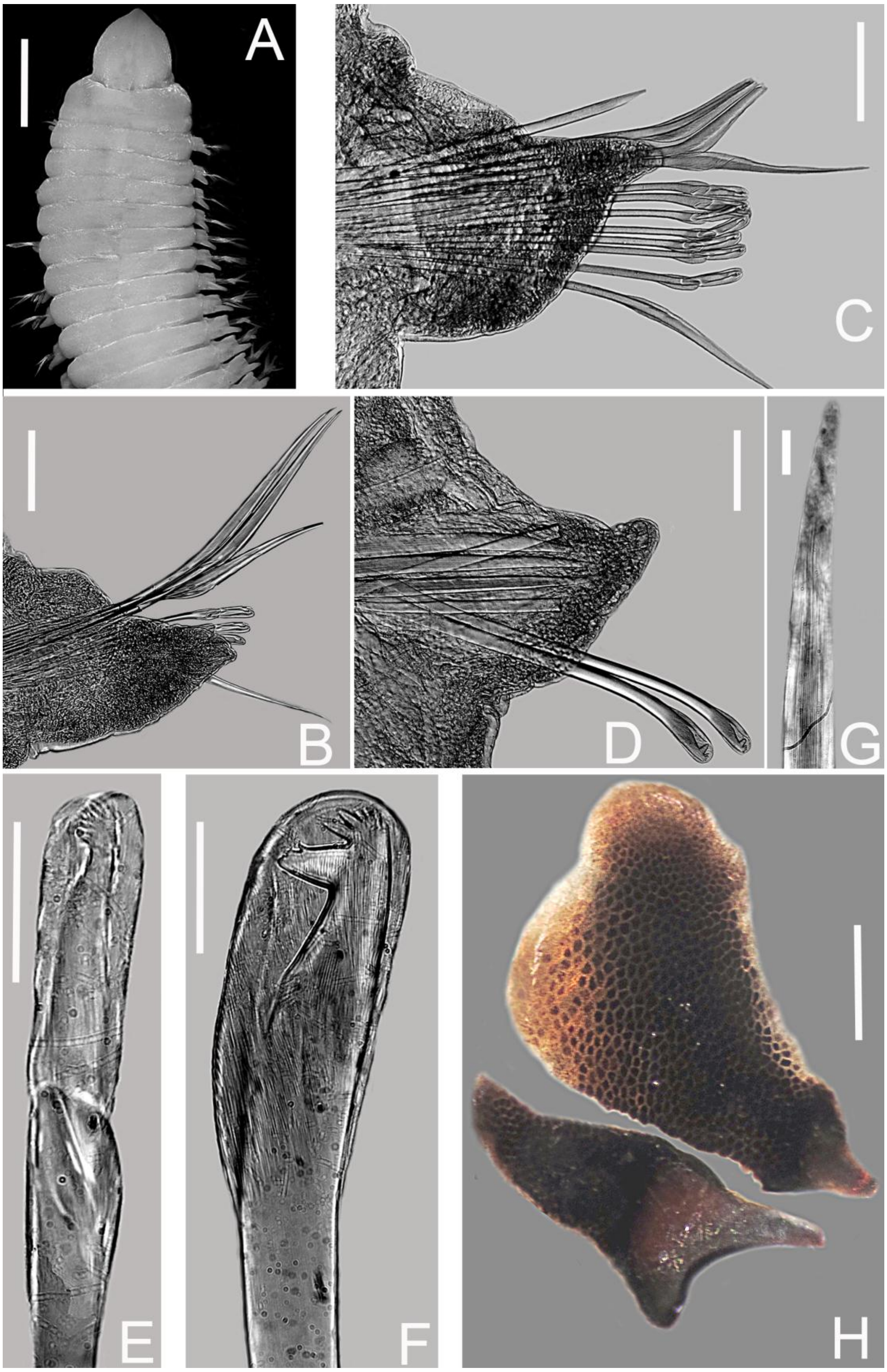


Figure 27 – *Lumbrineris luciliae* **sp. nov.** Paratype (ECOSUR0129). Legend: A, anterior end, dorsal view; B, parapodium 3, frontal view; C, parapodium 13, frontal view; D, parapodium 77, frontal view; E, composite multidentate hooded hook, from parapodium 3; F, simple multidentate hooded hook from parapodium 77; G, acicula from parapodium 86; H, maxillae III and IV, dorsal view. Scale bars: A, 1.0 mm; B, C, D, H 0.1 mm; E, F, 0.025 mm; G, 0.01 mm.

Lumbrineris lusitanica **sp. nov.**

Figure 28

Material examined. *Type material*: Holotype (MNHN TYPE 1540) northwestern Portuguese continental shelf, site R16, 41º27.557′ N 8º51.866′ W, October 2007, in fine sand, 52.3 m. *Paratypes*: MB29–000230, 2 specimens, same data as holotype. MB29–000231, 2 specimens, site PC114. MB29–000232, 6 specimens, site PC118. MB29–000233, 1 specimen, site PC119. ECOSUR0130, 2 specimens, site R25. DBUA 01316.01, 2 specimens, site PC118. DBUA 01316.02, 1 specimen, site PC119. *Additional material*: see Martins et al. (2012b).

Description. Holotype complete with 174 chaetigers, LT=33.5 mm, L10=2.5 mm, W10=0.7 mm. Prostomium conical, slightly longer than wide, with a pair of nuchal organs, short buccal lips ventrally. Peristomium shorter than prostomium, about half its length, with two rings of similar size (Figure 28–A). All parapodia well developed, first six smaller than following ones. Prechaetal lobe in parapodia 1–4 inconspicuous; from parapodia 5 very short, as a globular projection, gradually increasing in length between parapodia 6–15; from parapodia 16 as a digitiform lobe, always smaller than postchaetal lobe. Postchaetal lobe in parapodia 1 small and conical; in parapodia 2–48 digitiform wide basally; becoming longer in posterior parapodia (Figure 28–B–D). Short rounded dorsal cirri in all parapodia. Composite multidentate hooded hooks in chaetigers 1–11, 2–3 per chaetiger, with short blade, with up to 7 teeth, proximal tooth largest (Figure 28–E). Simple multidentate hooded hooks from chaetiger 11, with short hood, with up to 7 teeth, preacicular hook twice as big as postacicular hook, proximal tooth largest (Figure 28–F). Dorsal limbate chaetae in chaetigers 1–38, ventral limbate chaetae in chaetigers 1–11. Aciculae yellow, aristate, one in anterior parapodia and up to two in the posterior parapodia. Pygidium with terminal anus, with two pairs of anal cirri, dorsal longer than ventral pair. Mandible divided for about half its length. Maxillary apparatus with five pairs of maxillae; maxillary carriers as long as MI, anterior end constricted. MI forceps-like with attachment lamella well developed. MII as long as MI, with wide connecting plates slightly developed; with four teeth of similar size. MIII unidentate, followed by a knob, with a very prominent projection in the basal part of the maxilla. MIV unidentate, with a pointed tooth. MV free, prominent, lateral to MIV and MIII (Figure 28–G).

Variations. The material examined ranged in L10 from 1.4 to 3.2 mm, in W10 from 0.3 to 0.9 mm and varied in the following features: the last composite multidentate hooded hook was found from chaetigers 7 to 15; the first simple multidentate hooded hook was found from chaetigers 8 to 16; the last ventral limbate ranged from chaetiger 8 to 17 and the last dorsal limbate from 25 to 59 (cf. Table 9).

Reproduction. Mature specimens were found only in October. Male gametes of *Lumbrineris lusitanica* **sp. nov.** (Paratypes MB29-000231, DBUA 01316.02) were located from chaetiger 35 to 139, and had a long tail and head with a subspherical form, with diameters ranging from 2.8 to 3.2 µm. Female gametes (Paratypes MB29-000232, DBUA 01316.01) were located from parapodia 34 though the last segment of an incomplete specimen. The gametes were globular with a size diameter ranging between 181 and 192 µm.

Distribution and habitat. *Lumbrineris lusitanica* **sp. nov.** is widely distributed on the whole Portuguese continental shelf, at water depths ranging from 14 to 190 m, but mostly below 100 m (cf. Table 10). The species is recorded in mud as well as in fine gravel however, it is usually found in fine and very fine sands with low to moderate fines content. Overall, the sediments are characterized by very high sand content and low to moderate content in fines, gravel, biogenic fraction and TOM (averages of 77.5%, 15.4%, 7.1%, 3.8% and 2.6%, respectively) (cf. Table 10). Highest abundances were found in sheltered sites, mostly in the southern shelf (Figure 20–C).

Type locality. Northwestern and western Portuguese continental shelf.

Etymology. The specific name *lusitanica* refers to the western Iberian Roman province, where this species is very dominant.

Remarks. *Lumbrineris lusitanica* **sp. nov.** has digitiform wide basally postchaetal lobes in the anterior parapodia, CMHH with short blade, SMHH with short hood and MIII unidentate followed by a knob.

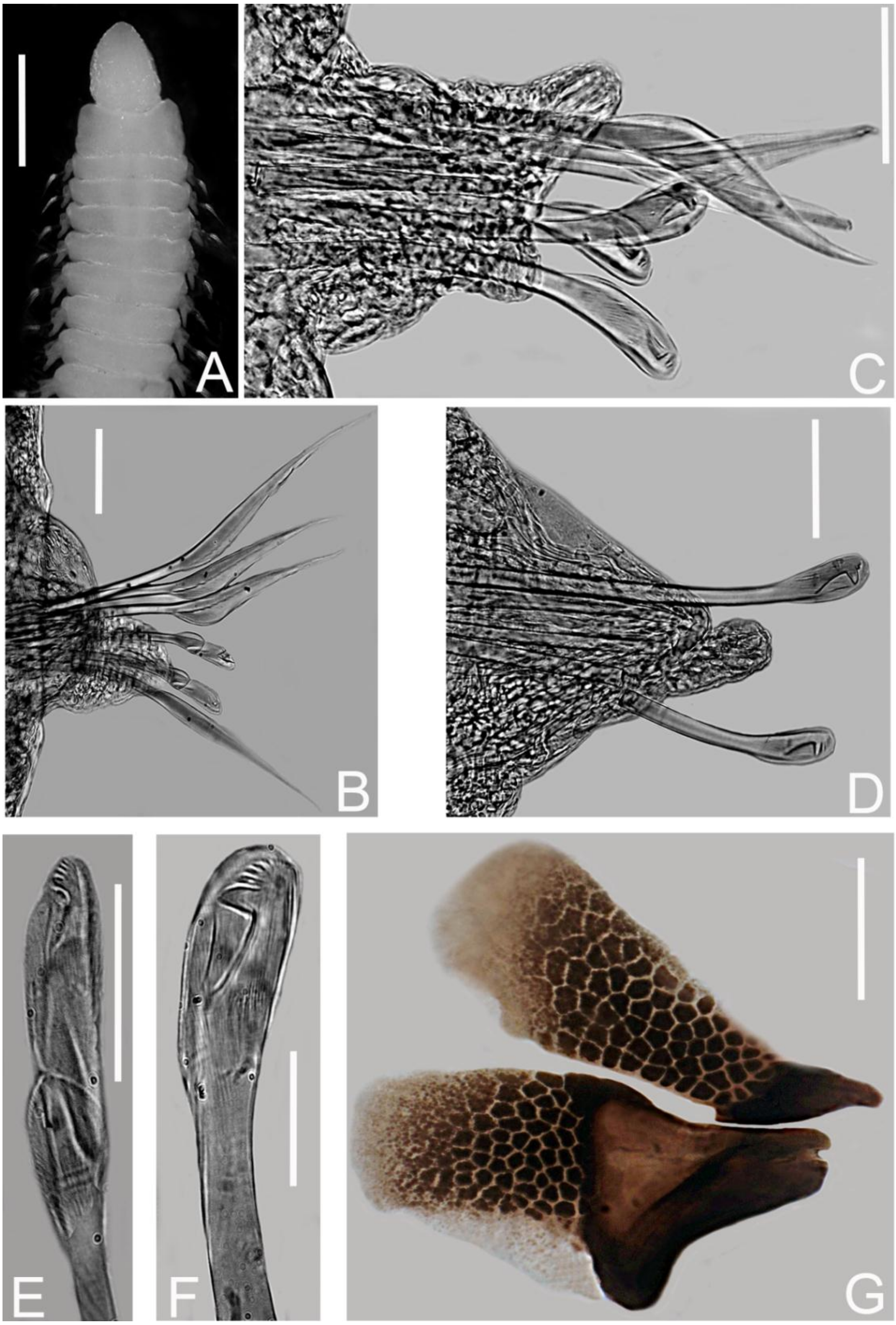


Figure 28 – *Lumbrineris lusitanica* **sp. nov.** Paratype (ECOSUR0130). Legend: A, anterior end, dorsal view; B, parapodium 3, frontal view; C, parapodium 13, frontal view; D, parapodium 79, frontal view; E, composite multidentate hooded hook, from parapodium 3; F, simple multidentate hooded hooks, from parapodium 79; G, maxillae III and IV, dorsal view. Scale bars: A, 0.7 mm; B, C, D, G 0.05 mm; E, F, 0.025 mm.

Lumbrineris pinaster sp. nov.

Figure 29

Material examined. *Type material*: Holotype (MNHN TYPE 1541) western Portuguese continental shelf (off Tagus Estuary, Lisbon), site PC115, 38º35.368′ N 9º25.567′ W, in mud, 97.7 m. *Paratypes*: ECOSUR0131, 1 specimen, site PC187. MB29–000234, 1 specimen, site PC203. MB29–000235, 10 specimens, site G19(2). MB29–000236, 3 specimens, site G28(1). MB29–000237, 3 specimens, site G28(2). DBUA 01318.01, 3 specimens, site G22(1). DBUA 01318.02, 10 specimens, site G19(2). *Additional material:* see Martins et al. (2012b).

Description. Holotype incomplete with 101 chaetigers, LT=18.1 mm, L10=1.6 mm, W10=0.4 mm. Prostomium conical, as long as wide, with a pair of nuchal organs, ventrally with short buccal lips. Peristomium half the length of prostomium, with two rings; anterior ring 0.75 of total peristomial length (Figure 29–A). All parapodia well developed, first four smaller than following ones. Prechaetal lobe rounded with globular protuberance directed dorsally, increasing in size gradually from chaetigers 1 to 12, preserving shape and size to end; always smaller than postchaetal lobe. Postchaetal lobe auricular from parapodia 1 to 13, gradually transforming to digitiform lobe, clearly visible from parapodium 30; longer in posterior parapodia (Figure 29–B–D). Short rounded dorsal cirri in all parapodia. Composite multidentate hooded hooks in chaetigers 1–10, 2–3 per chaetiger, with long blade, up to 7 teeth, all of similar size (Figure 29–E). Simple multidentate hooded hooks of two types; from chaetiger 11 to 22, with long hood, up to 7 teeth, proximal tooth slightly largest (Figure 29–F); from chaetiger 23 with short hood, up to 5 teeth, proximal tooth largest. Preacicular hook with a section that is twice as large as the postacicular hook (Figure 29–G–H). Dorsal limbate chaetae in chaetigers 1–41, ventral limbate chaetae in chaetigers 1–12. Aciculae yellow, aristate, up to two per chaetiger. Pygidium with terminal anus and two pairs of anal cirri (paratype MB29–000234). Mandible divided for about half its length. Maxillary apparatus with five pairs of maxillae; maxillary carriers as long as MI, anterior end constricted. MI forceps-like with well-developed attachment lamella. MII as long as MI, with wide connecting plates slightly developed; with four teeth of similar size. MIII unidentate, followed by a knob, .MIV unidentate with a well-developed plate. MV free, prominent, lateral to MIV and MIII (Figure 29–I).

Variations. The specimens examined ranged in L10 from 1.3 to 2.5 mm, in W10 from 0.4 to 0.7 mm, and varied in the following features: the last CMHH were observed from chaetiger 7 to 12; the first SMHH with long hood from chaetiger 8 to 13; the first SMHH with short hood from chaetiger 19 to 35; the end of ventral limbate from chaetiger 10 to 15; and the end of dorsal limbate from chaetiger 36 to 45 (cf. Table 9).

Reproduction. Mature specimens were only found in October. The male gametes of *Lumbrineris pinaster* **sp. nov.** are located posteriorly to chaetiger 37 (paratypes MB29–000235, MB29–000236, MB29–000237, DBUA 01318.01, DBUA 01318.02); they have a long tail and a subspherical nucleus with diameter between 2.5 and 3 µm. The female gametes cells are located from parapodia 38 (paratypes MB29–000235, MB29–000236, MB29–000237, DBUA 01318.01, DBUA 01318.02), the morphology is globular with diameter from 98 µm to 147 µm.

Distribution and habitat. This species occurred only on the southern Portuguese continental shelf and off the Tagus Estuary at shelf depths. It was mainly found at nearly 50 m depth (cf. Table 10). Highest abundances were found in the southern shelf (Figure 20–D). The species shows a preference for mud, very fine and fine sands. Sediments are characterized by high fines, biogenic and TOM contents (averaging, 39.7%, 6.4% and 4.7% respectively) (cf. Table 10). Although the northwestern deeper shelf is dominated by finer sediments (Martins et al., 2012a), the species was not recorded there. It is possible that the Lisbon/Cascais canyons could set a barrier to the distribution of this species. It is expected that *Lumbrineris pinaster* **sp. nov.** might also occur in the Gulf of Cádiz muddy area (southwestern Spain), which is a continuation of the extensive mud patch present in the southern Portuguese shelf.

Type locality: Off the Tagus Estuary (Lisbon), Portugal.

Etymology. The specific name was derived from the Maritime Pine seed (*Pinus pinaster*) which has a peculiar wing, resembling the Maxillae IV of this *Lumbrineris*.

Remarks. *Lumbrineris pinaster* **sp. nov.** has auricular postchaetal lobes in the anterior parapodia, CMHH with long blade, SMHH with short and long hood and MIII unidentate followed by a knob.

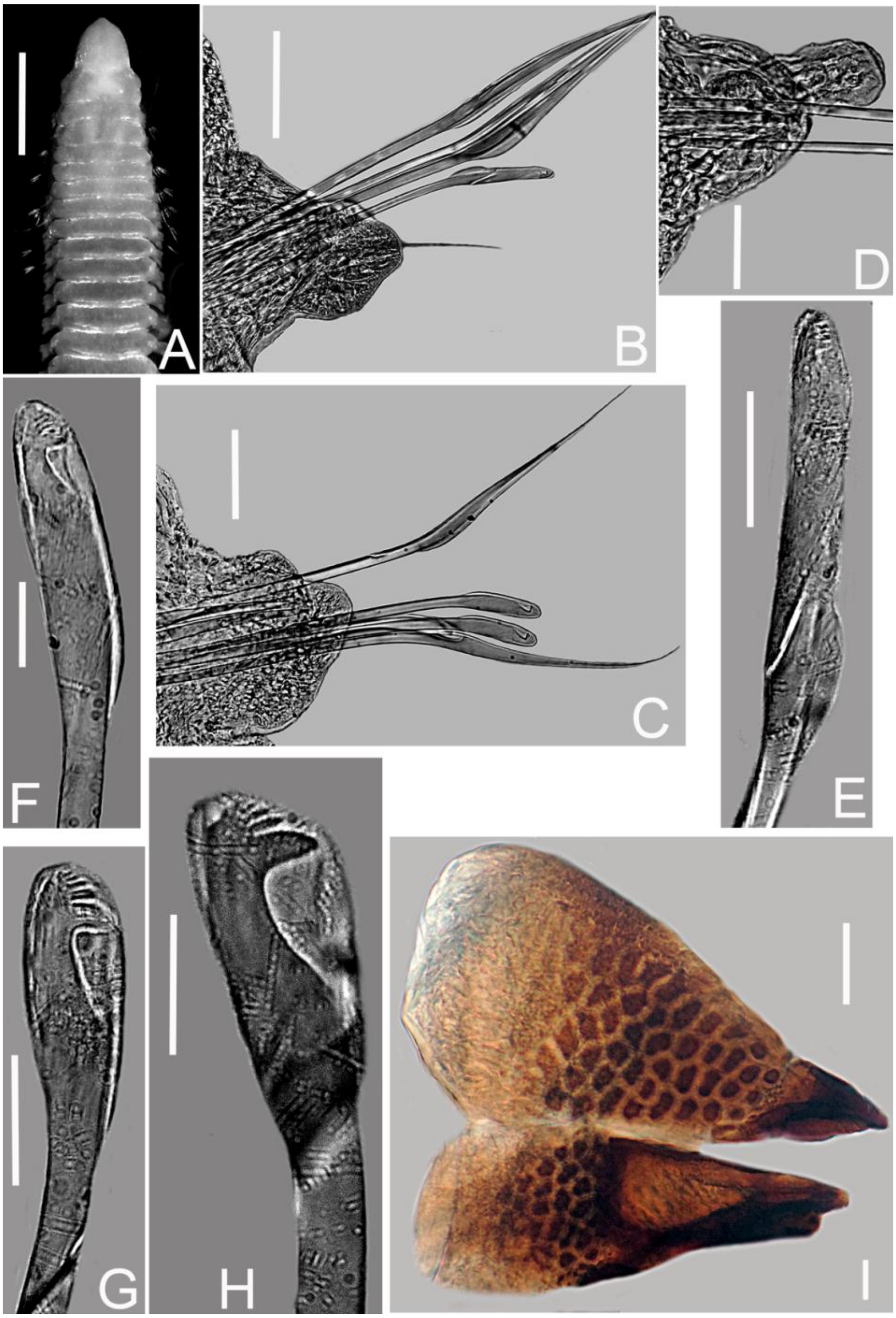


Figure 29 – *Lumbrineris pinaster* **sp. nov.** Paratype (ECOSUR0131). Legend: A, anterior end, dorsal view; B, parapodium 3, frontal view; C, parapodium 13, frontal view; D, parapodium 153, frontal view; E, composite multidentate hooded hook, from parapodium 3; F, simple multidentate hooded hook with long hood, from parapodium 13; G, preacicular simple multidentate hooded hook with short hood, from parapodium 79; H, postacicular simple multidentate hooded hook with short hood, from parapodium 79; I, maxillae III and IV, dorsal view. Scale bars: A, 0.4 mm; B, C, 0.5 mm; D, I, 0.025 mm; E, F, 0.012 mm.

Multivariate analysis

The results of the ordination analysis based on morphological descriptors of the lumbrinerid species occurring in the studied area are shown in Figure 30–A with a detailed analysis of the data relative to the three new *Lumbrineris* species shown in Figure 30–B. Axis 1 accounts for 35.6% of the total variation and is characterized by the separation of species with five maxillae, MIV completely pigmented, MI attachment lamellae, on the positive pole, and species with four maxillae and both MIII and MIV edentate, on the negative pole. This axis thus separates *Lumbrineris* species and *Ninoe armoricana*, on the positive pole, from *Gallardoneris iberica* **sp. nov**., on the left pole. Axis 2 accounts for 27.5% of the total variation and shows the separation of species with both CMHH and SMHH (*Lumbrineris* and *Gallardoneris* species) from species with simple bidentate hooks (*Lumbrinerides amoureuxi* and *Lumbrineriopsis paradoxa*) and limbated simple multidentate (*Abyssoninoe hibernica*). *Gallardoneris iberica* **sp. nov.** is positioned on the negative pole of axis 1 and positive pole of axis 2 in the ordination analysis (Figure 30–A). The main morphological characters that allow its differentiation from the other species, are the presence of four maxillae, MII without attachment lamellae, MIII edentate, MIV edentate with a whitish central area, presence of both composite and SMHH and absence of postchaetal branchiae, bidentate and limbated multidentate hooded hooks. The *Lumbrineris* species are positioned on the positive poles of axis 1 and 2 (Figure 30–A). They are separated from the other genera mostly by the absence of postchaetal branchiae (which is only found in *Ninoe*), bidentate simple hooded hooks (*Lumbrineriopsis* and *Lumbrinerides*) and limbated simple hooded hooks (*Abyssoninoe*), and the presence of five pairs of maxillae (*Abyssoninoe, Gallardoneris*, *Lumbrineriopsis* and *Lumbrinerides* have four pairs of maxillae). The detailed analysis of the morphological descriptors of the new *Lumbrineris* species are shown in Figure 30–B. Axis 1 accounts for 49.4% of the total variance and separates species with MIII unidentate, aciculae distally curved in median and posterior parapodia and the highest values of W10 (*Lumbrineris luciliae* **sp. nov.**) from the other two new species characterized by MIII unidentate followed by a knob and aciculae straitght (*L. lusitanica* **sp. nov** and *L. pinaster* **sp. nov**). Axis 2 accounts for 41% of total variance and separates the species on the positive pole, *L. pinaster* **sp. nov.**, from *L. lusitanica* **sp. nov.**, on the negative pole. The descriptors which contribute to this separation are MIV type, first SMHH and presence/absence of anterior postchaetal lobe auricular and prominent projection on MIII. The descriptor “anterior postchaetal lobe digitiform wide basally” contributes to both axes, being shared by the species *L. luciliae* **sp. nov.**, and *L. lusitanica* **sp. nov.**.

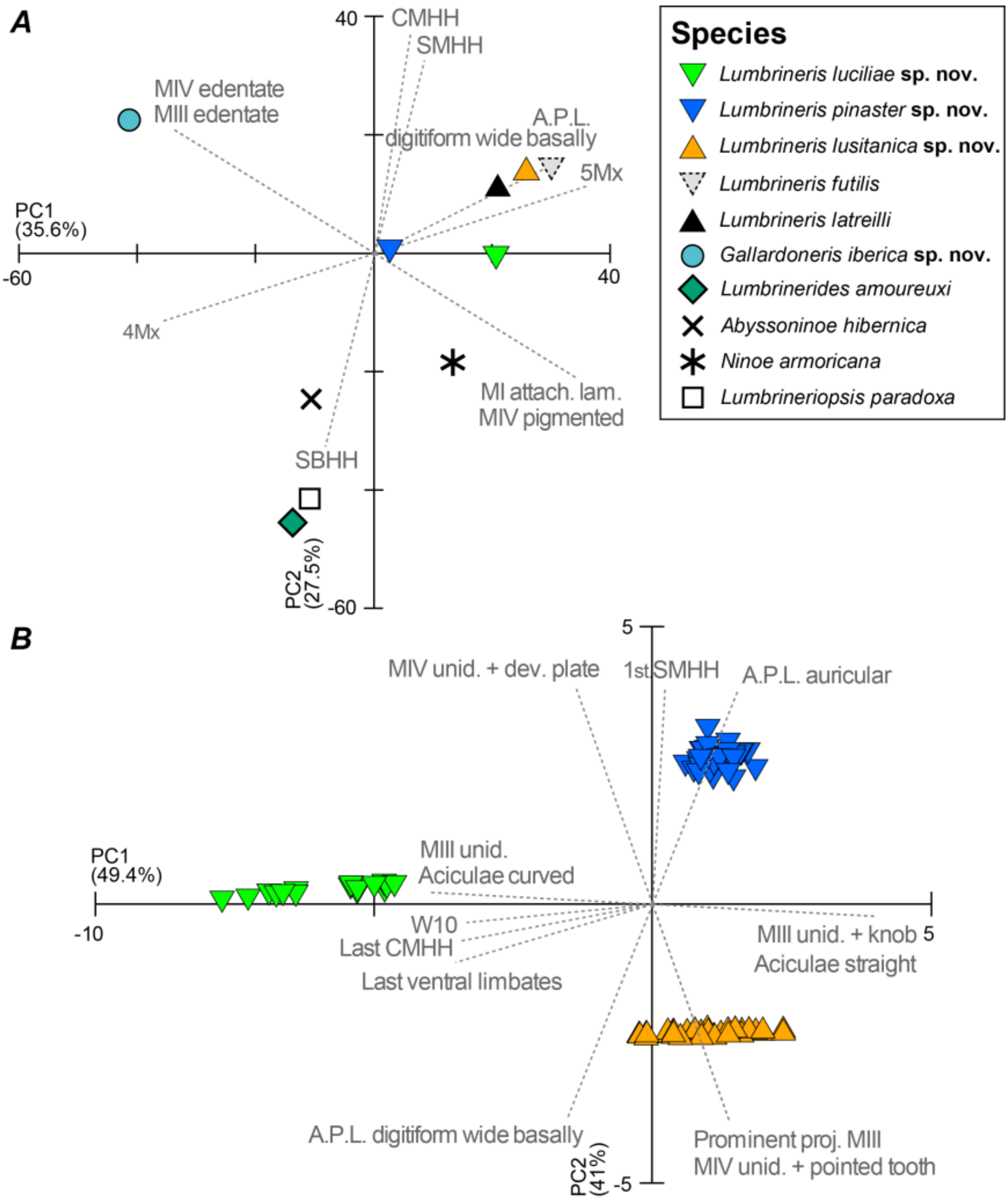


Figure 30 – Ordination analysis based on morphological descriptors of specimens of *Abyssoninoe, Lumbrineris, Gallardoneris, Lumbrinerides, Lumbrineriopsis* and *Ninoe* species (A) and of *Lumbrineris luciliae* **sp. nov.**, *L. lusitanica* **sp. nov.** and *L. pinaster* **sp. nov.** The most correlated variables (rho>0.8) are shown as dashed vectors. Legend: A.P.L. – postchaetal lobe shape in anterior parapodia; CMHH – composite multidentate hooded hook; SMHH – simple multidentate hooded hook; SBHH – simple bidentate hooded hook; MI attach. lam. – MI attachment lamellae; MIII unid. + knob – MIII unidentate followed by a knob; prominent proj. MIII – prominent projection in the basal part of MIII; MIV unid. + dev. plate – MIV unidentate with a developed plate; MIV unid. + pointed tooth – MIV unidentate with a pointed tooth; W10 – width at chaetiger 10 excluding parapodia.

The multivariate analysis of the morphological descriptors showed a very good separation of the four new species, and between these and the other recorded species on the Portuguese continental shelf. The following key to the Lumbrineridae species of Iberian waters is based on the understanding gained from that analysis.

Key to the Lumbrineridae species from the Iberian waters

1 Maxillary apparatus with four pairs of maxillae 2
- Maxillary apparatus with five pairs of maxillae 6
2 With both composite and simple hooded hooks 3
- With simple hooded hooks only 4
3 With antennae; MI and MII with attachment lamellae; mandible with both anterior and posterior end divergent…(*Augeneria*) 10
- Without antenna; MI and MII without attachment lamellae; mandible with wide distal end narrowing to the posterior end, totally fused … (*Gallardoneris*) … Prechaetal lobe longer than postchaetal lobe in posterior parapodia; postchaetal lobe auricular in anterior parapodia, digitiform in posterior ones; CMHH with short blade . . . . *Gallardoneris iberica* **sp. nov.**
4 With limbate simple multidentate hooded hooks; MIV as a broad rectangular lamella with a lateral protruding expansion…(*Abyssoninoe*) 11
- Without limbate simple multidentate hooded hooks; shape of MIV different from above. 5
5 Carriers joined to 1/2 of base of MI and longer than MI; MIV multidentate; mandible fused up to 3/4 of its length … (*Lumbrineriopsis*)…MIII unidentate; simple bidentate hooded hooks from chaetiger 1 . . . . *Lumbrineriopsis paradoxa*
- Carriers joined to entire base of MI and as long as MI; MIV with up to one tooth; mandibles completely fused … (*Lumbrinerides*) 12
6 Anterior parapodia with postchaetal branchiae, MIV multidentate … (*Ninoe*) … MIII multidentate, distal tooth largest; SMHH with long hood in branchial region, with short hood in postbranchial region . . . . *Ninoe armoricana*
- Anterior parapodia without postchaetal branchiae, MIV with up to two teeth 7
7 MII half as long as MI 8
- MII as long as MI 9
8 With composite spinigers … (*Lumbricalus*) … Aciculae black; postchaetal lobe in anterior parapodia digitiform wide basally, digitiform in posterior ones, with up to 2-3 spinigers per chaetiger; CMHH with long blade . . . . *Lumbricalus campoyi**
- Without composite spinigers … (*Hilbigneris*) … MIII unidentate, with prominent tooth followed by an expanded base; CMHH with long blade; aciculae yellow . . . . *Hilbigneris gracilis**
9 With only SMHH … (*Scoletoma*) 14
- With both SMHH and CMHH … (*Lumbrineris*) 15
10 With dark aciculae; with up to eight antennae . . . . *Augeneria riojai**
- With yellow aciculae; with up to three antennae. . . . . *Augeneria algida**
11 Prechaetal lobe inconspicuous in anterior parapodia; digitiform, and well-developed in posterior parapodia; postchaetal lobe in anterior parapodia small and conical being more developed in posterior parapodia . . . . *Abyssoninoe hibernica*
- Prechaetal lobe inconspicuous in all parapodia; postchaetal lobe well developed in all parapodia . . . . *Abyssoninoe scopa**
12 MI with one internal accessory tooth 13

- MI without internal accessory teeth . . . . *Lumbrinerides acuta sensu* Ramos, 1976*[1]

13 MII with three teeth;prostomium cylindrical, very elongated.. . ..*Lumbrinerides carpinei**

- MII with four teeth; prostomium acorn-shaped .. . . *Lumbrinerides amoureuxi*

14 MIII unidentate; aciculae black; SMHH from chaetiger 15 . . .. *Scoletoma fragilis*

- MIII bidentate; aciculae yellow; SMHH from chaetigers 1–5. . . . . *Scoletoma impatiens**[2]

15 MIII unidentate 16

- MIII unidentate followed by a knob 18

- MIII bidentate 20

- MIII tridentate . . . . *Lumbrineris inflata*[3]

16 Prechaetal lobe in posterior parapodia longer than postchaetal lobe . . . . *Lumbrineris nonatoi**

- Prechaetal lobe always shorter than postchaetal lobe 17

17 Postchaetal lobe auricular in anterior parapodia; all aciculae straight . . . . *Lumbrineris aniara**

- Postchaetal lobe digitiform wide basally in anterior parapodia; aciculae distally curved in median and posterior parapodia . . .. *Lumbrineris luciliae* **sp. nov.**

18 CMHH with short blade . . . . *Lumbrineris lusitanica* **sp. nov.**

- CMHH with long blade 19

19 Aciculae yellow; postchaetal lobe auricular in anterior parapodia . . . . *Lumbrineris pinaster* **sp. nov.**

- Aciculae black; postchaetal lobe digitiform in anterior parapodia . …. . .*Lumbrineris futilis*

20 CMHH with short blade; SMHH of two sizes, preacicular bigger; postchaetal lobe digitiform in all parapodia; prostomium rounded . . . . *Lumbrineris coccinea**

- CMHH with long blade, SMHH of similar size; postchaetal lobe digitiform wide basally in anterior chaetigers; prostomium conical . . . . *Lumbrineris latreilli*

* Recorded in Iberian waters, but not found in this study.

[1] Ramos (1976) recorded *L. acuta* from Spain and described MI without accessory teeth; however, *L. acuta*, a species described from Rhode Island, has MI with one accessory tooth (Perkins, 1979).

[2] *S. impatiens* (from France) has been considered synonym of *S. tetraura* (from South Africa), without a revision of both species. Therefore, we recommend that for European seas the name *S. impatiens* should be used instead *S. tetraura*. A complete revision of both species is needed to clarify their status which is beyond the scope of the present study.

[3] Record questionable according to Carrera-Parra (2006b).

3.8.2. Diversity of the Family Pisionidae

The following results present some details of the diversity and distribution of the genus *Pisione* Grube, 1857, Family Pisionidae Southern, 1914, on the Portuguese continental shelf. A total of 692 *Pisione* specimens were recorded at 48 sites sampled in various campaigns along the Portuguese shelf, belonging to *P. remota* (382 specimens, at 33 sites), *P. parapari* (295, at 35 sites), *P. inkoi* (7, at 4 sites) and *P. guanche* (8, at 6 sites). The present work shows that the four species can co-occur (Figure 31). Also, *P. remota* was found together with *P. parapari* at 16 sites, *P. remota, P. parapari and P. guanche* at 5 sites and *P. remota* with *P. inkoi* at 1 site. Nevertheless, *P. parapari* (13 sites, mainly in the southern near shore shelf), *P. remota* (10 sites mainly in the western shelf) and *P. inkoi* (2 sites of the western deeper shelf) may occur individually. These *Pisione* species occur with the molluscs *Thracia villosiuscula, Angulus pygmaeus, Caecum* sp.*, Limatula subovata, Digitaria digitaria*, *Gari costulata* and *Goodallia triangularis*, the polychaetes *Protodorvillea kefersteini* and *Gyptis propinqua* and the sipunculid *Aspidosiphon (Aspidosiphon) muelleri muelleri*. Table 11 reports the mean and associated variability of the morphological descriptors studied in the four *Pisione* species and Table 12 presents a summary of the environmental characteristics of the sampling sites is presented in. The species are characteristic of coarser sediments as shown by the high gravel and sand content and low fines content of the sediment sites.

The contents of this subchapter are published in Zootaxa in Martins R., San Martín G., Rodrigues A.M., Quintino V. (2012c) On the diversity of the genus *Pisione* (Polychaeta, Pisionidae) along the Portuguese continental shelf, with a key to European species. *Zootaxa*, 3450, 12–22.

Table 11 – Morphological descriptors mean values and standard deviation (SD) of the Pisione species found on the Portuguese continental shelf. Legend: W10 = width at chaetiger 10; CP2/CP3 = ratio between the length of the dorsal cirri of parapodia 2 (CP2) and parapodia 3 (CP3); NrT = number of teeth of the supra-acicular chaetae; P1/W10 = ratio between protruding length of the notoaciculae through the parapodia (P1) and W10; IA = presence/absence of infra-acicular simple chaeta; * = incomplete specimen.

	Pisione guanche	*Pisione inkoi*	*Pisione parapari*	*Pisione remota*
Number of specimens analysed	8	7	30	30
Total length (mean ± SD, mm)	13.933±4.631	7.900±1.771	4.114±1.390	6.915±4.576
W10 (mean ± SD, mm)	0.495±0.142	0.409±0.105	0.191±0.023	0.302±0.077
Number of parapodia	22*– 47	12*– 47	26 – 51	26 – 97
CP2 (mean ± SD, mm)	0.095±0.016	0.044±0.011	0.034±0.006	0.038±0.009
CP3 (mean ± SD, mm)	0.035±0.005	0.044±0.011	0.024±0.004	0.037±0.009
CP2/CP3 (mean ± SD, mm)	2.693±0.375	0.993±0.012	1.382±0.081	1.008±0.029
P1 (mean ± SD, mm)	0.032±0.009	0.089±0.011	0.000±0.000	0.000±0.000
P1/W10 (mean ± SD, mm)	0.066±0.013	0.233±0.062	0.000±0.000	0.000±0.000
Longest blade (mean ± SD, mm)	0.023±0.002	0.050±0.007	0.024±0.002	0.017±0.002
NrT (number)	2	1	2	1
IA (number)	0	0	0	1
Male copulatory organs (chaetigers)	33 – 38; 34 – 41; 40 – 47	No male found	10, 18; 11, 18; 11, 19; 11, 20; 10, 12, 20; 11, 12, 20; 11, 12, 21	16 – 17; 16 – 18; 20 – 21; 24 – 28; 28 – 35; 29 – 32

Table 12 – Environmental characterization of the sites where Pisione species occurred along the Portuguese continental shelf. Legend: SD = standard deviation; Gravel = grain-size fraction > 2 mm; Sand = grain-size fraction 0.063 — 2 mm; Fines = grain-size fraction < 0.063mm; Biogenic fraction = faunal skeletal remains > 2.0 mm; TOM = total organic matter content; MS = medium sand; CS = coarse sand; VCS = very coarse sand; G = fine gravel.

	Pisione guanche	***Pisione inkoi***	***Pisione parapari***	***Pisione remota***
Total abundance	7	8	295	382
Depth (range, m)	25 – 80	74 – 127	3 – 80	3 – 80
Depth (mean ± SD, m)	44.2±16.3	95.2±20.6	24.6±18.6	35.9±20.1
Gravel content (mean ± SD, %)	37.6±24.3	36.4±29.1	13.1±20.1	22.2±22.4
Sand content (mean ± SD, %)	54.3±21.4	60.6±25.8	85.0±21.1	75.8±22.8
Fines content (mean ± SD, %)	8.0±15.6	3.0±3.7	1.9±7.5	2.0±7.8
Biogenic content (mean ± SD, %)	4.6±3.6	1.4±0.3	5.9±6.9	6.6±7.7
TOM content (mean ± SD, %)	0.8±0.5	2.4±1.7	0.9±0.5	0.8±0.4
Main sediment types	G (33%), VCS (33%), CS (17%), MS (3%)	G (34%), VCS (33%), MS (33%)	CS (63%), VCS (14%), G (11%), MS (11%)	CS (42%), VCS (36%), G (18%), MS (3%)

Systematics

Class Polychaeta Grube, 1850

Order Phyllodocida Levinsen, 1883

Family Pisionidae Southern, 1914

Genus *Pisione* Grube, 1857

***Pisione guanche* San Martín, López and Núñez, 1999**

Material examined. MB29–000239, 1 specimen, site PC137; MB29–000240, 1 specimen, site PC138. Additional material: see Martins et al. (2012c).

Brief description. Body width (10th chaetiger) between 0.30 and 0.68 mm, total length between 9.80 and 20.40 mm and total number of chaetigers up to 74. Buccal acicula protruding obliquely, not exceeding chaetiger 1 backwards, with distal margin showing few irregular dentations at tip. All prechaetal lobes bilobed. Dorsal cirri of chaetiger 2, 2.3 to 3.3 times longer than dorsal cirri of chaetiger 3 and subsequent ones (Table 11). All dorsal cirri globular, with a short, spherical distal papilla with a pilose tip, except that of chaetiger 2, which is digitiform. Two types of chaetae: four short-bladed compound heterogomph chaetae (blade length ranging from 18 to 26 µm; cf. Table 11) and one supra-acicular simple chaeta distally bidentate. One stout protruding notoaciculum, up to 0.049 mm. Male genitalia with 6 to 8 pairs of consecutive copulatory organs, in chaetigers 33 – 38, 34 – 41, 40 – 47 (MB29–000240; cf. Table 11). Female sexual organs not visible externally (MB29–000239). Pygidium with two long anal cirri.

Distribution and habitat. This species occurred in fine gravel (33%), very coarse (33%), coarse (17%) and medium sand (17%), with low total organic matter content, usually below 1% of total sediment dry weight and high biogenic content (4.6% in average). Specimens were recorded mainly between 25 and 80 m deep (cf. Table 12). This work extends the distribution depth range of this species, previously recorded between 8 and 45 m (San Martín et al., 1999). The northern distribution limit of *P. guanche* is now extended to off Peniche (south of the Nazaré Canyon; Figure 31), being also present immediately south of the Setúbal Canyon, along the southwestern coastal shelf sector. This is the first record of *P. guanche* in the Lusitanean biogeographic province, increasing to five the number of species known for the European continental waters. *Pisione guanche* is presently known from three biogeographic provinces: the Macaronesia (San Martín et al., 1999; Moreira et al., 2010), the Lusitanean (this study) and the Mediterranean Sea (Çinar (2009) reported it as an alien species on the southern coast of Turkey).

Remarks. Dorsal cirri of chaetiger 2 is up to 3.3 times longer than the dorsal cirri of chaetiger 3 whilst San Martín et al. (1999) and Moreira et al. (2010) reported that the dorsal cirri of chaetiger 2 was only twice as long.

***Pisione inkoi* Martínez, Aguirrezabalaga and Adarraga, 2008**

Material examined. MB29–000241, 1 specimen, site PC89; MB29–000242, 1 specimen, site PC104. Additional material: see Martins et al. (2012c).

Brief description. Width of chaetiger 10 ranging from 0.25 and 0.62 mm, total length from 5.50 to 9.60 mm, with up to 47 chaetigers. Buccal aciculae protruding obliquely, not exceeding length of chaetiger 1, with subrounded distal margin. Prechaetal lobes bilobed in anterior chaetigers and entire on remaining segments. All dorsal cirri globular, small and similar in size (Table 11). Three types of chaetae: three long-bladed compound chaetae (blade length ranging from 39 to 65 µm; cf. Table 11), one short-bladed compound falciger and one supra-acicular simple chaeta, distally unidentate. One stout protruding notoacicula, up to 0.11 mm. Female genital chaetigers with a simple cirriform process developed ventrally at base of parapodium. Female gametes globular, with a diameter ranging from 40 µm to 89 µm, located in chaetigers 29 – 42 (MB29–000241). No males were found in our samples. Pygidium with two long anal cirri.

Distribution and habitat. This species occurred in fine gravel (33%), very coarse (33%), and medium sand (33%), with moderate total organic matter content, 2.4% of total sediment dry weight in average and low biogenic content (1.4% in average). Specimens of this species were recorded mainly in the western Portuguese coast, between 74 and 127 m deep (cf. Table 12). The present study extends the distribution depth range of *P. inkoi*, previously known from 56 to117 m (Martínez et al., 2008). This species was known for the northern Iberian Peninsula and this study extends its southern limit to the western sector of the Portuguese continental shelf (Figure 31).

***Pisione parapari* Moreira, Quintas and Troncoso, 2000**

Material examined. MB29–000243, 1 specimen, site PC91; MB29–000244, 1 specimen, site PC132. Additional material: see Martins et al. (2012c).

Brief description. Width of 10th chaetiger from 0.14 to 0.24 mm, total length from 2.24 to 7.60 mm, and total number of chaetigers ranging from 26 to 51. Buccal aciculae protrude obliquely the skin, not exceeding length of chaetiger 1, with a smooth distal margin. Prechaetal lobes entire. Dorsal cirri of chaetiger 2 is 1.3 to 1.6 times longer than the dorsal cirri of chaetiger 3 and following ones (cf. Table 11). All dorsal cirri globularpiriform, with a papilla with pilose tip, except on chaetiger 2 digitiform. Three types of chaetae: one long-bladed compound heterogomph chaeta with curved tip (blade length ranging from 21 to 28 µm; cf. Table 11), three short-bladed compound heterogomph chaetae and one supra-acicular simple chaeta distally bidentate. One stout notoaciculum embedded in all parapodia. Male genitalia with 2 to 3 pairs of copulatory organs appearing on chaetigers 11, 12, 21 (MB29–000243) or alternating on chaetigers 10, 18, 19, 20 in additional material (cf. Table 11). Female sexual organs not visible externally. Female gametes globular, with a diameter ranging from 38 µm to 64 µm, located in chaetigers 20 – 43 (MB29–000244) or earlier in additional material (19 – 28), depending on size of specimen. Pygidium with two long anal cirri.

Distribution and habitat. This species occurred in fine gravel (11%), very coarse (14%), coarse (63%) and medium sand (11%), with low total organic matter content, usually below 1% of total sediment dry weight and high biogenic content (5.9% in average). Specimens were recorded mainly in the near shore shelf of the western and southern Portuguese coast, between 3 and 80 m water depth, 24.6 m on average (cf. Table 12). The distribution depth range of this species is expanded since *P. parapari* was only previously recorded from 8 to 12 m (Moreira et al., 2000b). This species was only known in the northern Iberian Peninsula and this study extends its southern limit to the southern sector of the Portuguese continental shelf (Figure 31).

Remarks. In males, copulatory organs usually appeared in alternate parapodia, but in some cases they appeared in consecutive parapodia, which is not consistent with Moreira et al. (2000b).

Pisione remota **(Southern, 1914)**

Material examined. MB29–000245, 1 specimen, site R70; MB29–000246, 1 specimen, site PC91. Additional material: see Martins et al. (2012c).

Brief description. Width of 10th chaetiger ranged between 0.19 and 0.46 mm, total length up to 25.5 mm and maximum of 97 chaetigers. Buccal aciculae well developed and protruding, with slightly constricted distal ends subdistally and subrounded distal margin. Prechaetal lobe bilobed in anterior parapodia and entire in posterior ones. Dorsal cirri of chaetiger 2 similar to others in size and shape, bulbous with terminal papillae, ranging from 0.022 to 0.060 mm (cf. Table 11). Three types of chaetae: three short-bladed compound chaetae (longest blade up to 21 µm; cf. Table 11), one supra-acicular simple chaeta distally unidentate and one infra-acicular simple chaeta. One stout notoaciculum embedded in all parapodia. Male genitalia with 2 to 8 pairs of consecutive copulatory organs appear between chaetigers 29 and 32 (MB29–000246) or earlier in smaller specimens (16 – 17; cf. Table 11). Female genital chaetigers with a simple cirriform process developed ventrally at base of parapodium. Female gametes globular, with diameter ranging from 38 µm to 86 µm, 58 µm in average, located in chaetigers 29 – 74 (MB29–000245), earlier in smaller specimens (16 – 36). Pygidium with two long anal cirri.

Distribution and habitat. This species occurred mainly in coarse (42%) and very coarse (36%) sand and fine gravel (18%), with low total organic matter content, usually below 1% of total sediment dry weight and high biogenic content (6.6% in average; cf. Table 12). The species was recorded between 3 and 80 m depth, along the western and southern Portuguese coast (Figure 31). It is widely distributed along the North Atlantic, Mediterranean and Caribbean, at shelf depths (e.g. Dauvin et al., 2003; Lourido et al., 2010). A detailed revision of specimens from these other areas should be undertaken to confirm its cosmopolitan status (San Martín, 2004).

Remarks. In males, the number of pairs of successive copulatory organs varied between 2 and 8 which differed from the literature (4 – 18; San Martín, 2004). The distribution of female gametes was clearly related to body size, in agreement with Alikunhi (1951).

Multivariate analysis

The classification and ordination analysis based on selected morphological descriptors of *Pisione* species showed a clear separation of the four species (Figure 32). Axis 1 accounted for 46.6% of the total variation. On the positive pole, this axis separated the species with a proportionally longer dorsal cirri of chaetiger 2 and bidentate supra-acicular chaetae. On the negative pole, axis 1 separated the species with single unidentate supra-acicular chaeta, dorsal cirri of proportional similar length and an infra-acicular simple chaeta. This axis separated *P. guanche* and *P. parapari* on the positive pole, from *P. inkoi* and especially *P. remota* on the negative pole, this latter species being the single one with an infra-acicular simple chaeta. Axis 2 accounted for 31.5% of the total variation and showed the separation of species with higher width of the 10th chaetiger (W10) and with the highest ratio of the protruding length of the notoacicula and W10 on the positive pole (*P. inkoi*), from species with a lower W10 and aciculae embedded throughout the body (*P. parapari* and *P. remota*). The null hypothesis of no significant differences between the four species, on the basis of the selected morphological descriptors, was rejected with a very large value of the pseudo-F statistic ($p < 0.0001$), shown in Table 13.

Table 13 – Results of PERMANOVA main test and mean Euclidean distance between and within species.

Source	df	SS	MS	Pseudo-F	*p*
Species	3	332.09	110.70	207.33	0.0001
Residual	71	37.908	0.54		
Total	74	370			

	Pisione parapari	*Pisione remota*	*Pisione inkoi*	*Pisione guanche*
Pisione parapari	0.29			
Pisione remota	3.12	0.72		
Pisione inkoi	4.40	4.11	1.61	
Pisione guanche	3.70	4.83	4.80	1.86

Such strong rejection of the null hypothesis was due to a much larger sum of squares due to the species than the residual sum of squares, indicating that the intraspecific variability was much lower than the interspecific variability. A similar conclusion can be drawn from the inspection of the mean Euclidean distance within species and between species (cf. Table 13). The highest mean Euclidean distance within species was obtained with *P. guanche* due to the high variability of the W10 values among the specimens of this species. *Pisione parapari* presented the lowest mean Euclidean distance within species denoting a reduced intra species variability regarding the analyzed morphological descriptors. All pairwise comparisons between individual species also rejected the null hypothesis at $p < 0.0001$. Overall, the results showed that the interspecific variability was much higher than the intraspecific variability, supporting the validity of the four Iberian species of *Pisione*. The following key to the *Pisione* species of European waters is based on the understanding gained from the multivariate analysis:

Key to the European species of *Pisione*

1. Dorsal cirri of chaetiger 2 up to 3 times longer than dorsal cirri of chaetiger 3, supra-acicular chaetae bidentate 2
-. Dorsal cirri of chaetigers 2 and 3 of the same length, supra-acicular chaetae unidentate. 3
2. Notoacicula protruding from parapodial lobe, male copulatory organs appear in successive parapodia, dorsal cirri in chaetiger 2 from 2.3 to 3.3 times longer than in chaetiger 3 . . . . *P. guanche* San Martín, López and Núñez, 1999
-. Notoacicula not protruding from parapodial lobe, parapodia bearing male copulatory organs alternate with parapodia without these organs, dorsal cirri in chaetiger 2 from 1.3 to 1.6 times longer than in chaetiger 3 . . . .*P. parapari* Moreira, Quintas and Trancoso, 2000
3. Notoacicula protruding from parapodial lobe . . . .*P. inkoi* Martínez, Aguirrezabalaga and Adarraga, 2008
-. Notoacicula not protruding from parapodial lobe 4

4. With infra-acicular simple chaetae, prechaetal lobe bilobed in anterior parapodia, jaws without an inward projection . . . . *P. remota* (Southern, 1914)
-. Without infra-acicular simple chaetae, prechaetal lobes entire, jaws with an inward projection . . . .*P. puzae* Siewing, 1953*

* Not found in Iberian waters.

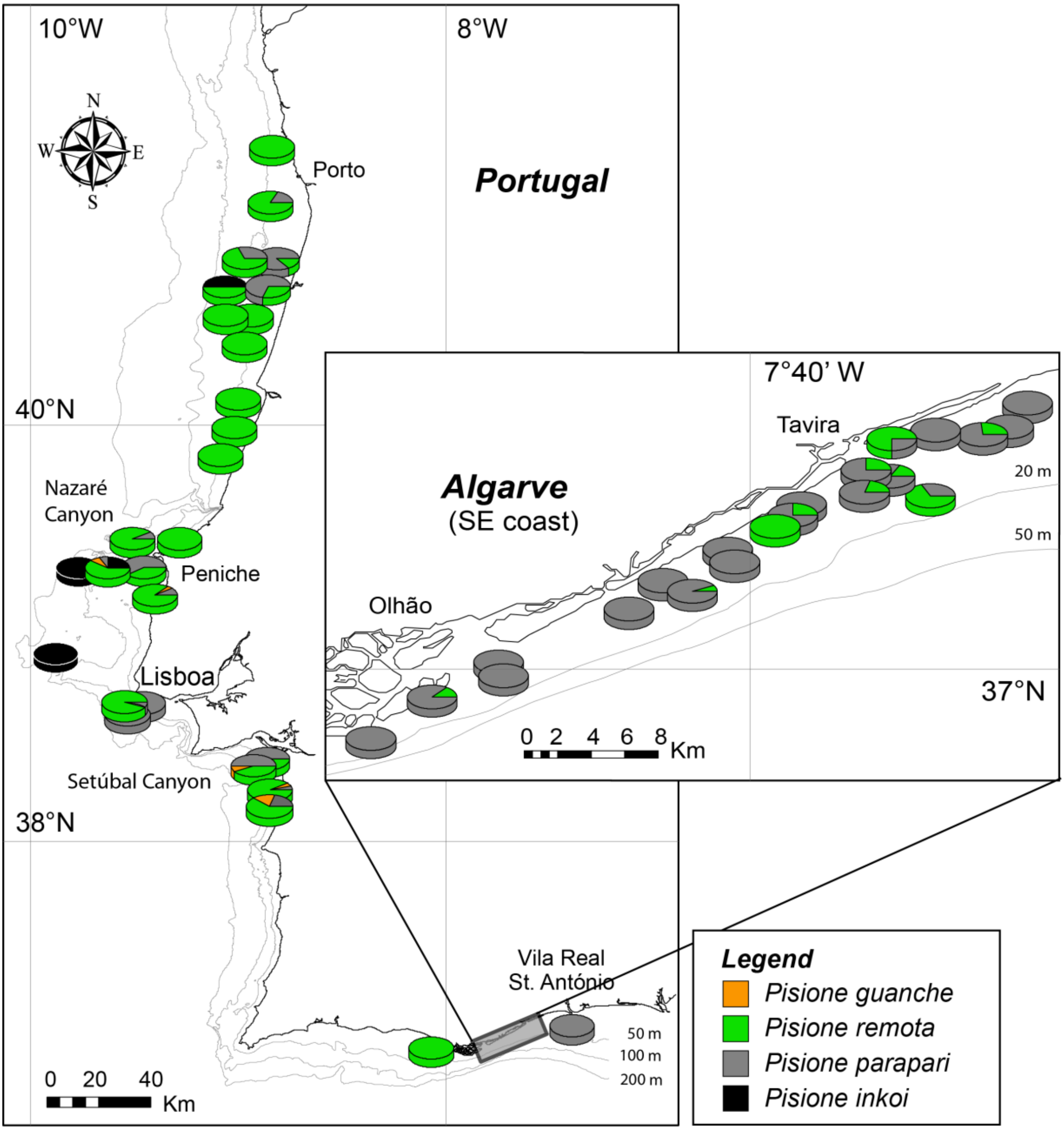


Figure 31 – Distribution and relative abundance of *Pisione* species along the Portuguese continental shelf (northeastern Atlantic).

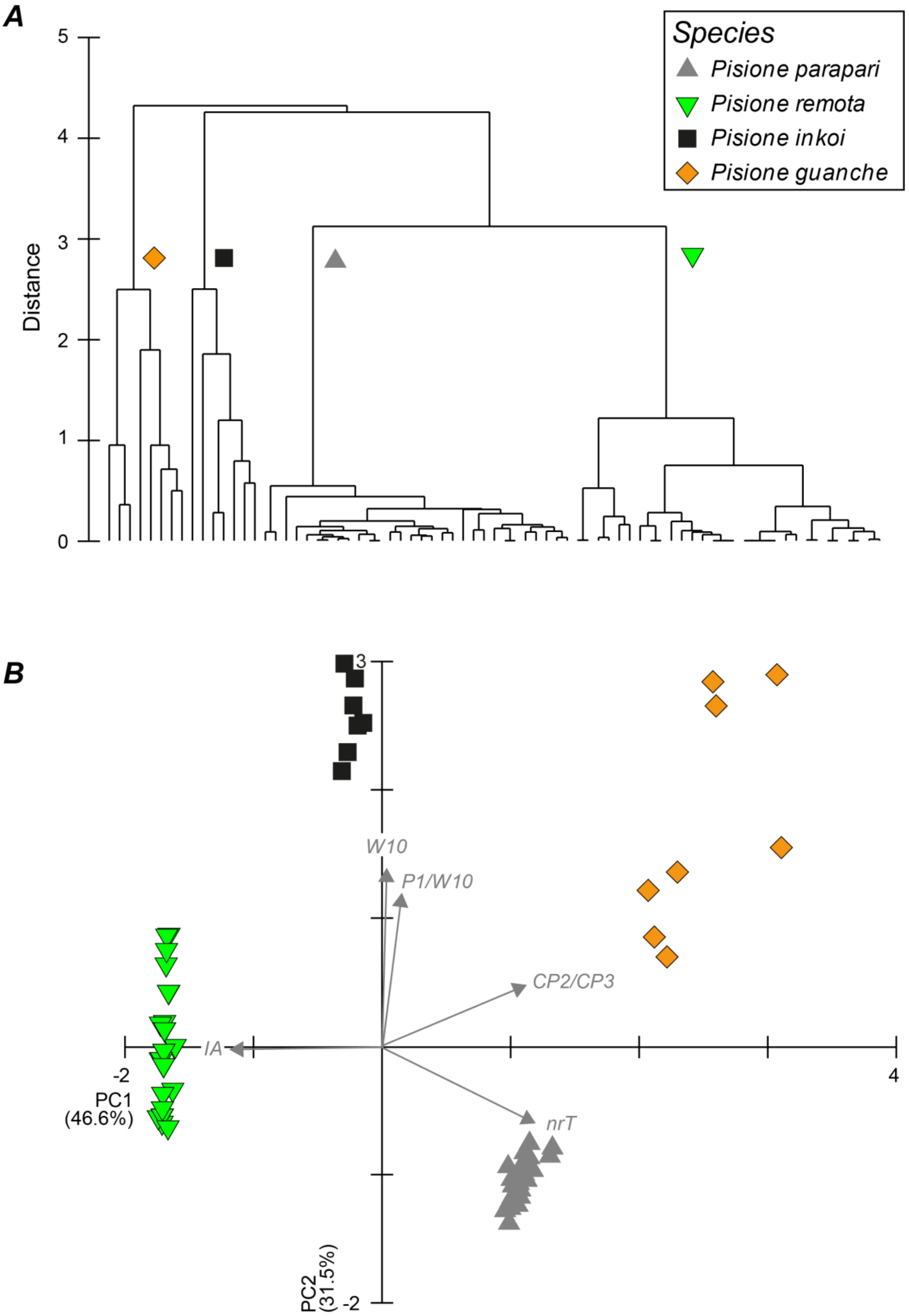


Figure 32 – Classification (A) and Principal Coordinates Analysis (B) based on morphological descriptors of the Pisione species occurring in the Portuguese continental shelf. Descriptors are represented as vectors. Legend: W10 – width at chaetiger 10; CP2/CP3 – ratio between the length of the dorsal cirri of parapodia 2 (CP2) and parapodia 3 (CP3); nrT – number of teeth of the supra-acicular chaetae; P1– protruding length of the notoaciculae; IA – presence/absence of infra-acicular simple chaetae.

Chapter 4

Discussion

4.1. *Physical habitat characterization*

4.1.1. Shelf sediments

The sedimentary seascape presented in this study is generally in agreement with the shelf sediments charts from the Portuguese Hydrographic Institute.[17] Recently the sediments from the Estremadura sector, unknown until 2012, were presented in MAMAOT (2012), confirming the heterogeneity of the shelf sediments.

The results obtained in the scope of the present investigation reveal that the Portuguese shelf sediments are composed by variable proportions of three main components (terrigenous, biogenic and authigenic).

4.1.1.1. Terrigenous component

All the samples of Portuguese shelf sediments contain terrigenous particles resulting from weathering of crustal continental rocks and transported by rivers as suspended load (e.g. Machado et al., 2005; Abrantes and Rocha, 2007). The high Al_2O_3 concentrations observed in the mud deposits point to a major terrigenous input, dominated by detrital clay minerals. Illite is probably the most abundant clay phyllosilicate, as indicated by the strong positive correlation between Al_2O_3 and K_2O and their low Na_2O and TiO_2 contents. However, the occurrence of smectite and chlorite particles, though not very expressive, can be inferred from the presence of positive correlations between MgO and Fe_2O_3 (T) and between Al_2O_3 and both Na_2O and TiO_2. As demonstrated by numerous authors, clay phyllosilicates have crystal lattices that can easily accommodate most trace metals and large reactive surface areas that enhance their adsorption ability (Bergaya et al., 2006 and references therein). The high positive correlation between Al_2O_3 and Ga, Pb, Ni, Zn, Cu and Cr appears therefore to reveal that these elements are predominantly fixed on clay minerals by preferential exchange and/or adsorption. The elevated SiO_2 contents recorded in the sandy sediments of the mid and near shore assemblages (C and D) suggest a significant contribution of detrital quartz. In the midshelf sandy samples (group C), Al_2O_3 and K_2O contents was also moderately high and positively correlated indicating that these deposits contain muscovite / illite and K-feldspar in addition to terrigenous quartz. Finally, the occurrence of pronounced Ba and Rb enrichments in the sediments of the muddy (A) and midshelf sandy assemblages (C) and their positive correlation with Al_2O_3 may reflect mineralogical partitioning of these elements between feldspars and phyllosilicates (mainly illite) (Shilts, 1995; Klassen, 1998).

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[17] http://www.hidrografico.pt, 28.10.2012

4.1.1.2. *Biogenic component*

The highest concentrations of CaO were found in the fine and very fine sand deposits (affinity group B) and may be primarily ascribed to the occurrence of carbonate minerals (aragonite, calcite and Mg-calcite) from skeletal debris of marine organisms. As shown in section 3.3, CaO contents define distinctive positive correlations with MgO, Sr and U. This can be attributed to the following reasons: magnesium is easily incorporated in Mg-calcite and/or aragonite, Sr substitutes Ca in calcareous shells of marine organisms (mainly aragonitic) and, to a lesser extent, uranyl carbonate complexes can replace CO_3 or $CaCO_3$ groups in biogenic calcium carbonates (Scoffin, 1987; Faure, 1992; Russell, 2004; Basaham, 2009). Unlike Sr and U, MgO was positively correlated with Fe_2O_3(T) and may have been partitioned between smectitic clay and carbonate minerals.

4.1.1.3. *Authigenic component*

The lack of coherent variation patterns between Al_2O_3 and both Fe_2O_3 (T) and MnO suggests that Fe and Mn are not exclusively associated with lithogenous clay minerals and may also occur in authigenic iron-manganese oxides and oxyhydroxides (Dill, 2010). Fe and Mn are carried into the ocean as reduced species by river runoff. Upon introduction into seawater, Fe^{2+} and Mn^{2+} react with O_2 and are converted into insoluble oxides and oxyhydroxides. Some of these precipitates settle in the seafloor becoming part of the sediments, whilst others are fixed onto the surface of sinking sedimentary particles and originate crusts, nodules and thin coatings. Trace metals (e.g. Cu, Ni, Zn, Pb) tend to coprecipitate with or adsorb onto iron-manganese oxides (Libes, 2009 and references therein). In the shelf sediments, Fe_2O_3(T) were positively correlated with Ga, Pb, Ni, Zn, Cu, V, Cr, As and TOM suggesting that trace metal adsorption and co-precipitation with secondary Fe-Mn oxides and oxyhydroxides may have occurred, leading to some decoupling in their distribution (Stockdale et al., 2010). Therefore, the strong metal enrichment observed in the Tagus and Guadiana mud patches (Group A) reflects the co-existence of both clay minerals and authigenic minerals. On the other hand, the high SiO_2, MnO and As contents recorded in the coarse sand sediments of Group D suggest that the detrital quartz particles are coated by authigenic Fe-Mn oxyhydroxides enriched in arsenic. The presence of high positive correlations between P_2O_5 and both Fe_2O_3(T) and MnO contents indicates that P is mostly authigenic and has probably been removed from seawater (together with Fe) and adsorbed onto the surfaces of Fe-oxides and/or of Fe-Mn oxyhydroxide particles (Palmer, 1985; Dutkiewicz et al., 2005; Monbet et al., 2007).

4.1.2. Factors best related to the spatial distribution of the shelf sediments

The lithology of mainland, fluvial input, hydrodynamics, physiography of the shelf (slope, morphological barriers), biological activity, paleoclimatic changes and anthropogenic contamination are the factors best related with the grain size distribution pattern and chemical composition of the Portuguese surface shelf sediments.

4.1.2.1. Mainland lithology and fluvial input

The geochemical signature of the Portuguese shelf sediments supports a major riverine input and shows that the terrigenous component is mainly derived from weathering of igneous and metamorphic source rocks. This is entirely consistent with the lithology of the adjacent land areas, since the major Portuguese rivers drain predominantly Late-Proterozoic – Paleozoic metamorphic terrains (metapelites/metagreywackes) and Carboniferous granitoids from the Iberian Variscan basement. To a lesser extent, the Meso-Cenozoic cover deposits exposed along the western and southwestern margins of Iberia can also contribute to feed the shelf with particles of siliciclastic origin (Monteiro et al., 1982; Dias and Nittrouer, 1984; Paiva et al., 1997; Araújo et al., 2002; Alves et al., 2003b; Machado et al., 2005; Abrantes and Rocha, 2007; Mil-Homens et al., 2006, 2009). Despite the widespread occurrence of limestones within the Mesozoic formations, it is unlikely that the breakdown of these rocks provides abundant clastic material, due to their rapid dissolution during weathering. The effects of regional lithology on sediment composition are particularly well documented in the mud deposits of the southern shelf (Machado et al., 2005; Gonzalez et al., 2007). Most of the sediment supply for this sector of the shelf is delivered by the Guadiana River that flows through a region dominated by Carboniferous volcano-sedimentary sequences hosting some of the most important polymetallic massive sulphide deposits in Europe (Mil-Homens et al., 2007; Delgado et al., 2010). Recent studies reveal that the Iberian Pyrite Belt is the main source of trace elements (e.g. Ni, Cu, Hg, Cd, Zn, As, Pb) for the sediments of the Guadiana mud patch (Machado et al., 2005; Gonzalez et al., 2007; Delgado et al., 2010; Sánchez-García et al., 2010). Precipitation and topography have a strong impact on river flow patterns and discharge rates. In the highlands of northern and central Portugal, rainfall is heavier than in the low lying areas of the southern part of the country explaining the larger fluvial inputs observed along the northwestern shelf. The Douro and Tagus rivers are the main sediment suppliers for this sector of the shelf (Oliveira et al., 1982; Vale and Sundby, 1987; Jouanneau et al., 1998).

4.1.2.2. *Hydrodynamics and shelf morphology*

Due to the high energetic conditions affecting the western coast, this sector presents low content in fines particles. The strong currents and dominant NW swells are responsible for the longshore N-S drifting of sediments, the accumulation of terrigenous sand deposits in the shelf and the transportation of mud-sized particles to the deep sea (e.g. Jouanneau et al., 1998; Dias et al., 2002). However, the occurrence of three important mud patches associated with the Tagus, Douro, Minho rivers shows that, in some cases, the fine suspended load may be trapped in the shelf. This can be ascribed to the presence of bedrock morphological barriers of tectonic origin (as in the shelf off the Douro River) or to gentle shelf gradients and weak bottom currents (as in shelf off the Minho and Tagus rivers) (Drago et al., 1999; Jouanneau et al., 1998; Dias et al., 2002). The low energy regime, with predominant SW-S and SE swells, prevailing in the southern shelf and the gentle slope of its eastern sector explain the development of the extensive Guadiana mud patch (Gonzalez et al., 2007; Mil-Homens et al., 2007). Coastal erosion is favored by strong swells and currents. As a result of mechanical breakdown, the Mesozoic limestone cliffs can contribute with a small amount of non-biogenic carbonate particles (including dolomite) to the shelf sediments. In the same rationale, subordinate amounts of siliciclastic particles resulted of the coastal erosion deposits can also feed the shelf.

4.1.2.3. *Biological activity*

Most of the CaO present in the Portuguese surface shelf sediments is derivated from calcareous remains of marine organisms (mainly molluscs, echinoderms and foraminifera). Quantitative estimates provided by Monteiro et al. (1982) for a set of samples of carbonate sands from the Portuguese shelf show that their biogenic component is primarily composed by molluscan fragments (> 30%) and subordinate amounts of benthic foraminifera (5.3%), echinoderms (3.6%) and other biological groups (24.6%). As a result of the upwelling of cold and nutrient-rich Eastern North Altantic Central Water, the marine biological productivity can be highly enhanced in several areas of the shelf (Fiúza et al., 1982; Fiúza, 1983; Peliz et al., 2005; Martins et al., 2006a, 2006b). These coastal upwelling events contribute directly to increase the nutrient availability and support a complex oceanic food chain, involving phytoplankton, zooplankton and fish (Schulz and Zabel, 2006 and references therein).

4.1.2.4. Paleoclimatic changes

In the final stages of the Pleistocene glacial period (16 k-13 k years BP), sea level was nearly 100 m below its present position and the shoreline was located several kilometres to the west of the actual coastline (Dias et al., 2000). Due to rapid sea level highstands in the deglaciation period and the Holocene, the terrigenous sediments accumulated at the edge of the paleocontinental shelf were preserved as relict deposits in the inner and middle shelf of the Northwestern sector, at depths between 20 and 80 m (Dias et al., 2000). Their depletion in mud-sized particles is attributed to subsequent reworking in high-energy hydrodynamic conditions (Dias and Nittrouer, 1984). Some of the coarse sands included in Group C were collected in the middle and inner shelf of the Northwestern sector and may therefore correspond to relict deposits.

4.1.2.5. Anthropogenic contamination

Recent studies have shown that, in addition to natural processes, the input of contaminants, via industrial, mining and/or domestic wastes, can increase the concentration of toxic heavy metals in river sand causing an important land to sea transfer of contamination in marine and estuarine areas (Karageorgis et al., 2005; Roussiez et al., 2006; Gonzalez et al., 2007; Radakovitch et al., 2008; Mil-Homens et al., 2009; Jesus et al., 2010; Nobi et al., 2010). The calculation of enrichment factors (EFs) provides a powerful tool for assessing the impact of anthropogenic activities in marine sediments and the environmental quality of continental shelves (Liaghati et al., 2004; Mil-Homens et al., 2007; Alagarsamy and Zhang, 2010; Delgado et al., 2010; Nobi et al., 2010; Sanchéz-García et al., 2010). The high concentrations of some trace metals (e.g. Zn, Pb, Cr and As) recorded in the samples from the Tagus and Guadiana patches (Group A) can be, at least in part, derived from anthropogenic contamination. The acid mine drainage associated with the exploration of polymetallic sulphide deposits from the Iberian Pyrite Belt (e.g. Neves Corvo and S. Domingos mines) has probably concurred to produce the strong metal enrichments observed in the mud sediments of the southern shelf (Mil-Homens et al., 2007; Delgado et al., 2010). On the other hand, it is unlikely that the elevated Pb, Cr, Zn and As contents found in the Tagus mud samples result from natural factors, pointing to an anthropogenic input from widespread industrial and urban wastes mobilized from the soils of the adjacent estuary margins (Paiva et al., 1997, Mil-Homens et al., 2007; 2009). As shown in several studies, coal / oil combustion and industrial activities are the main sources of Pb, Cr, Zn and As in worldwide shelves (e.g. Roussiez et al., 2006; Choi et al., 2007; Radakovitch et al., 2008; Reimann et al., 2009; Nobi et al., 2010). Pb and Zn can also be supplied from the atmosphere by man-made aerosols and the use of leaded gasoline is referred to as a major source of Pb contamination (Roussiez et al., 2006; Radakovitch et al., 2008). In some sandy samples from the western shelf, As and Cr are also enriched displaying scattered distribution patterns with no obvious relation to sediment grain-size or chemical composition. Most of these samples are located in the proximity of large urban centres, industrial complexes with pyrite roasting plants and smelters (Estarreja, NW Portugal; Barreiro, near Lisbon), ports and harbours (Sines, Setúbal, Figueira da Foz, Aveiro, Leixões), where transfer of pollutants from continent to offshore may occur (e.g. Cotté-Krief et al., 2000; Reimann et al., 2009).

4.1.3. Sediment quality guidelines

The NOAA (National Oceanic and Atmospheric Administration) and US-EPA (United States Environmental Protection Agency) monitoring programs have released large databases on sediment chemistry and toxicity and provided a set of natural trace metal background levels in uncontaminated reference areas that can be used to establish sediment quality guidelines. In these guidelines, the Effects Range-Low (ER-L) represents the elemental concentration above which toxicity may begin to affect the most sensitive species and the Effects Range-Median (ER-M) threshold corresponds to the level of trace metal contents above which adverse biological effects will be more frequently observed (Long et al., 1995; Buchman, 1999). These levels were used for an initial assessment of sediment quality in the studied area. All the studied samples have trace metal concentrations below the ER-M values (Long et al., 1995; Buchman, 1999). However, the As and, to a much lesser extent, the Cr and Pb contents may exceed the ER-L recommended threshold. This is particularly evident in the muddy sediments collected off the Tagus and Guadiana estuaries, where the level of detected contamination, if not fixed, may constitute a potential environmental risk.

4.2. *Macrofauna diversity distribution patterns*

This study revealed a very diverse benthic macrofauna for the Portuguese continental shelf. The 319 polychaetes species represented 43% of the total number of species recorded in the present work, 737 species, which is in agreement with several other studies where polychaetes represented nearly half the total species richness (e.g. Ellingsen and Gray, 2002; Dauvin et al., 2004; Hoey et al., 2004). In the Western European margin 12269 species are known (8404 animals), from which 2244 are crustaceans, 1554 are polychaetes, 1304 are molluscs and 291 are echinoderms (Narayanaswamy et al., 2010). The present study includes almost 10% of the total animal species known in the Northeastern Atlantic, and up to 20% of the polychaetes, 13% of the molluscs, 11% of the echinoderms and 9% of the crustaceans known for the Western European margin. The total species richness here reported was higher in absolute terms comparing with all works focused on the soft-bottom benthic macrofauna diversity and/or benthic habitat mapping carried out in parts of the Portuguese shelf (Reis et al., 1982; Marques, 1987; Freitas et al., 2003a, b, 2011; Gaudêncio and Cabral, 2007), despite all of these studies surveyed smaller areas and mostly in the near shore coast. Other studies in European coasts also found lower number of species compared to the present work. In the Iberian coasts 496 species were recorded in the Ría de Aldan (27 sites, Lourido et al., 2010), 379 taxa in the Ría de Vigo (29 sites, Cacabelos et al., 2009) and 404 species in the Guipúzcoa continental shelf (North Spain; 13 sites, Martínez and Adarraga, 2001). Furthermore, in the Bay of Seine, English Channel, 172 species were recorded (55 sites; Dauvin et al., 2004), 223 species in the North Bay of Biscay (Hily et al., 2008), 193 species in the Belgian continental shelf (728 samples; Hoey et al., 2004) and 547 species in the Crete continental shelf (99 sites; Karakassis and Eleftheriou, 1997). Other broadscale studies, which spanned at least twice the area of this study, recorded higher number of species, namely, in the Norwegian continental shelf (nearly 2000 Km length, in 101 sites) where 809 species were found (Ellingsen and Gray, 2002) and in the North Sea (197 sites) where approximately 1500 species were recorded (Heip and Craeymeersch, 1995). Differences in sampling devices, in the number of samples, in the area covered, sedimentary heterogeneity, depth range and hydrodynamics should account for part of the diversity variability observed among the mentioned studies. However, considering the area covered in this study, nearly 20,000 Km^2, the length of the Portuguese coast, less than 1000 Km, the narrow shelf, 3 – 60 Km, the sedimentary cover, geomorphology and hydrodynamics, it is reasonable to conclude that the number of species found in this study was high.

Despite the present study revealed a great diversity of polychaetes, molluscs and crustaceans, the number of species known for these Portuguese faunal groups is higher, nearly 600 polychaetes (Gil, 2011), nearly 1200 molluscs (Macedo et al., 1999) and more than 250 crustaceans species of the order Amphipoda (Marques, 1989; Marques and Santini, 1990, 1993). Other past works carried out in the Portuguese coast spanned small and patchy areas and their main objective were mostly to present new records and diversity insights. Furthermore, the majority of the studies were done in shallow coastal areas (e.g. both Tagus estuary and Peniche coast, Amoureux and Calvário, 1981) and others in the continental margin (e.g. bathyal depths off Portugal and Morocco, Härtmann-Schröder, 1977). Some relevant exceptions include for instance, the contributions of Bellan (1960) and Gil and Sardá (1999) (for polychaetes of the southwestern and southern shelf sectors), Jesus and Fonseca (1998) (for echinoderms of the southwestern) or Marques and Bellan-Santini (1990, 1993) (for the amphipods of the northernmost, southwestern and southern Portuguese shelf). The contributions of Nobre (e.g. 1903 a, b, 1904, 1937, 1942) and Cúmano (e.g. 1939, 1945, 1953) were also very relevant to the knowledge of the molluscan and echinoderms faunas of Portugal, respectively.

In this study, the areas with the highest diversity were found in the southern sheltered shelf and those with the higher abundances in coarser sediments, on the western shelf. Low diversity and abundance were recorded in deep mud bottoms, and in fine sands of the near shore shelf, exposed to intense wave action, which were in turn dominated by some species (e.g. *Magelona johnstoni* in near shore fine sands or *Heteromastus filiformis* in muds). Similar conclusions were also achieved when polychaetes and molluscs groups were analysed separately, however crustaceans showed low abundance in coarse sands and high abundance in the sheltered southern shelf. The complexity and heterogeneity of sediments tend to increase the diversity while extreme hydrodynamic conditions, volcanism or anthropogenic factors concur to species impoverishment (Simboura et al., 2000). Coastal detritic and muddy detritic bottoms have been ascribed to the establishment of biodiversity hotspots (e.g. Pérès and Picard, 1964; Marques, 1987). Coarser sediments, due to their high small-scale heterogeneity, have been also recognized as being important hotspots (Rees et al., 2004). The intense hydrodynamic regime prevalent in the northwestern Portuguese shelf, which is more intense in the near shore western shelf, provides strong sediment instability and creates disadvantageous conditions for several species, namely polychaetes. This is in agreement with other works which observed a higher predominance of crustaceans and molluscs rather than polychaetes in near shore sands in the Mediterranean Sea (Picard, 1965) and in the western part of the southern Portuguese shelf (Marques, 1987). Muds were usually associated to low diversity due to high content in fines where species with high muddy affinity (which can be strict or tolerant) tend to inhabit those habitats (e.g. Picard, 1965). The decrease of diversity in those sediments may also be related to an organic enrichment (Quintino et al., 2001; Silva et al. 2004) and contamination with some trace metals, namely zinc, lead, chromium and arsenic, mostly due to anthropogenic activities (e.g. acid mine drainage, industrial and urban wastes), recorded in the Portuguese shelf mud patches (Martins et al., 2012a).

The four new Lumbrineridae species here presented (*Gallardoneris iberica* **sp. nov.**, *Lumbrineris luciliae* **sp. nov.**, *L. pinaster* **sp. nov.** and *L. lusitanica* **sp. nov.**) were recently described by Martins et al. (2012b). It is expectable that some of those new species can occur in other shelf areas of the Iberian Peninsula, mainly in the Gulf of Cádiz due to its seascape similarity with the eastern part of the southern muddy shelf. The crustaceans *Psammogammarus caecus* (Mediterranean species; Vonk et al., 2011), *Anapagurus pusillus* (Macaronesian species known for Azores and Canary Islands) and *Othomaera othonis* (cold-temperate species) are firstly reported for Portugal. The molluscs *Mercenaria mercenaria, Leptochiton asellus, Astarte borealis* and the commensal *Montacuta phascolionis*, well known in the northern Europe and in the Mediterranean Sea, are also firstly recorded in the Portuguese coast (Tebble, 1976; Macedo et al., 1999). The polychaete *Aricidea (Acmira) lopezi* is firstly reported for the Iberian fauna, increasing up to 13 the number of species of the genus *Aricidea* in Portuguese waters (Gil and Sardá, 1999). According to literature (e.g. Marques, 1987; Gil and Sardá, 1999; San Martín, 2003; Viéitez et al., 2004), several polychaetes species already known for the Spanish coasts are firstly recorded in the Portuguese shelf, from which we can highlight the following hesionids *Gyptis propinqua* and *Ophiodromus pallidus*, ophelids *Ophelia celtica* and *Ophelina modesta*, the scalibregamatid *Scalibregma celticum*, spionid *Prionospio pulchra,* pisionids *Pisione guanche*, *Pisione inkoi* and *Pisione parapari* (Martins et al., 2012c), and syllids *Myrianida brachycephala, Odontosyllis fulgurans, Opisthodonta serratisetosa, Parexogone gambiae, Parapionosyllis brevicirra, Plakosyllis brevipes, Sphaerosyllis bulbosa, Sphaerosyllis* sp. (description accordingly to San Martín, 2003), *Streptodonta pterochaeta, Streptosyllis bidentata, Syllides convolutus, Syllides edentatus, Syllis mercedesae, Syllis parapari, Syllis pontxioi* and *Synmerosyllis lamelligera.* The endemic Mediterranean species *Parexogone gambiae* and *Sphaerosyllis* sp. (San Martín, 2003; Musco & Giangrande, 2005) are firstly recorded in the Atlantic Ocean, more exactly in the southern Portuguese continental shelf and off Peniche, respectively. The introduction of the alien species *Prionospio pulchra,* known for the Japan seas and recently recorded in the Galician coast (e.g. Moreira et al., 2000a; Lourido et al., 2008), were probably due to anthropogenic activities, such as oceanic shipping (in ballast water) or bivalve aquacultures (Moreira et al., 2000a). Other species were firstly reported for the Portuguese shelf although they were already recorded in lagoons or estuaries, such as *Podarkeopsis capensis* (Mira estuary; Duarte, 2011) and *Microphthalmus similis* (Óbidos lagoon; Fonseca et al., 2006) or in the continental margin, like *Leiocapitella dollfusi* (Amoureux, 1974). This study stated that the species *Sabellaria spinulosa*, already known for Portugal (Saldanha, 1995), is spread all over the continental shelf. This small, tube-building polychaete worm can form reefs (habitat A4.221 in the EUNIS classification) or lives solitary or in small groups, encrusting pebbles, shells or bedrock (EUNIS habitat A5.611, named *S. spinulosa* on stable circalittoral mixed sediment) such was the case in this study. In some biogeographic zones, the OSPAR list states that this protected habitat is under threat and/or decline (Connor, 2010). This study also gives new insights about the ecology (sediments and bathymetry) and geographic distribution of several species (Martins et al., 2012a, b, *in press*). Seven species were firstly noticed in soft-bottoms, namely *Haplosyllis spongicola*, *Opisthodonta serratisetosa*, *Parexogone gambiae*, *Syllis gerlachi*, *S. armillaris*, *S. gracilis* and *S. mercedesae*, since they were previously associated to different hard bottom types (Lucas et al., 2012; San Martín, 2003). The meridional distribution limit of the Lusitanean species *Syllis mercedesae*, recently described for the continental slope off Galicia (NW Spain; Lucas et al., 2012), is now set in the southern Portuguese shelf. The distribution limit of *Syllis licheri* is now established between the Chausey Islands (English Channel; Olivier et al., 2011) and the Setúbal canyon vicinity. *Pisione inkoi* and *P. parapari* were known for the northern Iberian Peninsula and this study extends its southern limit to the western sector and southern sector of the Portuguese continental shelf, respectively. The northern distribution limit of *Pisione guanche* is now extended to off Peniche, setting the first record of *P. guanche* in the Lusitanian biogeographic province, increasing to five the number of species known for the European continental waters (Martins et al., 2012 c). The present work amplifies the distribution range of *Magelona lusitanica*, from the northernmost shelf sector to the southern shelf. The species *Anadara polii*, *Glycymeris nummaria* and *Leptochiton algesirensis* are southern species with their northern limit located in the southwestern shelf (Macedo et al., 1999). This study purposes an extension of the distribution of these species further north, in the northwestern shelf. It should be emphasized that several new species were recently described for the Portuguese shelf highlighting an increasing knowledge regarding the benthic fauna, particularly polychaetes, in this area and opening the possibility that more species can be described soon for the Lusitanean province. Besides the new lumbrinerids, other species were recently found in the continental shelf, namely the onuphid *Diopatra micrura* (Pires et al., 2010), the magelonid *Magelona lusitanica* (Mortimer et al., 2011), the syllid *Syllis licheri* (Ravara et al., 2004) and the gastropod *Fusinus albacarinoides* (Hadorn et al., 2009).

The highest molluscan diversity and abundance was mainly recorded in the northwestern shelf, in areas immediately south of Carvoeiro Cape and in the western part of the southern shelf. In the Portuguese nearshore coast, the northwest and the southern molluscan banks are exploited, pointing towards mainly to the surf clam, *Spisula solida*, although other species (e.g. *Glycymeris glycymeris*) could be occasionally taken for the canning industry, due to their strong food transformation potential (Gaspar et al., 2004, 2005). Bivalves dredge fishing is one of the most important fishing activities undertaken in the south (Pereira et al., 2007). The Portuguese Fisheries Institute have been assessing the conservation status of the explored banks (e.g. Gaspar et al., 2004, 2005), and from the list of most abundant species recorded there, this study found the striped venus (*Chamelea gallina*), the Norwegian egg cockle (*Laevicardium crassum*), the mature dosinia (*Dosinia exoleta*), the bean solen (*Pharus legumen*), the big tellina (*Arcopagia crassa*), the banded venus (*Clausinella fasciata*), the striped venus (*Chamelea striatula*) and the dog cockle (*Glycymeris glycymeris*). Other economically relevant resources, such as crustaceans (e.g. *Palaemon serratus, Cancer pagurus, Maja squinado,* or *Liocarcinus puber*, Borja et al., 2004) were not recorded or were irrelevant in terms of abundance, reflecting the limitation of this sampling strategy to catch highly motile species.

Finally, the recent focus in the diversity and ecology of the Portuguese shelf benthic macrofauna was also shown by Gil (2011), whom inventoried nearly 600 species of polychaetes in Portugal, and by the effort to map the seabed marine habitats of the southwestern European coast, including Portugal, within the MeshAtlantic project[18], based on few historic maps available[19] and new campaigns. Several scientific expeditions along the Portuguese deep sea and islands (Azores, Porto Santo, Desertas, Formigas and Berlengas) were also undertaken recently, under the M@rBis program of the authority of the Task Group for the Extension of the Portuguese Continental Shelf. Although none of them explored the Portuguese continental shelf, it is relevant to emphasize its importance to improve the benthic (and pelagic) fauna insight.

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[18] www.meshatlantic.eu, 24.10.2012

[19] www.rensub.com, 24.10.2012

4.3. *Soft-bottom benthic habitats*

This study identified six assemblages in the Portuguese continental shelf soft-bottom benthic macrofauna. Atlantic and Mediterranean benthic communities were described by Petersen (1918), Thorson (1957), Jones (1950), Pérès and Picard (1964), Picard (1965), Cabioch (1968), Glémarec (1973), Gentil (1976), Marques (1987), among others. The single study carried out in the Portuguese shelf, in the western part of the southern shelf sector, devoted to the study of the biocenosis was presented by Marques (1987). However, recently, the Portuguese implementation of the Marine Strategy Framework Directive (Continent subdivision) presented the knowledge of the soft-bottom macrobenthic communities (among several other subjects), dividing the Portuguese coast in three major depths (<50 m; 50 – 150 m; >150 m) and in three main geographical areas (northern border to Nazaré Canyon – Area A, Nazaré Canyon to Ponta da Piedade – Area B and Ponta da Piedade to Vila Real de Sto. António – Area C; (MAMAOT, 2012). A confidence level assessment was also provided. The methodology applied can be considered controversial, since it imposed a standard geographic and depth subdivision to the definition of the benthic communities and did not reflect their natural spatial distribution, such as the heterogeneity of the Portuguese shelf seascape (e.g. coarser sediments appear in both areas A and C or muds in areas B and C), like it was supposed to occur (e.g. Levinton, 2009). The coastal benthic habitat from the northern area (<50 m) mentioned in MAMAOT (2012), included a mixture of the most characteristic species from three shelf habitats described in this study (e.g. *Angulus pygmaeus* (A), *Angulus fabula* (B), *Amphiura chiajei* (C1)). Furthermore, the assessment of the confidence level presented in that work was low for the majority of the Portuguese shelf, reflecting the lack of information in several sectors and showing a clear weakness of the methodological strategy applied. Due to this reason and the difficult to match any of the assemblages identified in this study to those considered in MAMAOT (2012), they were not considered for comparison purposes.

4.3.1. Coarse sediments with *Protodorvillea kefersteini, Pisione remota* and *Angulus pygmaeus*

Within the six affinity groups defined in the present work, the coarser sediments assemblage (group A), characterized by *Protodorvillea kefersteini, Pisione remota* and *Angulus pygmaeus,* and several other species is recognized worldwide. It corresponds well to the *Venus* community identified in several European coasts (*Clausinella fasciata* (earlier *Venus*) – *Spisula elliptica* – *Branchiostoma lanceolatum*; Thorson, 1957) or to the gravels of *Astarte sulcata* – *Venus casina* (Glémarec, 1973) or to the biocenosis of coarse sands and fine gravels under the influence of bottom currents found in the Mediterranean French coast (Picard, 1965) or to the boreal offshore gravel association (Jones, 1950). The coarse sands of the northwestern Spanish inlets also supported similar assemblages, namely characterized by *Protodorvillea kefersteini*, *Branchiostoma lanceolatum* and *Polygordius lacteus* in the Ría de Aldan (Lourido et al., 2010) and by *Pisione remota, P. parapari,* several syllids species and *Polygordius appendiculatus* in the Enseñada de Baiona (Moreira et al., 2006). Although *Clausinella fasciata, Spisula elliptica* and *Astarte sulcata* were present in this study, the abundance of these northern species was residual here, comparing with other characteristic species. In turn, the present community shared several species with the Mediterranean biocenosis of Picard (1965), namely *Dosinia exoleta*, *Thracia villosiuscula, Sigalion squamosus*, *Pontocrates arenarius*, among others. Several species occurring in this assemblage, mostly syllids and pisionids, correspond to Lusitanean species and therefore, this replacement of species along the Eastern Atlantic coasts is probably due to biogeographic issues (e.g. Martins et al., 2012 b, c).

4.3.2. Near shore hydrodynamic exposed fine sands with *Magelona johnstoni, Urothoe pulchella* and *Angulus fabula*

The near shore hydrodynamic exposed fine sands assemblage (group B) presented low abundance, diversity and evenness, and was characterized by the polychaetes *Magelona johnstoni, Sigalion mathildae* and *Magelona filiformis*, the crustaceans *Urothoe pulchella* and *Megaluropus agilis* and the bivalves *Angulus fabula* and *Pharus legumen*. The strong hydrodynamic energy near the coast, due to the wave energy and currents may explain the generalized impoverishment of this community. The shallow pure sandy bottoms define a very particular habitat which is occupied by a well reported community. It has been identified as the *Angulus tenuis* and *Angulus fabula* boreal Lusitanean community (formerly *Tellina* genus for both species; Thorson, 1957), also as the boreal offshore sand association (Jones, 1950) or the fine sands with *Chamelea gallina* (formerly *Venus gallina*) and *Mactra stultorum* (formerly *Mactra corallina*) in the infralittoral étage of the North Gascony continental shelf (Glémarec, 1973) or the well sorted fine sands biocenosis in the French Mediterranean coast (Picard, 1965). In Portugal, a similar community was already documented by Reis et al. (1982) and Freitas et al. (2003b). Some of our species were not recognized in those European communities, like the magelonids which presented a very high mean abundance here or *Diopatra micrura*, a Lusitanean onuphid species from subtidal bottoms (Pires et al., 2010); however the majority of the species sampled in this study were shared with those mentioned, namely *Angulus fabula, Spisula subtruncata*, *Sigalion mathildae, Onuphis eremita, Diogenes pugilator*, *Pontocrates altamarinus*, among others.

4.3.3. *Abra alba* community in northwestern deep muddy sands

The affinity group C1 corresponds to the northwestern muddy sands deep community characterized by the polychaetes *Prionospio fallax*, *Chaetozone gibber* and *Prionospio aluta* (exclusive species) and the bivalves *Abra alba, Tellina compressa*, *Phaxas pellucidus* and *Thyasira flexuosa*. This community is ecologically relevant in our study due to its high abundance and species richness, particularly molluscs which can be important food resource for demersal fishes and to the occurrence of habitat structuring species, such as *Lanice conchilega* (Hoey et al., 2004). This faunal assemblage is also widely recognized in the Northern European shelves as the *Abra alba* (formerly *Syndosmya alba)* community defined by Petersen (1918), Thorson (1957), Glémarec (1973) or Hoey et al. (2004), or the boreal offshore muddy sand association (Jones, 1950) or the muddy fine sands with *Abra alba* and *Corbula gibba* (Cabioch, 1968; Gentil, 1976). This community, which was already reported in northwestern Spain (Lourido et al., 2010), was present in our study in muddy sands with moderate organic matter content, and also included the polychaetes *Nephtys hombergii, Lagis koreni, Pista cristata*, *Owenia fusiformis* and *Spiophanes bombyx.*

4.3.4. *Galathowenia oculata* and *Lumbrinerides amoureuxi* in southwestern very deep muddy sands

The southwestern shelf assemblage (C2) was characterized mostly by burrowers and tubicolous polychaetes, such as *Galathowenia oculata* and *Lumbrinerides amoureuxi*, and dominated in the muddy sands of the deepest seascape. Along the northern European shelves, several deep communities in mud or muddy sandy bottoms have been recognized: the sandy muds of *Nucula sulcata* and *Brissopsis lyrifera* in the North Gascony continental shelf (Glémarec, 1973), the circumpolar *Maldane sarsi* and *Ophiura sarsii* community (Thorson, 1957) or the *Brissopsis lyrifera* and *Ophiura sarsii* community (Petersen, 1918). The faunal composition of these assemblages however has little correspondence with the biological assemblage from our study, dominated by deep species (e.g. *Lumbrinerides amoureuxi*, *Magelona minuta*, *Magelona wilsoni, Saccella commutata*, *Fustiaria rubescens*) and of warmer waters (e.g. *Monticellina heterochaeta, Leiocapitella dollfusi*). The biological assemblage C2 is in fact more similar to two communities defined for the Mediterranean Sea, namely in the deep Crete continental shelf, dominated by *Tharyx* (now *Monticellina*) *heterochaeta, Sarsonuphis* sp. (here identified as *S. bihanica*) and *Terebellides stroemii* (Karakassis and Eleftheriou, 1997), and in the continental shelf off Marseille, with *Terebellides stroemii*, *Leiocapitella dollfusi*, *Golfingia (Golfingia) elongata* and *Amphiura filiformis* among others, corresponding to the biocenosis of the circalittoral muddy detritic bottoms (Picard, 1965). The difficulty to match the assemblage identified in this study with the Northeastern Atlantic and the Mediterranean communities reveals that it probably corresponds to a warm temperate deep group with influence of northern and southern species.

4.3.5. ***Euchone rubrocincta*** **and** ***Nematonereis unicornis*** **in muddy sands of the southern and sheltered shelf**

The southern muddy sand assemblage (C3) was characterized mostly by polychaetes, namely *Euchone rubrocincta* and *Nematonereis unicornis,* most of them corresponding to southern species with warm Lusitanean, Mediterranean or western African affinity (e.g. *Parapionosyllis brevicirra*, *Syllis garciai, Lumbrineris pinaster*, *Lumbrineris luciliae*, *Chaetopleura (Chaetopleura) angulata* or *Chiton (Rhyssoplax) olivaceus*). In the northern European coasts, two communities share a few species with C3: the facies of *Sthenelais boa* and *Eunice vittata* from the heterogeneous sediments in the Gulf of Normandy, France (Retière, 1979) and the community *Prionospio mulibranchiata* and *Thyasyra* spp*.* defined in the offshore of northern North Sea (Basford et al., 1990). The terrigenous coastal muds from the Mediterranean French coast shared the species *Goniada maculata*, *Magelona alleni*, *Malmgreniella lunulata*, *Paraprionospio pinnata*, *Necallianassa truncata* and *Othomaera othonis* (Picard, 1965), while a sandy mud circalittoral community in the Italian continental shelf also shared the species *Calyptraea chinensis*, *Nephtys cirrosa*, *Levinsenia gracilis* and *Paralacydonia paradoxa* (Somaschini, 1999). In the western part of the southern Portuguese shelf, Marques (1987) defined four circalittoral communities, being the coastal detritic biocenosis the closest to C3, having in common *Eunice vittata, Nephtys cirrosa*, *Drilonereis filum*, *Aponuphis brementi*, *Jasmineira elegans*, *Notomastus latericeus* and *Paralacydonia paradoxa*. Like in the southwestern affinity group, the biological assemblage here recognized did not largely overlap with other known communities. Benthic communities in circalittoral bottoms are usually more difficult to define according to Somaschini (1999), where transitional communities or facies can be established. The non-overlapping of the assemblages in the southern shelf can be related to biogeographic issues, to the spatial resolution in our study (other communities may be seen by increasing the sampling effort) or eventually due to temporal differences.

4.3.6. Muds of *Sternaspis scutata*, *Heteromastus filiformis* and *Psammogammarus caecus*

The muddy community (group D) with *Sternaspis scutata*, *Heteromastus filiformis* and *Psammogammarus caecus* occurred mostly in the southern shelf and off Lisbon. This macrofauna assemblage corresponds to the well-known mud shelf community spread along the European coasts. Glémarec (1973) named it muds of *Ninoe armoricana* and *Sternapsis scutata,* in the Atlantic French coast. In the southern Portuguese muddy bottoms Marques (1987) recognized two assemblages: the coastal muddy detritic biocenosis (fines content ranged up to 50%) and the deep mud biocenosis. Although the present community was established in muds, it showed highest resemblance with the coastal muddy detritic bioceonosis rather than the pure mud community from Marques (1987), sharing namely the polychaetes *Dasybranchus caducus*, *Heteromastus filiformis*, *Nephtys incisa*, *Glycera unicornis*, *Labioleanira yhleni*, *Sternaspis scutata* and the crustaceans *Alpheus glaber*, *Galathea intermedia* and *Goneplax rhomboides*. The two communities described by Marques (1987) presented high constancy and abundance of *Amphiura chiajei* and *Amphiura filiformis,* unlike what happened in the assemblage D in the present study, where both species presented very low constancy, and in the Guipúzcoa continental shelf (Martínez and Adarraga, 2001). Also, this assemblage did not overlap the equivalent Mediterranean deep mud biocenosis identified by Picard (1965). The moderate content in sand found in the samples (< 20%) may defined the settlement of mud-tolerant species instead of strict mud species, common in the “pure” mud biocenosis, such was highlighted by several authors (e.g. Picard, 1965; Marques, 1987). It is possible to state that this assemblage corresponded to a Lusitanean mud community according to the presence of Lusitanean species (e.g. *Dasybranchus caducus* and *Ninoe armoricana*). This may also justify some of the differences between the communities.

4.4. *Environmental – biological relationships*

Several works have shown the relationship between soft bottom benthic macrofauna and abiotic factors, such as sediments, habitats heterogeneity, depth, hydrodynamics, among others (e.g. Ellingsen, 2002; Hily et al., 2008; Lourido et al., 2010). This study showed that the spatial distribution of the benthic macrofauna along the Portuguese continental shelf was mainly related to the sediment grain-size, organic matter, depth and hydrodynamic energy.

Sediment grain-size and organic matter content have been identified as factors strongly related to benthic fauna spatial distributions (e.g. Dauvin et al., 2004; Hily et al., 2008; Lourido et al., 2010). It is widely accepted that species, particularly bivalves and polychaetes, show their higher abundance and biomass in a specified grain-size range (Hily, 1987). The Portuguese shelf macrofauna main groups corresponded well to a range of sediment types: coarse sediments (group A), purely fine sands (group B), muddy sands (groups C1, C2 and C3) and muds (group D). Such primary relationship with grain-size was also suggested for the Crete continental shelf (Karakassis and Eleftheriou, 1997), the Gulf of Lions continental shelf (Labrune et al., 2007), the North Bay of Biscay continental shelf (e.g. Hily et al., 2008), the Bay of Banyuls-sur-mer (northwestern Mediterranean Sea; Grémare et al., 1998), the Bay of Veys (English Channel; Dauvin et al., 2004), in Spanish Rías/inlets (e.g. Lourido et al., 2010), among others. The distribution of the sediments and their organic enrichment along the Portuguese shelf reflect the intensity of the hydrodynamics on the coast and the origin of the sediments (Martins et al., 2012a). The northwestern inner and mid shelf is dominated by clean coarse sediments indicative of the high hydrodynamic exposition to swells and currents and the paleodeposition of sediments in that area; sands with moderate organic matter content predominate in the deeper shelf and in the southwestern shelf due to the prevalent moderate hydrodynamic regime and the longshore N–S drifting of sediments (Martins et al., 2012a); finer sediments organically enriched (mostly muds) are prevalent in the sheltered southern coast and off the major rivers which contribute to an input of terrigenous particles (Martins et al., 2012a; Quintino et al., 2001; Silva et al., 2004). The northwestern shelf, due to the coarser sediments, provides several interstitial microhabitats for small-sized organisms, like pisionids, syllids, polygordiids and some bivalves. Byrnes et al. (2003) reported a direct correlation between gravel content in sediments and the abundance of some species, such as *Hesionura elongata*, *Pisione remota*, *Polycirrus* sp. and several syllids which correspond to gravel-inhabiting polychaetes. These species occupy and move through the interstitial space between the grains of gravel and sand which support high abundance and diversity. The abundance of the macrofauna was four to six times higher in gravel or coarser sand than in mud and the *alpha* diversity was 2.5 times higher in gravel than in mud.

Depth (or related descriptors) also shows some relationship with the distribution of the benthic macrofauna in the Portuguese shelf. It is recognized that marine biological distribution patterns are depth related in several continental shelves (e.g. Ellingsen et al., 2002; Dauvin et al., 2004; Moulaert et al., 2007; Serrano et al., 2008; Freitas et al., 2011). Our study highlighted the decrease of *alpha* diversity and abundance with increasing depth, as was documented all over the Mediterranean Sea (e.g. Coll et al., 2010; Karakassis and Eleftheriou, 1997) or in the eastern United States continental shelf (Bergen et al., 2001). The particular low abundance and diversity observed in the near shore sandy shelf community in our study should be mainly due to the exposure of this community to stressful hydrodynamic conditions and not to depth, as was also indicated by Pérès and Picard (1964), Cabioch (1968) or Reis et al., (1982). According to Saldanha (1995), the distribution of benthic fauna in the infralittoral zone (which can reach nearly 30 metres depth in the Portuguese coast) is mostly influenced by light intensity, hydrodynamic energy (induced by wave action) and sediments, rather than depth. Moreover, Brooks et al. (2006) revised several studies from the US eastern coast and Gulf of Mexico and found inconsistent relationships between depth and both macrofaunal diversity and abundance, depicting in some cases negative, positive and no relationships. Karakassis and Eleftheriou (1997) showed that the quality and quantity of chlorophyll *a*, which decreased with increasing depth, influenced the faunal community structure and contributed to the decrease in biomass, abundance and diversity. In shallow areas, depth must be used as surrogate of the hydrodynamic energy profile, as the effect of wave energy is higher than in deeper areas, where this effect is more residual (Bergen et al., 2001).

Latitude was also related to the distribution of the macrofauna assemblages along the Portuguese shelf. Diversity measurements (except *alpha* diversity) slightly decreased with increasing latitude, while an inverse pattern was found regarding the abundance data. It is recognized that species richness of benthic macrofauna, mostly gastropods, bivalves and isopods, decrease towards high latitudes in both southern and northern hemispheres, although few causal relationships have been identified to explain this pattern (e.g. Roy et al., 1998, 2004; Thorson, 1957). However, this pattern seems to be controversial since some works showed positive gradients with increasing latitude along the North Atlantic for nematodes (Lambshead et al., 2000) and polychaetes (Dauvin et al., 1994, Quiroz-Martinez et al., 2011), while others concluded that latitude was not a governing factor for macrofauna (e.g. Ellingsen and Gray 2002; Gobin and Warwick, 2006). In this study however, the latitudinal gradient can explain the co-occurrence of colder water species, from the Arctic-Boreal and the Boreal biogeographic provinces, and warmer water species, from the Lusitanean, the Mediterranean and the West African Transition biogeographic provinces, as the Portuguese shelf is the meeting place for subtropical warm and northern cold waters due to a complex current system acting along the Portuguese coast (Fiúza, 1983). The latitudinal distribution of species can also be affected by the variation of seawater temperature and rapid changes in shelf conditions, such as the presence of canyons or other morphological barriers (Cunha et al., 2011; Spalding et al., 2007). In fact, the major western Portuguese canyons (Nazaré, Lisboa and S. Vicente) may act as biogeographic barriers for the spatial distribution of several species along the Portuguese shelf, limiting colder species occurrence further south, such as *Ophelia celtica* or *Ophelina modesta*, and southern species progressing further north, e.g. *Anadara polii*, *Glycymeris nummaria*, *Leptochiton algesirensis*, *Pisione guanche* or *Parapionosyllis brevicirra*.

4.5. *Biogeography of benthic macrofauna species and communities*

The western Portuguese shelf acts as the southernmost limit for several species (e.g. *Ophelia celtica* (known for the English Channel and surrounding UK seas; Rowe, 2010), *Ophelina modesta* (known for the northeastern Atlantic Ocean; Rowe, 2010), *Syllis licheri*) and the northernmost limit for several others (e.g. *Aricidea (Acmira) lopezi*, *Pisione guanche, Parexogone gambiae, Parapionosyllis brevicirra*). In the other hand, the Portuguese macrofauna is composed by species with different biogeographic distribution: Temperate cold and/or Arctic-Boreal affinities (e.g. *Bathyarca pectunculoides, Leptochiton asellus, Abyssoninoe hibernica*, *Eunice harassii, Ophelina minima*), Lusitanean province (e.g. *Gallardoneris iberica* **sp. nov.**, *Lumbrineris luciliae* **sp. nov.**, *L. lusitanica* **sp. nov.**, *L., pinaster* **sp. nov.** (Martins et al., 2012b); *Pisione inkoi*, *P. parapari* (Martins et al., 2012c); *Syllis licheri*), Mediterranean and/or Macaronesian and/or West African provinces (e.g. *Turritella turbona*, *Vitreolina curva*, *Parapionosyllis brevicirra*, *Syllis garciai*, *Pisione guanche, Parexogone gambiae*). The high local diversity and the co-occurrence of cold, temperate and subtropical species show that this area is a transitional zone with high ecological and biogeographic importance, being remarkable the high number of species exclusively found in the southern shelf, most of them with Mediterranean or African affinities. Marques (1987) studying the benthic communities of the western part of the southern Portuguese shelf also highlighted the co-occurrence of a considerable number of species with Mediterranean, African and Boreal affinities. Furthermore, the French Atlantic fauna includes mostly fauna from Arctic-boreal/cold temperate areas while the French Mediterranean fauna is mostly composed by warm and temperate warm species (e.g.

Dauvin et al., 2006). The absence of African species in the French western coast and the progressive influence of Mediterranean and Africa faunas in the southwestern Iberia, particularly in the southern coast, indicate that the Portuguese shelf is a transitional biogeographic zone, between colder and warmer faunas. This is supported by previous studies of several faunal groups that referred the Portuguese coast as biogeographically important and one of the most interesting in the Northeastern Atlantic (e.g. Cúmano, 1945; Ardré, 1970). Saldanha (1974), Almaça (1985) and Marques (1989) highlighted the coexistence of both Mediterranean and Atlantic faunas along the Portuguese coast. Researchers involved in the most recent campaign of M@rbis, in the rocky substrata of Berlengas islands, found 120 new records of species for these islands, some of them with southern affinities, denoting an increased influence of warmer species along the Portuguese western shelf (based in press releases[20]). Ardré (1970, 1971) studied the marine algae of Portugal and set the distribution limit of more than 60 species in the Portuguese coast (e.g. Portugal was the southern limit for *Laminaria saccharina* and *L. hyperborea*, while it was the northern limit for *Amphiroa beauvoisii* or *Ulva linearis*). Marques and Santini (1990) observed high biogeographic affinities between the amphipods from the Portuguese coast and the Lusitanean, Mediterranean and Northern faunas, and concluded that the mixture of faunas was also related to the transitional characteristics of the Portuguese coast. Macedo et al. (1999) presented the most comprehensive study about the seashells of Portugal (based on the several malacological studies of D. Carlos de Bragança, Augusto Nobre, Fischer-Piétte, among others) and showed that several molluscs species have their distribution limit along the Portuguese shelf (e.g. *Dentalium inaequicostatum* or *Clausinella brogniarti* have their setentrional limit in the western coast while *Ensis arcuatus* and *Neptunea despecta* have their meridional limit in the Portuguese coast). The co-occurrence of species with different biogeographic affinities may be related to the hydrodynamic regime, the variation of seawater temperature, upwelling processes and rapid changes in shelf conditions, such as the presence of canyons or other morphological barriers (Spalding et al., 2007; Cunha et al., 2011). The deep indentation in the coastal rim of the Nazaré, Lisboa and Setúbal canyons, cutting the entire margin to the near shore coast, affect locally the currents and capture the sediment particles derived from the littoral drift and rivers input (Guerreiro et al., 2009). Similar disturbing effects are expected to occur in benthic species, particularly with those with limited larval dispersion capacity, affecting therefore their spatial distributions. The dominance of equatorward wind parallel to coastline and Earth rotation

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[20] http://ecosfera.publico.pt/noticia.aspx?id=1565989, 24.10.2012

(north winds), mainly in the northwestern coast, but also around the S. Vicente Cape promotes the occurrence of upwelling events which are responsible by the replacement of the surface coastal waters by cold, nutrient rich deep waters (Reboreda et al., 2010). Despite the increase of biological productivity in these periods, the seawater temperature decrease abruptly influencing the progression of warmer species further north and colder species further south. Moreover, the Portuguese margin is affected by a complex current system which favors the meeting of subtropical warm (from the Western Africa and Mediterranean Sea) and northern cold waters (Fiúza, 1983). This factor was also considered by Marques (1987), when he stated that the migration of African and Mediterranean species to the southern Iberia would be related to the influence of the dominant warmer currents in the Gulf of Guiné and Cádiz, mainly during summer.

Furthermore, the presence of three muddy sand communities along the Portuguese shelf, one in the northwestern deep shelf (mainly up to the Nazaré Canyon), other restricted mainly to the southwestern shelf (limited between the Nazaré Canyon and the southern boarder) and other with a distinct composition in the southern coast corroborate the main conclusion that the Portuguese shelf acts as transitional biogeographic zone, but also allow the definition of three main biogeographic areas:

a) the northern area, from the Portuguese northern border to the Nazaré Canyon, dominated by boreal/cold temperate and cosmopolitan (large ecological repartition) faunas; it must correspond to the southern boundary of the Lusitanean Cool biogeographic zone (Dinter, 2001).
b) a biogeographic transition area, between the Nazaré and S. Vicente capes. In this area, the Lisbon and the Setúbal canyons also plays a key role, since several species present their meridional or setentrional limits nearby these canyons. Due to the meeting of northern, warm temperate and subtropical species, this area must correspond to a transition between the two biogeographic zones defined by Dinter (2001). This also suggest that the Lusitanean Warm South and the Lusitanean Cool biogeographic zones do not meet in the S. Vicente canyons as proposed by Dinter (2001), but further North along the western coast, close to the Nazaré Canyon or eventually closer to the Lisbon or Setúbal canyons.
c) the southern shelf area with high abundance and frequency of warmer species with Mediterranean or African affinities (cosmopolitan species are also abundant). The southern shelf is already integrated in the Lusitanean Warm South biogeographic zone (Dinter, 2001).

The existence of boundaries delimiting biogeographic zones along the Portuguese coast was already presented and discussed in previous works. Cúmano (1939, 1945, 1953) defined three biogeographic zones according to the echinoderms fauna being their boundaries set in the Roca Cape and S. Vicente Cape. Species richness increases further south, particularly the Mediterranean species which increase from the Roca Cape to the Guadiana River mouth. In fact, the echinoderms fauna are mostly Boreal (and cosmopolitan) in the northernmost group (Minho River to Roca Cape), Atlantic-Mediterranean in the southwestern group and Atlantic-Mediterranean and Mediterranean in the southern group which clearly agrees with the divisions presented in this work (Cúmano, 1945). Lopes (1989) recognized two main biogeographic zones based on intertidal Demospongiae, nearly separated in the region between Peniche and Sintra. Pereira (2004) found two transitional areas along the rocky Portuguese beaches, studying the diversity and biogeography of the isopods: one in the Raso Cape and other in the S. Vicente Cape. Later, Pereira et al. (2006) studied the biogeographic patterns of intertidal epifaunal crustaceans (Amphipoda, Isopoda and Tanaidacea) and showed a gradient of species substitution between the three main areas sampled (northernmost coast, central western coast and southwestern coast) and significant differences in the species assemblages were found. As can be easily seen, the unmatching results achieved by those authors (Cúmano, 1939, 1945, 1953; Lopes, 1989; Pereira et al., 2004, 2006), keep controversial the identification of the biogeographic barrier between the Atlantic Ocean and Mediterranean Sea biotas. It is relevant to note that the boundaries here proposed are only one approach to explain the reality seen and, therefore are not rigid or static. The suggestion of a wider transition limit, which can easily incorporate the natural biota complexity, is in agreement with other authors (e.g. Olivero et al., 2012) that defended the idea that biogeographic regions may be limited by broad transition zones in some parts of their limits, whereas in other areas they may be defined by abrupt boundaries. Olivero et al. (2012) defined consistent biogeographic regions boundaries and biotic transition zones based on the amphibian species of the Mediterranean applying a combined methodology based on fuzzy logic and statistics. Therefore, future studies, applying this method or others, may improve the reliability of the biogeographic delimitation here proposed.

This work sets the first broadscale assessment of the soft-bottom macrofauna benthic biodiversity and the first overview of the benthic habitat distribution in the Portuguese continental shelf. It fulfill a historical gap in the marine environment knowledge at national level, of which seabed habitats are an essential component, and provide key baseline information for future works, such as, the study of fuctional aspects of the marine ecosystem or monitoring of anthropogenic perturbations (urban and/or industrial discharges, oil spills or fishing impacts) or temporal variation patterns. The quantitative data can be considered a baseline since the Portuguese shelf is globally non-polluted and the environment is anthropogenically undisturbed. The knowledge here enclosed may be used by itself or combined with other studies, to recognize habitats already known in the EUNIS classification (or other classification systems), to adapt and to improve their descriptions and to identify and to propose new habitats (if their distinctiveness, representativeness distribution and ecological importance justify it); to recognize, characterize and map the distribution of the most threatened habitat types at national level (e.g. red lists) and therefore to define, justify and propose Special Area of Conservation (set up under the Bern Convention[21] on the conservation of European wildlife and natural habitats) or Special Areas of Conservation of the Natura 2000 network[22] (which can be used for single species or habitats), under the application of the EU Habitats Directive (92/43/EEC)[23] and EU Biodiversity Strategy to 2020 (COM (2011) 244)[24], in line with the OSPAR Convention[25] and Convention on Biological Diversity[26]. The data here collected, can be used to manage the marine resources from the Portuguese coast, to assess their ecological status and the level of impact and recovery capacity when submitted to anthropogenic activities. This knowledge is key, because Portugal (and the EU members) must implement marine spatial planning approaches, in the sequence of diverse European legislation/directives (e.g. the Europe 2020 COM(2010) 2020[27], the Marine Strategy Framework Directive (2008/56/EC)[28]) and National legislation (e.g. Decree-Law 142/2008[29] which created the Nature Conservation Key Network and the National System for Classified Areas). These policies are intended to prepare marine environment management and planning measures to achieve and preserve the good marine environmental status of marine waters - including their biological diversity - by 2020 (Marine Strategy Framework Directive[1]) and fully protect the valuable natural marine heritage of Portugal and the marine resources from which economic and social activities depend on.

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[21] http://conventions.coe.int/Treaty/Commun/QueVoulezVous.asp?NT=104&CM=8&DF=&CL=ENG, 30.10.2012
[22] http://ec.europa.eu/environment/nature/natura2000/index_en.htm, 30.10.2012
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Chapter 5

Conclusions

The present study gives an overall view of the soft-bottom benthic habitats of the entire Portuguese continental shelf.

The grain size distribution and geochemical signature of the Portuguese shelf sediments are highly complex, reflecting strong differences in the sources (natural and anthropogenic), fluvial input, shelf morphology, hydrodynamism and biological activity.

Due to the high energetic hydrodynamic regime and large fluvial sediment supply, the northwestern and central shelf sectors display a general seawards decrease in grain size, with coarse relict deposits dominating in the inner and middle shelf, carbonate-rich fine sands characterizing the outer shelf and muds ruling the seascape off the mouths of major rivers (Douro and Tagus) and north of the Nazaré Canyon. The southwestern shelf consists mainly of carbonate fine sands of marine origin and lack significant riverine contributions. Finally, the southern shelf corresponds to a low energy environment receiving most of its sediment supply from the Guadiana River. As a result, an expressive mud patch is developed off the Guadiana estuarine system (eastern part) and heterogeneous muddy sands in western part. Trace metal enrichments were observed in the muddy areas from both the western and the southern shelf sectors, most of which appear to result from natural causes and do not exceed the international sediment quality thresholds. There is, however, local evidence for As, Zn, Cr and Pb anthropogenic contamination. The highest enrichment factor values for these trace metals are found in near-shore sediments delivered by rivers draining regions potentially polluted by urban, industrial or mine activities (Ave, Cávado, Lima, Douro, Tagus, Sado and Guadiana), highlighting the potential environmental risk of these sites.

A total of 30008 individuals were identified corresponding to 737 species. The most abundant taxa were the polychaetes, bivalves, nematodes, nemerteans and amphipods while the highest species richness was found within the polychaetes, bivalves, amphipods, gastropods and decapods. This work showed that the most frequent species were *Ampharete finmarchica, Ampelisca* sp. and *Lumbrineris lusitanica* **sp. nov.** and the most abundant were *Mediomastus fragilis*, *Polygordius appendiculatus* and *Ampharete finmarchica*. Four new species of polychaetes were found and nearly forty species are firstly reported for the Portuguese coast. Coarser sediments and very fine sands, shallow and sheltered areas presented higher diversity values while muds and deeper sites presented lower diversity. Six major soft-bottom benthic habitats were found in the Portuguese continental shelf: (a) coarse sediments with *Protodorvillea kefersteini, Pisione remota, Angulus pygmaeus* and several other interstitial species, such as polygordiids, syllids and nematodes (Lusitanean *Venus* community); (b) Near shore hydrodynamic exposed fine sands with *Magelona johnstoni, Urothoe pulchella* and *Angulus fabula* (Boreal Lusitanean *Tellina* community) and characterized by low abundance, diversity and evenness; (c) *Abra alba* community in northwestern deep muddy sands (with northern biogeographic affinity); (d) *Galathowenia oculata, Lumbrineriopsis paradoxa* and other burrowers and tubicolous polychaetes in southwestern very deep muddy sands (biological community with warmer affinity); (e) *Euchone rubrocincta, Nematonereis unicornis* and several warmer species in muddy sands of the southern and sheltered shelf; (f) Muds of *Sternaspis scutata*, *Heteromastus filiformis* and *Psammogammarus caecus.* Sediment grain-size, organic matter, depth and hydrodynamic regime were the best variables explaining the observed macrofauna distribution patterns.

Cosmopolitan and northern species (Cold temperate and Boreal affinities) dominated the northwestern sector being replaced by warmer species (Lusitanean, Mediterranean and African affinities) in the transition area between the Nazaré and S.Vicente canyons which ruled then the southern shelf. Therefore, the present study showed the ecological importance of this study area due to its high macrofauna abundance and diversity, as well as, highlighted their transitional characteristics, where both cold temperate, warm temperate and subtropical faunas can coexist.

This work sets the first broadscale assessment of the soft-bottom macrofauna benthic biodiversity in the Portuguese continental shelf and the first holistic map of the benthic habitats. It fulfill a historical gap in the marine environment knowledge at national level, of which seabed habitats are an essential component, and provide key baseline information for future works, since the majority of the Portuguese shelf is non-polluted and the environment is anthropogenically undisturbed. Furthermore, the scientific knowledge here presented can be used in the future, as a baseline, for future integrated studies to define strategies to better manage the Portuguese coast and its resources.

Chapter 6

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Annexes

Table 1 – Environmental data and geographic coordinates of all sites sampled along the Portuguese continental shelf. Hydrodynamics are simplified according to the hydrodynamic regime classification of Bettencourt et al. (2004) for the Portuguese coast (1 –sheltered coast; 2 – moderately exposed coast; 3 –exposed coast). G – gravel, VCS – very coarse sand, CS – coarse sand, MS – medium sand, FS – fine sand, VFS – very fine sand, M – mud, C – coarse sediment, Mx – mixed sediment, S – sand, mS – muddy sand and sM – sandy mud. n.a. – no available data.

Sites	Longitude	Latitude	Hydrodynamics	Depth (m)	Median (Φ)	Gravel (%)	Sand (%)	Fines (%)	Biogenic fraction (%)	TOM (%)	Sediment classification (Wentworth)	Sediment classification (Folk adapted)
2	-9.028267	41.863000	3	93.94	4.00	0.00	41.72	58.31	0.37	3.33	M	sM
3	-9.172200	41.862900	3	117.64	2.49	0.01	89.00	11.10	0.00	2.60	FS	mS
4	-9.259433	41.863200	3	130.76	3.22	0.00	77.05	23.01	0.06	3.51	VFS	mS
6	-9.158317	41.721567	3	114.00	3.99	2.78	47.50	49.78	0.28	4.32	VFS	sM
7	-9.058767	41.721883	3	95.70	2.61	0.00	83.99	16.08	0.11	1.93	FS	mS
9	-8.872850	41.590800	3	46.13	0.41	3.15	95.75	0.99	1.89	1.34	CS	S
10	-8.986550	41.589350	3	75.53	-1.11	54.62	41.31	3.97	1.99	0.73	G	C
11	-9.087433	41.589333	3	98.06	2.95	0.06	60.61	39.39	0.19	4.66	FS	mS
12	-9.201850	41.587083	3	127.72	2.52	0.00	91.93	8.16	0.22	1.60	FS	S
13	-9.163433	41.456167	3	128.25	2.60	0.00	86.33	13.67	0.07	1.88	FS	mS
16	-8.864433	41.459283	3	52.27	2.73	0.00	84.70	15.36	0.36	1.72	FS	mS
17	-8.786833	41.324617	3	33.19	0.49	0.05	99.36	0.58	1.85	0.79	CS	S
18	-8.830567	41.323450	3	42.64	-1.64	59.72	39.15	1.04	2.42	0.59	G	C
19	-8.947700	41.322567	3	72.00	3.50	0.14	58.44	41.37	0.60	2.06	VFS	mS
23	-9.058300	41.188217	3	96.86	4.00	0.00	2.20	97.74	0.00	4.08	M	M
24	-8.954700	41.189317	3	64.31	4.00	0.00	49.58	50.37	0.01	2.23	M	sM
25	-8.856533	41.189300	3	47.25	-0.42	28.30	67.52	4.10	8.34	0.85	VCS	C
26	-8.761150	41.186633	3	28.86	1.30	0.00	99.04	1.03	0.00	0.49	MS	S
27	-8.734533	41.058283	3	24.30	-0.55	38.84	60.63	0.38	1.59	0.40	VCS	C
28	-8.844850	41.057233	3	48.41	0.35	6.56	92.94	0.50	2.63	1.07	CS	C
31	-9.166900	41.059383	3	134.59	3.23	3.81	61.12	35.13	0.05	3.28	VFS	mS
39	-8.814500	40.788367	3	29.25	0.38	23.75	75.97	0.01	4.33	0.49	CS	C
40	-8.917167	40.790433	3	45.15	-1.23	58.44	41.46	0.04	5.40	0.40	G	C
41	-9.001733	40.788383	3	68.55	-0.66	40.94	58.58	0.37	0.53	0.87	VCS	C
42	-9.105117	40.787967	3	99.56	2.56	0.00	94.04	5.96	0.07	1.82	FS	S
45	-9.109517	40.649317	3	90.94	2.50	0.00	98.44	1.57	0.00	0.89	FS	S
46	-9.037267	40.653233	3	74.10	-0.60	38.10	61.39	0.50	1.82	0.62	VCS	C
47	-8.934517	40.653000	3	49.88	-0.57	38.54	61.19	0.19	1.32	0.49	VCS	C
48	-8.854850	40.654917	3	35.10	-1.10	52.90	46.87	0.14	9.86	0.49	G	C
51	-8.937117	40.515583	3	48.45	-0.06	18.66	81.37	0.00	1.48	0.40	VCS	C
52	-9.061067	40.516383	3	73.84	-0.75	37.41	61.56	0.49	0.43	0.53	VCS	C
53	-9.178983	40.532200	3	100.27	2.26	0.12	93.85	6.13	0.37	2.41	FS	S
58	-9.062117	40.380933	3	69.32	2.50	0.00	97.85	3.45	0.01	1.61	FS	S
59	-8.968500	40.380567	3	54.90	-0.30	14.02	85.57	0.36	6.72	0.99	VCS	C
60	-8.877267	40.379617	3	24.11	2.46	0.16	97.44	2.15	0.04	0.59	FS	S
61	-8.938150	40.246417	3	32.10	2.40	0.16	99.36	0.84	0.03	0.65	FS	S
62	-9.065067	40.248067	3	68.85	2.54	0.00	98.63	1.44	0.11	1.02	FS	S
63	-9.142167	40.250967	3	91.57	2.65	0.00	90.74	9.33	0.11	1.77	FS	S
67	-9.119650	40.113667	3	82.69	2.56	0.01	97.47	3.18	0.25	1.47	FS	S
68	-8.998767	40.113933	3	42.34	-1.50	62.45	37.32	0.03	1.77	0.80	G	C
69	-8.934317	40.113567	3	20.66	2.59	0.00	98.50	1.46	0.01	0.72	FS	S
70	-9.017650	39.977867	3	38.70	-0.80	42.24	57.11	0.58	0.22	0.48	VCS	C
71	-9.109667	39.977567	3	67.93	-0.84	45.99	53.34	0.68	5.60	1.28	VCS	C
72	-9.235467	39.978017	3	98.70	2.78	0.00	88.46	11.53	0.13	2.98	FS	mS
73	-9.377167	39.977233	3	125.51	3.43	0.00	68.10	31.98	2.04	4.87	VFS	mS
74	-9.383417	39.844900	3	123.67	4.00	0.00	31.01	68.99	1.20	3.89	M	sM
77	-9.083500	39.845530	3	48.19	-1.00	49.97	49.53	0.47	0.49	0.65	VCS	C
78	-9.129854	39.709600	3	49.24	2.84	0.00	93.15	6.65	0.01	0.94	FS	S
79	-9.184633	39.705483	3	90.30	2.61	0.00	95.46	4.53	0.03	0.85	FS	S
80	-9.300050	39.712050	3	119.92	4.00	0.00	14.09	85.85	0.00	7.06	M	sM
85	-9.280650	39.442533	3	44.47	-0.30	0.21	99.36	0.33	22.87	0.41	VCS	S
86	-9.401533	39.441033	3	88.88	2.50	0.00	79.76	19.91	0.61	4.93	FS	mS
87	-9.508767	39.444517	3	65.63	-0.04	13.11	86.40	0.50	8.07	1.51	VCS	C
89	-9.718917	39.304917	2	99.41	1.76	0.00	91.74	8.18	1.03	4.74	MS	S
90	-9.601917	39.304150	2	80.21	-1.77	71.21	28.58	0.20	1.27	1.72	G	C
91	-9.454483	39.306017	2	49.80	-0.17	3.74	94.79	1.33	1.62	0.69	VCS	S
92	-9.402000	39.308367	2	32.70	-1.41	73.08	25.75	1.09	12.43	0.97	G	C
98	-9.618800	39.048950	2	96.81	3.65	0.00	62.65	37.39	0.24	3.94	VFS	mS
101	-9.497517	38.909567	2	61.74	2.54	0.00	97.49	2.52	0.08	1.08	FS	S
102	-9.557750	38.907400	2	103.35	2.35	0.00	75.38	24.80	0.24	6.93	FS	mS
103	-9.695083	38.912683	2	127.39	2.06	0.50	76.65	22.85	0.60	4.31	FS	mS
104	-9.870033	38.906900	2	126.90	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
109	-9.577133	38.678000	2	100.46	4.00	0.00	1.67	98.33	0.03	9.26	M	M
110	-9.653650	38.676667	2	121.39	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
113	-9.470833	38.638500	2	87.19	4.00	0.04	1.49	98.72	0.35	8.70	M	M
114	-9.430183	38.668683	2	31.20	2.71	0.00	94.86	5.12	0.18	1.63	FS	S
115	-9.426117	38.589467	2	97.72	4.00	0.00	0.90	99.12	0.03	8.96	M	M
116	-9.427917	38.488400	2	137.40	4.00	0.00	45.19	54.78	0.03	6.19	M	sM
117	-9.367017	38.524950	2	110.17	4.00	0.01	3.50	96.55	0.01	8.24	M	M

Sites	Longitude	Latitude	Hydrodynamics	Depth (m)	Median (Φ)	Gravel (%)	Sand (%)	Fines (%)	Biogenic fraction (%)	TOM (%)	Sediment classification (Wentworth)	Sediment classification (Folk adapted)
118	-9.306400	38.571917	2	34.58	3.42	0.00	76.40	23.69	0.13	2.42	VFS	mS
119	-9.263850	38.600100	2	17.32	2.73	0.02	95.44	5.02	1.55	1.43	FS	S
122	-9.278050	38.417433	2	131.14	3.34	1.69	63.24	34.77	0.49	5.04	VFS	mS
123	-9.229183	38.360583	2	190.00	2.20	6.16	85.47	8.28	1.99	4.83	FS	C
124	-9.165000	38.344667	2	160.46	2.64	1.78	82.48	15.39	0.54	4.59	FS	mS
125	-9.166283	38.376917	2	120.86	3.06	1.86	64.07	34.08	1.40	3.66	VFS	mS
126	-9.168333	38.411167	2	33.60	-0.25	20.10	69.39	10.34	0.53	2.16	VCS	C
127	-9.100150	38.416483	2	99.56	4.00	0.00	24.22	75.72	0.32	7.78	M	sM
128	-9.074950	38.386650	2	116.70	2.93	0.01	76.58	23.48	0.17	2.88	FS	mS
132	-8.832683	38.368017	2	25.13	-0.14	16.03	83.72	0.07	5.80	0.31	VCS	C
133	-8.859167	38.344933	2	48.71	1.58	8.32	45.90	45.64	4.11	0.97	MS	Mx
134	-8.891433	38.305967	2	99.04	2.62	0.00	90.71	9.26	0.90	2.87	FS	S
135	-8.948167	38.252950	2	133.46	1.22	4.22	78.18	17.52	0.17	2.82	MS	mS
136	-8.869517	38.252833	2	100.95	1.23	6.66	65.97	26.84	0.40	3.68	MS	Mx
137	-8.818900	38.254383	2	37.50	0.25	17.23	82.16	0.53	3.79	0.54	CS	C
138	-8.826050	38.155567	2	40.99	-0.59	39.93	59.88	0.17	0.38	0.30	VCS	C
139	-8.865733	38.152700	2	92.70	0.11	0.34	98.38	1.08	1.33	1.51	CS	S
140	-8.963850	38.150317	2	133.72	2.63	0.75	80.97	18.35	0.29	2.96	FS	mS
141	-9.024717	38.154000	2	144.90	0.85	7.12	74.26	18.59	3.56	2.65	CS	Mx
146	-8.930167	37.954033	2	94.16	3.46	0.00	66.14	33.96	9.43	2.88	VFS	mS
147	-8.982367	37.956417	2	129.70	2.02	4.79	80.96	14.14	2.09	2.85	FS	mS
148	-9.038117	37.954433	2	168.19	0.79	14.40	67.80	17.62	0.16	4.23	MS	Mx
149	-9.043550	37.844800	2	195.00	1.38	4.99	81.60	13.45	0.54	2.95	MS	mS
150	-8.986800	37.850217	2	140.47	2.65	0.13	82.87	17.07	0.31	3.93	FS	mS
151	-8.924883	37.851900	2	100.72	2.78	0.00	81.05	18.98	0.17	3.29	FS	mS
158	-9.013567	37.655533	2	182.00	2.69	0.07	79.57	20.26	0.16	4.21	FS	mS
159	-8.936750	37.656633	2	136.13	3.16	0.00	75.92	24.07	0.29	3.47	VFS	mS
161	-8.830217	37.655250	2	42.04	2.60	0.00	96.41	3.61	0.08	2.11	FS	S
170	-8.869017	37.354417	2	36.90	2.08	0.26	98.88	0.78	0.60	1.08	FS	S
171	-8.942050	37.355917	2	96.60	2.62	0.00	88.53	11.52	0.46	2.65	FS	mS
172	-9.032517	37.350700	2	147.41	2.71	0.00	87.95	12.07	0.13	2.55	FS	mS
173	-9.050150	37.253733	2	123.07	2.67	0.01	87.72	13.13	0.61	2.51	FS	mS
175	-8.902567	37.250750	2	45.15	2.45	0.00	93.85	6.16	0.00	1.70	FS	S
176	-8.937855	37.154224	2	33.30	2.55	0.01	93.74	6.37	0.05	1.66	FS	S
180	-9.035483	37.038583	2	75.30	3.31	0.08	68.99	30.79	0.35	3.35	VFS	mS
181	-9.007617	37.030383	2	39.08	2.28	0.00	100.02	0.01	0.04	1.57	FS	S
186	-8.865233	36.939933	2	102.67	4.00	0.00	23.13	77.01	0.06	5.51	M	sM
187	-8.872933	37.016817	2	53.32	4.00	0.00	46.56	53.36	0.99	4.13	M	sM
188	-8.750517	37.032550	2	46.54	2.40	0.61	67.11	32.24	9.12	5.18	FS	mS
191	-8.647750	36.872017	1	179.29	1.79	0.66	82.91	16.49	6.55	3.54	MS	mS
192	-8.643150	36.920933	1	94.27	1.59	1.63	84.36	13.99	17.88	3.24	MS	mS
193	-8.642867	37.023667	1	47.50	2.53	0.00	80.32	19.65	5.29	3.85	FS	mS
194	-8.642450	37.078183	1	28.72	3.22	3.73	65.85	30.43	6.02	2.93	VFS	mS
195	-8.530567	37.086883	1	25.57	1.95	0.20	87.21	12.52	1.36	3.73	MS	mS
196	-8.530733	37.016250	1	46.13	2.42	0.20	71.45	28.55	3.18	4.13	FS	mS
197	-8.533150	36.908833	1	99.15	2.60	0.07	81.45	17.45	2.75	3.00	FS	mS
198	-8.413683	36.850383	1	129.22	4.00	0.25	44.28	55.80	2.53	4.78	M	sM
199	-8.421150	36.924350	1	98.70	4.00	0.00	20.77	79.17	0.24	7.10	M	sM
200	-8.421417	36.970350	1	62.06	3.75	0.02	53.09	46.88	3.56	4.58	VFS	mS
201	-8.421417	37.047667	1	32.74	2.68	0.00	79.69	20.29	6.44	3.91	FS	mS
202	-8.305050	37.036900	1	12.97	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	maërl	maërl
203	-8.303700	36.987633	1	48.75	3.99	3.96	46.09	49.91	4.64	5.43	VFS	sM
204	-8.301817	36.884433	1	100.05	4.00	0.02	8.76	91.20	0.09	8.48	M	M
206	-8.185117	36.845100	1	101.81	4.00	0.07	25.32	74.57	0.60	5.53	M	sM
207	-8.188417	36.903233	1	77.14	4.00	0.02	20.06	79.89	0.20	8.21	M	sM
208	-8.188033	36.950417	1	45.34	1.75	0.21	78.17	21.45	3.00	4.50	MS	mS
209	-8.186850	37.024933	1	31.16	3.29	0.55	61.09	38.39	4.57	4.79	VFS	mS
210	-8.070700	36.999400	1	25.00	-0.57	32.36	63.83	3.79	16.97	1.13	VCS	C
211	-8.073417	36.965567	1	38.25	3.48	0.00	60.26	39.84	1.80	4.62	VFS	mS
212	-8.071700	36.930800	1	48.11	2.60	0.00	62.34	37.47	2.32	4.10	FS	mS
213	-8.072067	36.881300	1	97.54	4.00	0.00	4.94	95.00	0.00	7.27	M	M
214	-8.072583	36.856567	1	173.74	4.00	0.04	0.50	99.48	0.00	8.88	M	M
215	-7.958733	36.888517	1	96.86	4.00	0.00	8.95	90.95	0.01	7.26	M	M
216	-7.954900	36.940233	1	43.88	4.00	0.00	29.52	70.56	2.89	7.43	M	sM
217	-7.834017	36.959033	1	54.15	4.00	0.05	43.19	56.73	2.60	6.23	M	sM
218	-7.828500	36.921567	1	92.92	2.88	0.13	59.54	40.35	5.30	5.44	FS	mS
219	-7.718600	36.950950	1	169.16	4.00	0.59	43.74	55.80	14.52	6.21	M	sM
220	-7.719550	36.973600	1	94.11	4.00	0.11	37.49	62.54	18.84	5.57	M	sM
222	-7.569767	37.098183	1	15.79	0.55	4.42	94.21	1.22	10.47	1.07	CS	S
223	-7.568933	37.055117	1	55.13	4.00	0.00	1.25	98.75	0.03	8.24	M	M
224	-7.568600	37.016583	1	86.92	4.00	0.00	8.48	91.52	3.29	9.18	M	M
225	-7.569550	36.955633	1	159.26	4.00	0.07	46.53	53.35	17.86	6.05	M	sM
226	-7.411550	36.935367	1	148.20	4.00	0.06	48.82	51.11	0.33	5.47	M	sM
227	-7.409483	36.995000	1	95.10	4.00	0.00	1.12	98.88	0.01	8.89	M	M
228	-7.406533	37.067250	1	46.46	4.00	0.00	1.34	98.70	0.07	7.79	M	M
229	-7.402000	37.115150	1	13.84	0.48	3.23	93.80	2.77	14.91	1.75	CS	S

Table 2 – Complete faunistic list with values of total abundance (A) and occurences (O) per species. Legend: * - Subphyllum Crustacea; ** - Subphyllum Hexapoda.

Phyllum	***Class***	***Family***	***Species name***	***A***	***O***
Annelida	Polychaeta	Lumbrineridae	*Abyssoninoe hibernica* (Mc Intosh, 1903)	53	32
Annelida	Polychaeta	Acrocirridae	*Acrocirrus frontifilis* (Grube, 1860)	23	9
Annelida	Polychaeta	Acrocirridae	*Acrocirrus* sp.	3	2
Annelida	Polychaeta	Nephthyidae	*Aglaophamus agilis* (Langerhans, 1880)	17	13
Annelida	Polychaeta	Ampharetidae	*Ampharete finmarchica* (M. Sars, 1864)	800	94
Annelida	Polychaeta	Sabellidae	*Amphiglena mediterranea* (Leydig, 1851)	3	1
Annelida	Polychaeta	Terebellidae	*Amphitrite cirrata* (O. F. Müller, 1771 in 1776)	15	8
Annelida	Polychaeta	Pilargidae	*Ancistrosyllis groenlandica* McIntosh, 1879	2	2
Annelida	Polychaeta	Spionidae	*Aonides oxycephala* (Sars, 1862)	239	31
Annelida	Polychaeta	Cirratulidae	*Aphelochaeta* sp.1	113	32
Annelida	Polychaeta	Cirratulidae	*Aphelochaeta* sp.2	10	8
Annelida	Polychaeta	Cirratulidae	*Aphelochaeta* sp.3	23	10
Annelida	Polychaeta	Cirratulidae	*Aphelochaeta* sp.4	2	1
Annelida	Polychaeta	Aphroditidae	*Aphrodita aculeata* Linnaeus, 1758	1	1
Annelida	Polychaeta	Onuphidae	*Aponuphis bilineata* (Baird, 1870)	335	65
Annelida	Polychaeta	Onuphidae	*Aponuphis brementi* (Fauvel, 1916)	129	38
Annelida	Polychaeta	Onuphidae	*Aponuphis grubii* (Marenzeller, 1886)	244	16
Annelida	Polychaeta	Onuphidae	*Aponuphis juvenile* sp. 1	15	12
Annelida	Polychaeta	Onuphidae	*Aponuphis juvenile* sp. 2	35	11
Annelida	Polychaeta	Oenonidae	*Arabella geniculata* (Claparède, 1868)	2	1
Annelida	Polychaeta	Oenonidae	*Arabella iricolor* (Montagu, 1804)	5	4
Annelida	Polychaeta	Archiannelida n.i.	Archiannelida n.i.	16	1
Annelida	Polychaeta	Paraonidae	*Aricidea (Acmira) assimilis* Tebble, 1959	37	15
Annelida	Polychaeta	Paraonidae	*Aricidea (Acmira) catherinae* Laubier, 1967	37	21
Annelida	Polychaeta	Paraonidae	*Aricidea (Acmira) cerrutii* Laubier, 1966	15	7
Annelida	Polychaeta	Paraonidae	*Aricidea (Acmira) lopezi* Berkeley and Berkeley, 1956	5	5
Annelida	Polychaeta	Paraonidae	*Aricidea (Allia) roberti* Hartley, 1984	73	32
Annelida	Polychaeta	Paraonidae	*Aricidea (Aricidea) pseudoarticulata* Hobson, 1972	55	16
Annelida	Polychaeta	Paraonidae	*Aricidea (Aricidea) wassi* Pettibone, 1965	25	14
Annelida	Polychaeta	Paraonidae	*Aricidea capensis bansei* Laubier and Ramos, 1974	5	2
Annelida	Polychaeta	Paraonidae	*Aricidea claudiae* Laubier, 1967	1	1
Annelida	Polychaeta	Paraonidae	*Aricidea simonae* Laubier and Ramos, 1974	4	3
Annelida	Polychaeta	Paraonidae	*Aricidea suecica* Eliason, 1920	1	1
Annelida	Polychaeta	Ophelliidae	*Armandia cirrhosa* Filippi, 1861	4	4
Annelida	Polychaeta	Terebellidae	*Artacama proboscidea* Malmgren, 1866	20	11
Annelida	Polychaeta	Sabellidae	*Bispira mariae* Lo Bianco, 1893	3	2
Annelida	Polychaeta	Sabellidae	*Bispira volutacornis* (Montagu, 1804)	4	2
Annelida	Polychaeta	Flabelligeridae	*Brada villosa* (Rathke, 1843)	30	11
Annelida	Polychaeta	Capitellidae	*Capitella tripartita* Hartman, 1961	3	2
Annelida	Polychaeta	Cirratulidae	*Caulleriella alata* (Southern, 1914)	231	9
Annelida	Polychaeta	Cirratulidae	*Caulleriella bioculata* (Keferstein, 1862)	28	11
Annelida	Polychaeta	Cirratulidae	*Caulleriella zetlandica* (McIntosh, 1911)	27	6
Annelida	Polychaeta	Ampharetidae	cf. *Lysippe labiata* Malmgren, 1866	2	2
Annelida	Polychaeta	Cirratulidae	*Chaetozone carpenteri* McIntosh, 1911	357	20
Annelida	Polychaeta	Cirratulidae	*Chaetozone gibber* Woodham and Chambers, 1994	37	17
Annelida	Polychaeta	Cirratulidae	*Chaetozone* sp.1	3	2
Annelida	Polychaeta	Cirratulidae	*Chaetozone* sp.2	64	33
Annelida	Polychaeta	Maldanidae	*Chirimia biceps* (M. Sars, 1861)	113	21
Annelida	Polychaeta	Amphinomidae	*Chloeia venusta* Quatrefages, 1866	14	10
Annelida	Polychaeta	Chrysopetalidae	*Chrysopetalum* cf. *debile* (Grube, 1855)	3	2
Annelida	Polychaeta	Cirratulidae	*Cirratulus* cf. *cirratus* (O. F. Müller, 1776)	8	7
Annelida	Polychaeta	Cirratulidae	*Cirriformia* sp.	12	7
Annelida	Polychaeta	Cirratulidae	*Cirriformia tentaculata* (Montagu, 1808)	5	4
Annelida	Polychaeta	Paraonidae	*Cirrophorus branchiatus* Ehlers, 1908	23	12
Annelida	Polychaeta	Paraonidae	*Cirrophorus furcatus* (Hartman, 1957)	9	4
Annelida	Polychaeta	Sigalionidae	*Claparedepelogenia inclusa* (Claparède, 1868)	1	1
Annelida	Polychaeta	Maldanidae	*Clymenella* cf. *torquata* (Leidy, 1855)	34	13
Annelida	Polychaeta	Cossuridae	*Cossura soyeri* Laubier, 1964	1	1
Annelida	Polychaeta	Capitellidae	*Dasybranchus* cf. *caducus* (Grube, 1846)	1	1
Annelida	Polychaeta	Onuphidae	*Diopatra micrura* Pires, Paxton, Quintino and Rodrigues, 2010	3	1
Annelida	Polychaeta	Onuphidae	*Diopatra* sp. Juvenile	1	1
Annelida	Polychaeta	Syllidae	*Dioplosyllis cirrosa* Gidholm, 1962	8	4
Annelida	Polychaeta	Flabelligeridae	*Diplocirrus glaucus* (Malmgren, 1867)	53	18
Annelida	Polychaeta	Serpulidae	*Ditrupa arietina* (O. F. Müller, 1776)	103	10
Annelida	Polychaeta	Oenonidae	*Drilonereis filum* (Claparède, 1868)	45	27
Annelida	Polychaeta	Phyllodocidae	*Eteone* sp.	20	13
Annelida	Polychaeta	Acoetidae	*Euarche tubifex* Ehlers, 1887	2	2
Annelida	Polychaeta	Sabellidae	*Euchone rubrocincta* (Sars, 1862)	52	13
Annelida	Polychaeta	Maldanidae	*Euclymene* cf. *droebachiensis* (M. Sars in G.O. Sars, 1871)	67	22
Annelida	Polychaeta	Maldanidae	*Euclymene* cf. *oerstedi* (Claparède, 1863)	52	26
Annelida	Polychaeta	Maldanidae	*Euclymene lombricoides* (Quatrefages, 1865)	5	3
Annelida	Polychaeta	Maldanidae	*Euclymene* sp. A	27	14
Annelida	Polychaeta	Maldanidae	*Euclymeninae* sp. A	11	4
Annelida	Polychaeta	Maldanidae	*Euclymeninae* sp. B	2	2
Annelida	Polychaeta	Phyllodocidae	*Eulalia mustela* Pleijel, 1987	52	18
Annelida	Polychaeta	Phyllodocidae	*Eumida sanguinea* (Örsted, 1843)	112	37
Annelida	Polychaeta	Nereididae	*Eunereis longissima* Johnston, 1840	74	24

Phyllum	***Class***	***Family***	***Species name***	***A***	***O***
Annelida	Polychaeta	Eunicidae	*Eunice harassii* Audouin and Edwards, 1834	4	3
Annelida	Polychaeta	Eunicidae	*Eunice* sp.	5	4
Annelida	Polychaeta	Eunicidae	*Eunice vittata* (Delle Chiaje, 1828)	451	57
Annelida	Polychaeta	Euphrosinidae	*Euphrosine armadillo* Sars, 1851	1	1
Annelida	Polychaeta	Terebellidae	*Eupolymnia nebulosa* (Montagu, 1818)	3	1
Annelida	Polychaeta	Syllidae	*Eurysyllis tuberculata* Ehlers, 1864	88	20
Annelida	Polychaeta	Syllidae	*Exogone (Exogone) naidina* Örsted, 1845	4	4
Annelida	Polychaeta	Syllidae	*Exogone (Exogone) verugera* (Claparède, 1868)	2	2
Annelida	Polychaeta	Fabriciidae	*Fabricia sabella* (Ehrenberg, 1836)	3	3
Annelida	Polychaeta	Serpulidae	*Filograna implexa* Berkeley, 1835	2	1
Annelida	Polychaeta	Serpulidae	*Filogranula calyculata* (O. G. Costa, 1861)	1	1
Annelida	Polychaeta	Owenidae	*Galathowenia oculata* (Zachs, 1923)	336	56
Annelida	Polychaeta	Lumbrineridae	*Gallardoneris iberica* (Martins, Carrera-Parra, Quintino and Rodrigues, 2012)	44	22
Annelida	Polychaeta	Glyceridae	*Glycera alba* (O.F. Müller, 1776)	44	26
Annelida	Polychaeta	Glyceridae	*Glycera celtica* O'Connor, 1987	1	1
Annelida	Polychaeta	Glyceridae	*Glycera convoluta* Keferstein, 1862	59	7
Annelida	Polychaeta	Glyceridae	*Glycera dayi* O'Connor, 1987	65	34
Annelida	Polychaeta	Glyceridae	*Glycera gigantea* Quatrefages, 1865	1	1
Annelida	Polychaeta	Glyceridae	*Glycera lapidum* Quatrefages, 1865	208	36
Annelida	Polychaeta	Glyceridae	*Glycera mimica* Hartman, 1965	9	6
Annelida	Polychaeta	Glyceridae	*Glycera oxycephala* Ehlers, 1887	6	5
Annelida	Polychaeta	Glyceridae	*Glycera unicornis* Savigny in Lamarck, 1818	60	42
Annelida	Polychaeta	Goniadidae	*Glycinde nordmanni* (Malmgren, 1866)	100	36
Annelida	Polychaeta	Goniadidae	*Goniada emerita* Andouin and Milne Edwards, 1834	1	1
Annelida	Polychaeta	Goniadidae	*Goniada maculata* Oersted, 1843	81	50
Annelida	Polychaeta	Goniadidae	*Goniadella gracilis* Verril, 1873	157	28
Annelida	Polychaeta	Goniadidae	*Goniadella* sp.	4	4
Annelida	Polychaeta	Hesionidae	*Gyptis propinqua* Marion, 1875	129	16
Annelida	Polychaeta	Syllidae	*Haplosyllis spongicola* (Grube, 1855)	11	4
Annelida	Polychaeta	Polynoidae	*Harmothoe antilopes* (McIntosh, 1876)	16	15
Annelida	Polychaeta	Polynoidae	*Harmothoe* cf. *impar* (Johnston, 1839)	2	1
Annelida	Polychaeta	Polynoidae	*Harmothoe fraserthomsoni* McIntosh, 1897	27	12
Annelida	Polychaeta	Polynoidae	*Harmothoe glabra* (Malmgren, 1866)	9	7
Annelida	Polychaeta	Polynoidae	*Harmothoe* sp.	1	1
Annelida	Polychaeta	Phyllodocidae	*Hesionura elongata* (Southern, 1914)	104	17
Annelida	Polychaeta	Capitellidae	*Heteromastus filiformis* (Claparède, 1864)	33	10
Annelida	Polychaeta	Onuphidae	*Hyalinoecia tubicola* (O.F. Müller, 1776)	14	10
Annelida	Polychaeta	Serpulidae	*Hyalopomatus marenzelleri* Langerhans, 1884	1	1
Annelida	Polychaeta	Serpulidae	*Hydroides norvegicus* Gunnerus, 1768	32	17
Annelida	Polychaeta	Nephthyidae	*Inermonephtys foretmontardoi* Ravara, Cunha and Pleijel, 2010	4	3
Annelida	Polychaeta	Ampharetidae	*Isolda pulchella* Müller in Grube, 1858	171	26
Annelida	Polychaeta	Sabellidae	*Jasmineira elegans* Saint-Joseph, 1894	147	49
Annelida	Polychaeta	Sigalionidae	*Labioleanira yhleni* (Malmgren, 1867)	51	25
Annelida	Polychaeta	Lacydoniidae	*Lacydonia miranda* Marion and Bobretzky, 1875	17	4
Annelida	Polychaeta	Aphroditidae	*Laetmonice hystrix* (Savigny in Lamarck, 1818)	3	3
Annelida	Polychaeta	Pectinariidae	*Lagis koreni* Malmgren, 1866	137	20
Annelida	Polychaeta	Terebellidae	*Lanice conchilega* (Pallas, 1766)	22	17
Annelida	Polychaeta	Spionidae	*Laonice bahusiensis* Söderström, 1920	39	22
Annelida	Polychaeta	Capitellidae	*Leiocapitella dollfusi* (Fauvel, 1936)	17	9
Annelida	Polychaeta	Maldanidae	*Leiochone leiopygos* (Grube, 1860)	66	34
Annelida	Polychaeta	Polynoidae	*Lepidasthenia brunnea* Day, 1960	5	5
Annelida	Polychaeta	Paraonidae	*Levinsenia gracilis* (Tauber, 1879)	60	39
Annelida	Polychaeta	Lumbrineridae	*Lumbrinerides amoureuxi* Miura, 1981	28	12
Annelida	Polychaeta	Lumbrineridae	*Lumbrineriopsis paradoxa* (Saint-Joseph, 1888)	64	19
Annelida	Polychaeta	Lumbrineridae	*Lumbrineris futilis* Kinberg, 1865	9	9
Annelida	Polychaeta	Lumbrineridae	*Lumbrineris latreilli* Audouin and Milne Edwars, 1834	1	1
Annelida	Polychaeta	Lumbrineridae	*Lumbrineris luciliae* (Martins, Carrera-Parra, Quintino and Rodrigues, 2012)	17	11
Annelida	Polychaeta	Lumbrineridae	*Lumbrineris lusitanica* (Martins, Carrera-Parra, Quintino and Rodrigues, 2012)	366	68
Annelida	Polychaeta	Lumbrineridae	*Lumbrineris pinaster* (Martins, Carrera-Parra, Quintino and Rodrigues, 2012)	128	25
Annelida	Polychaeta	Lumbrineridae	*Lumbrineris* sp.	10	5
Annelida	Polychaeta	Sabellariidae	*Lygdamis muratus* (Allen, 1904)	107	22
Annelida	Polychaeta	Eunicidae	*Lysidice ninetta* Audouin and Milne-Edwards, 1833	2	2
Annelida	Polychaeta	Magelonidae	*Magelona alleni* Wilson, 1958	110	31
Annelida	Polychaeta	Magelonidae	*Magelona filiformis* Wilson, 1959	106	15
Annelida	Polychaeta	Magelonidae	*Magelona johnstoni* Fiege, Licher and Mackie, 2000	427	14
Annelida	Polychaeta	Magelonidae	*Magelona lusitanica* Mortimer, Gil and Fiege, 2011	16	10
Annelida	Polychaeta	Magelonidae	*Magelona minuta* Eliason, 1962	39	14
Annelida	Polychaeta	Magelonidae	*Magelona wilsoni* Glémarec, 1966	38	19
Annelida	Polychaeta	Spionidae	*Malacoceros fuliginosus* (Claparède, 1870)	41	13
Annelida	Polychaeta	Maldanidae	*Maldane glebifex* Grube, 1860	2	2
Annelida	Polychaeta	Polynoidae	*Malmgreniella* cf. *arenicolae* (de Saint Joseph, 1888)	16	6
Annelida	Polychaeta	Polynoidae	*Malmgreniella* cf. *lunulata* (Delle Chiaje, 1830)	10	8
Annelida	Polychaeta	Polynoidae	*Malmgreniella* cf. *mcintoshi* (Tebble and Chambers, 1982)	3	2
Annelida	Polychaeta	Polynoidae	*Malmgreniella ljungmani* (Malmgren, 1867)	225	32
Annelida	Polychaeta	Polynoidae	*Malmgreniella* sp.	1	1
Annelida	Polychaeta	Eunicidae	*Marphysa bellii* (Audouin and Milne-Edwards, 1833)	19	8
Annelida	Polychaeta	Eunicidae	*Marphysa kinbergi* McIntosh, 1910	1	1
Annelida	Polychaeta	Capitellidae	*Mediomastus fragilis* Rasmussen, 1973	967	56
Annelida	Polychaeta	Neriliidae	*Meganerilla* sp.	10	1
Annelida	Polychaeta	Ampharetidae	*Melinna cristata* (M. Sars, 1851)	20	6
Annelida	Polychaeta	Ampharetidae	*Melinna palmata* Grube, 1870	35	12
Annelida	Polychaeta	Chaetopteridae	*Mesochaetopterus saggitarius* (Claparède, 1870)	5	5

Phyllum	***Class***	***Family***	***Species name***	***A***	***O***
Annelida	Polychaeta	Serpulidae	*Metavermilia multicristata* (Philippi, 1844)	6	6
Annelida	Polychaeta	Maldanidae	*Microclymene tricirrata* Arwidsson, 1906	5	4
Annelida	Polychaeta	Hesionidae	*Microphtalmus similis* Bobretzky, 1870	4	2
Annelida	Polychaeta	Spionidae	*Microspio mecznikowianus* (Claparède, 1869)	11	3
Annelida	Polychaeta	Cirratulidae	*Monticellina heterochaeta* Laubier, 1961	362	55
Annelida	Polychaeta	Cirratulidae	*Monticellina* sp.	23	15
Annelida	Polychaeta	Syllidae	*Myrianida brachycephala (Marenzeller, 1874)*	7	4
Annelida	Polychaeta	Owenidae	*Myriochele danielsseni* Hansen, 1878	137	29
Annelida	Polychaeta	Eunicidae	*Nematonereis unicornis* (Grube, 1840)	40	17
Annelida	Polychaeta	Nephthyidae	*Nephtys assimilis* Örsted, 1843	16	9
Annelida	Polychaeta	Nephthyidae	*Nephtys cirrosa* (Ehlers, 1868)	16	7
Annelida	Polychaeta	Nephthyidae	*Nephtys hombergii* Savigny in Lamarck, 1818	94	25
Annelida	Polychaeta	Nephthyidae	*Nephtys incisa* Malmgren, 1865	61	15
Annelida	Polychaeta	Nephthyidae	*Nephtys kersivalensis* McIntosh, 1908	127	45
Annelida	Polychaeta	Phyllodocidae	*Nereiphylla paretti* Blainville, 1828	6	4
Annelida	Polychaeta	Phyllodocidae	*Nereiphylla rubiginosa* (Saint-Joseph, 1888)	1	1
Annelida	Polychaeta	Nereididae	*Nereis zonata* Malmgren, 1867	15	9
Annelida	Polychaeta	Lumbrineridae	*Ninoe armoricana* (Glémarec, 1968)	21	13
Annelida	Polychaeta	Onuphidae	*Nothria* sp.	27	14
Annelida	Polychaeta	Capitellidae	*Notomastus latericeus* Sars, 1851	263	62
Annelida	Polychaeta	Amphinomidae	*Notopygos megalops* McIntosh, 1885	1	1
Annelida	Polychaeta	Syllidae	*Odontosyllis fulgurans* (Audouin and Milne-Edward, 1833)	1	1
Annelida	Polychaeta	Syllidae	*Odontosyllis gibba* Claparède, 1863	18	10
Annelida	Oligochaeta	Oligochaeta n.i.	Oligochaeta n.i.	510	56
Annelida	Polychaeta	Onuphidae	Onuphidae n.i.	12	6
Annelida	Polychaeta	Onuphidae	*Onuphis eremita* Audouin and Milne Edwards, 1833	1	1
Annelida	Polychaeta	Ophelliidae	*Ophelia celtica* Amoureux and Dauvin, 1981	3	2
Annelida	Polychaeta	Ophelliidae	*Ophelia radiata* (Delle Chiaje, 1828)	3	2
Annelida	Polychaeta	Ophelliidae	*Ophelia roscoffensis* Augener, 1910	1	1
Annelida	Polychaeta	Ophelliidae	*Ophelina minima* Hartmann-Schröder, 1974	18	9
Annelida	Polychaeta	Ophelliidae	*Ophelina modesta* Støp-Bowitz, 1958	1	1
Annelida	Polychaeta	Hesionidae	*Ophiodromus flexuosus* (Delle Chiaje, 1827)	2	2
Annelida	Polychaeta	Hesionidae	*Ophiodromus pallidus* (Claparède, 1864)	34	15
Annelida	Polychaeta	Syllidae	*Opisthodonta serratisetosa* López, San Marin & Jiménez, 1997	49	5
Annelida	Polychaeta	Orbiniidae	*Orbinia (Orbinia) sertulata* (Savigny, 1820)	2	2
Annelida	Polychaeta	Owenidae	*Owenia fusiformis* delle Chiaje, 1844	85	28
Annelida	Polychaeta	Syllidae	*Palposyllis prosostoma* Hartmann-Schröder, 1977	26	10
Annelida	Polychaeta	Polynoidae	*Panthalis oerstedi* Kinberg, 1856	27	12
Annelida	Polychaeta	Paraonidae	*Paradoneis armata* Glemarec, 1966	10	3
Annelida	Polychaeta	Paraonidae	*Paradoneis lyra* (Southern, 1914)	118	46
Annelida	Polychaeta	Syllidae	*Paraehlersia ferrugina* (Langerhans, 1881)	26	12
Annelida	Polychaeta	Paralacydoniidae	*Paralacydonia paradoxa* Fauvel, 1913	397	55
Annelida	Polychaeta	Terebellidae	*Paramphitrite tetrabranchia*Holthe, 1976	62	21
Annelida	Polychaeta	Phyllodocidae	*Paranaitis kosterensis* (Malmgren, 1867)	4	4
Annelida	Polychaeta	Syllidae	*Parapionosyllis brevicirra* San Martin, 1984	68	13
Annelida	Polychaeta	Syllidae	*Parexogone gambiae* Lanera, Sordino & San Martín, 1994	4	1
Annelida	Polychaeta	Syllidae	*Parexogone hebes* (Webster & Benedict, 1884)	2	2
Annelida	Polychaeta	Syllidae	*Parexogone* sp.	2	2
Annelida	Polychaeta	Spionidae	*Paraprionospio pinnata* (Ehlers, 1901)	87	42
Annelida	Polychaeta	Sabellidae	*Parasabella* sp.	2	2
Annelida	Polychaeta	Ampharetidae	*Parathelepus* sp.	3	3
Annelida	Polychaeta	Amphinomidae	*Pareurythoe* cf. *borealis* (M. Sars, 1862)	5	2
Annelida	Polychaeta	Pectinariidae	*Pectinaria (Amphictene) auricoma* (O.F. Müller, 1776)	18	8
Annelida	Polychaeta	Maldanidae	*Petaloproctus terricolus* Quatrefages, 1866	2	2
Annelida	Polychaeta	Pectinariidae	*Petta pusilla* Malmgren, 1866	1	1
Annelida	Polychaeta	Flabelligeridae	*Pherusa plumosa* (Müller, 1776)	4	4
Annelida	Polychaeta	Pholoidae	*Pholoe synophthalmica* Claparède, 1868	3	3
Annelida	Polychaeta	Phyllodocidae	*Phyllodoce lineata* (Claparède, 1870)	8	7
Annelida	Polychaeta	Phyllodocidae	*Phyllodoce longipes* Kinberg, 1866	11	11
Annelida	Polychaeta	Phyllodocidae	*Phyllodoce maculata* (Linnaeus, 1767)	26	11
Annelida	Polychaeta	Phyllodocidae	*Phyllodoce madeirensis* (Langerhans, 1880)	2	2
Annelida	Polychaeta	Phyllodocidae	*Phyllodoce rosea* McIntosh, 1877	20	7
Annelida	Polychaeta	Pisionidae	*Pisione guanche* San Martin, López and Núñez, 1999	11	5
Annelida	Polychaeta	Pisionidae	*Pisione inkoi* Martínez, Aguirrezabalaga and Adarraga, 2008	12	5
Annelida	Polychaeta	Pisionidae	*Pisione parapari* Moreira, Quintas and Troncoso, 2000	203	14
Annelida	Polychaeta	Pisionidae	*Pisione remota* (Southern, 1914)	308	23
Annelida	Polychaeta	Terebellidae	*Pista cristata* (Müller, 1776)	66	17
Annelida	Polychaeta	Terebellidae	*Pista lornensis* (Pearson, 1969)	37	25
Annelida	Polychaeta	Serpulidae	*Placostegus* cf. *tridentatus* (Fabricius, 1779)	2	1
Annelida	Polychaeta	Syllidae	*Plakosyllis brevipes* Hartmann-Schröder, 1956	32	9
Annelida	Polychaeta	Hesionidae	*Podarkeopsis capensis* (Day, 1963)	18	12
Annelida	Polychaeta	Poecilochaetidae	*Poecilochaetus serpens* Allen, 1904	66	40
Annelida	Polychaeta	Polychaeta n.i.	Polychaeta n.i. 1	1	1
Annelida	Polychaeta	Polychaeta n.i.	Polychaeta n.i. 2	1	1
Annelida	Polychaeta	Polychaeta n.i.	Polychaeta n.i. 3	5	2
Annelida	Polychaeta	Terebellidae	*Polycirrus medusa* Grube, 1850	99	33
Annelida	Polychaeta	Spionidae	*Polydora ciliata* (Johnston, 1838)	5	5
Annelida	Polychaeta	Spionidae	*Polydora cornuta* Bosc, 1802	34	14
Annelida	Polychaeta	Spionidae	*Polydora flava Claparède, 1870*	82	30
Annelida	Polychaeta	Polygordiidae	*Polygordius appendiculatus* Fraipont, 1887	890	34
Annelida	Polychaeta	Sabellidae	*Potamilla torelli* (Malmgren, 1866)	90	28
Annelida	Polychaeta	Maldanidae	*Praxillella affinis* (M. Sars in G.O. Sars, 1872)	3	2

Phyllum	*Class*	*Family*	*Species name*	*A*	*O*
Annelida	Polychaeta	Maldanidae	*Praxillella gracilis* (M. Sars, 1861)	4	4
Annelida	Polychaeta	Maldanidae	*Praxillura longissima* Arwidsson, 1906	1	1
Annelida	Polychaeta	Spionidae	*Prionospio aluta* Maciolek, 1985	55	8
Annelida	Polychaeta	Spionidae	*Prionospio ehlersi* Fauvel, 1928	124	22
Annelida	Polychaeta	Spionidae	*Prionospio fallax* Söderström, 1920	684	40
Annelida	Polychaeta	Spionidae	*Prionospio multibranchiata* Berkeley, 1927	96	21
Annelida	Polychaeta	Spionidae	*Prionospio pulchra* Imajima, 1990	20	7
Annelida	Polychaeta	Spionidae	*Prionospio* sp.	58	19
Annelida	Polychaeta	Spionidae	*Prionospio steenstrupi* Malmgren, 1867	119	20
Annelida	Polychaeta	Terebellidae	*Proclea graffi* (Langerhans, 1884)	2	1
Annelida	Polychaeta	Dorvilleidae	*Protodorvillea kefersteini* (McIntosh, 1869)	557	31
Annelida	Polychaeta	Hesionidae	*Psamathe fusca* Johnston, 1836	130	22
Annelida	Polychaeta	Phyllodocidae	*Pseudomystides limbata* Sain-Joseph, 1888	110	19
Annelida	Polychaeta	Spionidae	*Pseudopolydora antennata* (Claparède, 1869)	177	32
Annelida	Polychaeta	Ampharetidae	*Pterolysippe vanelli* (Fauvel, 1936) sensu Eliason, 1955, emend	305	34
Annelida	Polychaeta	Capitellidae	*Pulliella* sp.	79	16
Annelida	Polychaeta	Maldanidae	*Rhodine loveni* Malmgren, 1865	1	1
Annelida	Polychaeta	Sabellariidae	*Sabellaria spinulosa* Leuckart, 1849	12	7
Annelida	Polychaeta	Ampharetidae	*Sabellides octocirrata* (M. Sars, 1835)	2	2
Annelida	Polychaeta	Syllidae	*Salvatoria* sp.	1	1
Annelida	Polychaeta	Onuphidae	*Sarsonuphis bihanica* (Intes and le Loeuff, 1975)	405	40
Annelida	Polychaeta	Scalibregmatidae	*Scalibregma celticum* Mackie, 1991	9	6
Annelida	Polychaeta	Scalibregmatidae	*Scalibregma inflatum* Rathke, 1843	1	1
Annelida	Polychaeta	Scalibregmatidae	*Scalibregma* sp.	15	10
Annelida	Polychaeta	Dorvilleidae	*Schistomeringos neglecta* (Fauvel, 1923)	16	8
Annelida	Polychaeta	Dorvilleidae	*Schistomeringos rudolphii* (delle Chiaje, 1828)	10	6
Annelida	Polychaeta	Spionidae	*Scolelepis (Scolelepis)* cf. *cantabra* (Rioja, 1918)	9	6
Annelida	Polychaeta	Spionidae	*Scolelepis* cf. *tridentata* (Southern, 1914)	14	7
Annelida	Polychaeta	Lumbrineridae	*Scoletoma fragilis* (O.F. Müller, 1766)	3	2
Annelida	Polychaeta	Lumbrineridae	*Scoletoma* sp. 1	1	1
Annelida	Polychaeta	Lumbrineridae	*Scoletoma* sp. 2	1	1
Annelida	Polychaeta	Orbiniidae	*Scoloplos (Scoloplos) armiger* (Müller, 1776)	9	8
Annelida	Polychaeta	Orbiniidae	*Scoloplos typicus* (Eisig, 1914)	20	13
Annelida	Polychaeta	Serpulidae	*Serpula lobiancoi* Rioja, 1917	1	1
Annelida	Polychaeta	Sigalionidae	*Sigalion mathildae* Audouin and Milne Edwards in Cuvier, 1830	30	14
Annelida	Polychaeta	Sigalionidae	*Sigalion* sp.	1	1
Annelida	Polychaeta	Sigalionidae	*Sigalion squamosus* Delle Chiaje, 1830	8	4
Annelida	Polychaeta	Pilargidae	*Sigambra parva* (Day, 1963)	7	5
Annelida	Polychaeta	Phyllodocidae	*Sige fusigera* Malmgren, 1865	6	5
Annelida	Polychaeta	Syllidae	*Sphaerosyllis bulbosa* Southern, 1914	311	28
Annelida	Polychaeta	Syllidae	*Sphaerosyllis hystrix* Claparède, 1863	45	13
Annelida	Polychaeta	Syllidae	*Sphaerosyllis* sp.	38	6
Annelida	Polychaeta	Syllidae	*Sphaerosyllis taylori* Perkins, 1981	56	13
Annelida	Polychaeta	Spionidae	*Spio filicornis* (Müller, 1776)	560	35
Annelida	Polychaeta	Spionidae	*Spio multioculata* (Rioja, 1918)	1	1
Annelida	Polychaeta	Chaetopteridae	*Spiochaetopterus solitarius* (Rioja, 1917)	51	32
Annelida	Polychaeta	Spionidae	*Spiophanes bombyx* (Claparède, 1870)	267	47
Annelida	Polychaeta	Spionidae	*Spiophanes kroyeri* Grube, 1860	204	64
Annelida	Polychaeta	Serpulidae	*Spiraserpula massiliensis* (Zibrowius, 1968)	29	10
Annelida	Polychaeta	Serpulidae	*Spirobranchus lamarcki* (Quatrefages, 1866)	15	3
Annelida	Polychaeta	Serpulidae	*Spirobranchus polytrema* (Philippi, 1844)	2	1
Annelida	Polychaeta	Serpulidae	*Spirobranchus triqueter* (Linnaeus, 1758)	3	2
Annelida	Polychaeta	Sternaspidae	*Sternaspis scutata* Ranzani, 1817	19	9
Annelida	Polychaeta	Sigalionidae	*Sthenelais boa* (Johnston, 1833)	1	1
Annelida	Polychaeta	Sigalionidae	*Sthenelais limicola* (Ehlers, 1864)	44	19
Annelida	Polychaeta	Spionidae	*Streblospio* sp.	1	1
Annelida	Polychaeta	Syllidae	*Streptodonta pterochaeta* Southern, 1914	23	8
Annelida	Polychaeta	Polynoidae	*Subadyte pellucida* (Ehlers, 1864)	1	1
Annelida	Polychaeta	Syllidae	*Streptosyllis bidentata* Southern, 1914	4	1
Annelida	Polychaeta	Syllidae	*Syllides convolutus* (Webster y Benedict, 1884)	7	1
Annelida	Polychaeta	Syllidae	*Syllides edentatus* Westheide, 1974	1	1
Annelida	Polychaeta	Hesionidae	*Syllidia armata* Quatrefages, 1866	16	8
Annelida	Polychaeta	Syllidae	*Syllis armillaris* (O.F. Müller, 1776)	51	13
Annelida	Polychaeta	Syllidae	*Syllis garciai* (Campoy, 1982)	204	35
Annelida	Polychaeta	Syllidae	*Syllis gerlachi* (Hartmann-Schröder, 1960)	1	1
Annelida	Polychaeta	Syllidae	*Syllis gracilis* Grube, 1840	1	1
Annelida	Polychaeta	Syllidae	*Syllis licheri* Ravara, San Martín and Moreira, 2004	32	7
Annelida	Polychaeta	Syllidae	*Syllis mercedesae* Lucas, San Martín, Parapar, 2012	69	20
Annelida	Polychaeta	Syllidae	*Syllis parapari* San Martín and López, 2000	2	2
Annelida	Polychaeta	Syllidae	*Syllis pontxioi* San Martín and López, 2000	91	19
Annelida	Polychaeta	Syllidae	*Synmerosyllis lamelligera* Saint Joseph, 1887	53	12
Annelida	Polychaeta	Terebellidae	*Terebellides stroemii* Sars, 1835	140	44
Annelida	Polychaeta	Cirratulidae	*Tharyx marioni* (Saint-Joseph, 1894)	26	20
Annelida	Polychaeta	Cirratulidae	*Timarete* cf. *norvegica* (Quatrefages, 1866)	9	8
Annelida	Polychaeta	Cirratulidae	*Timarete* sp.	1	1
Annelida	Polychaeta	Opheliidae	*Travisia forbesii* Johnston, 1840	1	1
Annelida	Polychaeta	Syllidae	*Trypanosyllis coeliaca* Claparède, 1868	103	19
Annelida	Polychaeta	Serpulidae	*Vermiliopsis* sp.	1	1
Annelida	Polychaeta	Syllidae	*Xenosyllis scabra* (Ehlers, 1864)	23	6
Arthropoda*	Malacostraca	Melitidae	*Abludomelita gladiosa* (Bate, 1862)	3	1
Arthropoda*	Malacostraca	Melitidae	*Abludomelita obtusata* (Montagu, 1813)	1	1
Arthropoda*	Malacostraca	Mysidae	*Acanthomysis* cf. *longicornis* (Milne-Edwards, 1837)	1	1

Phyllum	***Class***	***Family***	***Species name***	***A***	***O***
Arthropoda*	Malacostraca	Alpheidae	*Alpheus* cf. *glaber* (Olivi, 1792)	6	5
Arthropoda*	Malacostraca	Ampeliscidae	*Ampelisca brevicornis* (Costa, 1853)	85	35
Arthropoda*	Malacostraca	Ampeliscidae	*Ampelisca* sp.	549	78
Arthropoda*	Malacostraca	Amphipoda n.i.	Amphipoda n.i.	1	1
Arthropoda*	Malacostraca	Amphipoda n.i.	Amphipoda sp.1	1	1
Arthropoda*	Malacostraca	Amphipoda n.i.	Amphipoda sp.2	1	1
Arthropoda*	Malacostraca	Amphitoidae	*Ampithoe* sp.	3	2
Arthropoda*	Malacostraca	Paguridae	*Anapagurus hyndmanni* (Bell, 1846)	17	9
Arthropoda*	Malacostraca	Paguridae	*Anapagurus laevis* (Bell, 1846)	18	15
Arthropoda*	Malacostraca	Paguridae	*Anapagurus pusillus* Henderson, 1888	6	6
Arthropoda*	Malacostraca	Mysidae	*Anchialina agilis* (G.O. Sars, 1877)	8	5
Arthropoda*	Malacostraca	Maeridae	*Animoceradocus semiserratus* (Bate, 1862)	23	6
Arthropoda*	Pycnogonida	Phoxichilidiidae	*Anoplodactylus petiolatus* (Kroyer, 1844)	10	4
Arthropoda*	Malacostraca	Anthuridae	*Anthura gracilis* (Montagu, 1808)	2	1
Arthropoda*	Malacostraca	Anthuridae	*Anthura* sp.1	9	4
Arthropoda*	Malacostraca	Anthuridae	*Anthura* sp.2	1	1
Arthropoda*	Malacostraca	Anthuridae	Anthuridae n.i.	1	1
Arthropoda*	Malacostraca	Aoridae	*Aora spinicornis* Afonso, 1977	6	2
Arthropoda*	Malacostraca	Aoridae	Aoridae n.i.	5	4
Arthropoda*	Malacostraca	Calliopiidae	*Apherusa bispinosa* (Bate, 1857)	5	2
Arthropoda*	Malacostraca	Calliopiidae	*Apherusa* cf. *cirrus* (Bate, 1862)	1	1
Arthropoda*	Malacostraca	Apseudidae	*Apseudes* sp. 1	2	2
Arthropoda*	Malacostraca	Apseudidae	*Apseudes* sp. 2	96	15
Arthropoda*	Malacostraca	Apseudidae	*Apseudes* sp. 3	4	4
Arthropoda*	Malacostraca	Apseudidae	*Apseudes talpa* (Montagu, 1808)	2	1
Arthropoda*	Malacostraca	Apseudidae	*Apseudopsis latreillii* (Milne-Edwards, 1828)	4	2
Arthropoda*	Malacostraca	Argissidae	*Argissa hamatipes*	1	1
Arthropoda*	Malacostraca	Arcturidae	*Astacilla* sp.1	9	6
Arthropoda*	Malacostraca	Arcturidae	*Astacilla* sp.2	1	1
Arthropoda*	Malacostraca	Atelecyclidae	*Atelecyclus rotundatus* (Olivi, 1792)	4	3
Arthropoda*	Malacostraca	Alpheidae	*Athanas nitescens* (Leach, 1813 [in Leach, 1813-1814])	7	5
Arthropoda*	Malacostraca	Atylidae	*Atylus swammerdami* (Milne-Edwards, 1830)	1	1
Arthropoda*	Malacostraca	Atylidae	*Atylus vedlomensis* (Bate and Westwood, 1862)	30	13
Arthropoda*	Malacostraca	Axiidae	Axiidae n.i.	1	1
Arthropoda*	Malacostraca	Pontoporeiidae	*Bathyporeia elegans* Watkin, 1938	5	4
Arthropoda*	Malacostraca	Pontoporeiidae	*Bathyporeia guilliamsoniana* (Bate, 1857)	2	1
Arthropoda*	Malacostraca	Pontoporeiidae	*Bathyporeia tenuipes* Meinert, 1877	2	2
Arthropoda*	Malacostraca	Bodotriidae	*Bodotria scorpioides* (Montagu, 1804)	23	15
Arthropoda*	Malacostraca	Bodotriidae	*Bodotria* sp.	1	1
Arthropoda*	Malacostraca	Bopyridae	Bopyridae n.i.	1	1
Arthropoda*	Malacostraca	Callianassidae	*Callianassa* sp.	3	3
Arthropoda*	Malacostraca	Nannastacidae	*Campylaspis* cf. *glabra* Sars, 1878	56	4
Arthropoda*	Malacostraca	Caprellidae	*Caprella rapax* Mayer, 1890	21	2
Arthropoda*	Malacostraca	Melitidae	cf. *Allomelita pellucida* (Sars, 1882)	5	1
Arthropoda*	Malacostraca	Dulichiidae	cf. *Dulichia falcata* (Bate, 1857)	3	2
Arthropoda*	Malacostraca	Hyperiidae	cf. *Hyperia* sp.	1	1
Arthropoda*	Malacostraca	Mysidae	cf. *Leptomysis gracilis* (G.O. Sars, 1864)	1	1
Arthropoda*	Malacostraca	Euphausiidae	cf. *Meganyctiphanes norvegica* (M. Sars, 1857)	10	8
Arthropoda*	Malacostraca	Mysidae	cf. *Schistomysis spiritus* (Norman, 1860)	1	1
Arthropoda*	Malacostraca	Cheirocratidae	*Cheirocratus sundevalli* (Rathke, 1843)	30	13
Arthropoda*	Malacostraca	Cirolanidae	*Cirolana cranchi* Leach, 1818	13	1
Arthropoda*	Malacostraca	Cirolanidae	*Cirolana* sp.	41	10
Arthropoda*	Malacostraca	Cirolanidae	*Conilera cylindracea* (Montagu, 1804)	19	4
Arthropoda*	Malacostraca	Anthuridae	*Cyathura carinata* (Krøyer, 1847)	23	10
Arthropoda*	Malacostraca	Anthuridae	*Cyathura* sp.	2	1
Arthropoda*	Malacostraca	Sphaeromatidae	*Cymodoce truncata* Leach, 1814	24	7
Arthropoda*	Malacostraca	Dexaminidae	Dexaminidae n.i.	1	1
Arthropoda*	Malacostraca	Diastylidae	*Diastylis bradyi* Norman, 1879	28	20
Arthropoda*	Malacostraca	Diastylidae	*Diastylis rugosa* Sars, 1865	2	1
Arthropoda*	Malacostraca	Diastylidae	*Diastyloides serrata* (G.O. Sars, 1865)	1	1
Arthropoda*	Malacostraca	Diogenidae	*Diogenes pugilator* (Roux, 1829)	6	2
Arthropoda*	Malacostraca	Leucosiidae	*Ebalia* cf. *tumefacta* (Montagu, 1808)	1	1
Arthropoda*	Malacostraca	Leucosiidae	*Ebalia granulosa* H. Milne Edwards, 1837	2	2
Arthropoda*	Malacostraca	Leucosiidae	*Ebalia nux A.* Milne-Edwards, 1883	7	5
Arthropoda*	Malacostraca	Leucosiidae	*Ebalia* sp.	1	1
Arthropoda*	Malacostraca	Bodotriidae	*Eocuma dimorphum* Fage, 1928	3	2
Arthropoda*	Malacostraca	Bodotriidae	*Eocuma dollfusi Calman, 1907*	1	1
Arthropoda*	Malacostraca	Ischyroceridae	*Ericthonius punctatus* (Bate, 1857)	5	1
Arthropoda*	Malacostraca	Ischyroceridae	*Ericthonius* sp.	1	1
Arthropoda*	Malacostraca	Mysidae	*Erythrops elegans* (G.O. Sars, 1863)	1	1
Arthropoda*	Malacostraca	Cirolanidae	*Eurydice naylori* Jones and Pierpoint, 1997	1	1
Arthropoda*	Malacostraca	Cirolanidae	*Eurydice pulchra* Leach, 1815	26	11
Arthropoda*	Malacostraca	Cirolanidae	*Eurydice spinigera* Hansen, 1890	45	15
Arthropoda*	Malacostraca	Majidae	*Eurynome spinosa* Hailstone, 1835	7	7
Arthropoda*	Malacostraca	Eusiridae	*Eusirus longipes* Boeck, 1861	1	1
Arthropoda*	Malacostraca	Galatheidae	*Galathea intermedia* Liljeborg, 1851	15	7
Arthropoda*	Malacostraca	Galatheidae	*Galathea* sp.	1	1
Arthropoda*	Malacostraca	Melitidae	*Gammarella fucicola* (Leach, 1814)	2	1
Arthropoda*	Malacostraca	Photidae	*Gammaropsis maculata* (Johnston, 1828)	6	4
Arthropoda*	Malacostraca	Photidae	*Gammaropsis nitida* (Stimpson, 1853)	1	1
Arthropoda*	Malacostraca	Photidae	*Gammaropsis sophiae* (Boeck, 1861)	1	1
Arthropoda*	Malacostraca	Gnathiidae	*Gnathia* cf. *africana* Barnard, 1914a	15	8

Phyllum	***Class***	***Family***	***Species name***	***A***	***O***
Arthropoda*	Malacostraca	Goneplacidae	*Goneplax rhomboides* (Linnaeus, 1758)	4	3
Arthropoda*	Malacostraca	Dexaminidae	*Guernea (Guernea) coalita* (Norman, 1868)	42	7
Arthropoda*	Malacostraca	Mysidae	*Haplostylus normani* (G.O. Sars, 1877)	22	10
Arthropoda*	Malacostraca	Phoxocephalidae	*Harpinia antennaria* Meinert, 1890	44	22
Arthropoda*	Malacostraca	Phoxocephalidae	*Harpinia* cf. *antennaria* Meinert, 1891	1	1
Arthropoda*	Malacostraca	Phoxocephalidae	*Harpinia* cf. *truncata* Sars, 1891	7	6
Arthropoda*	Malacostraca	Phoxocephalidae	*Harpinia pectinata* Sars, 1891	19	9
Arthropoda*	Malacostraca	Lysianassidae	*Hippomedon denticulatus* (Bate, 1857)	13	11
Arthropoda*	Malacostraca	Janiridae	*Iathrippa bisbidens* (Barnard, 1955a)	2	1
Arthropoda*	Malacostraca	Uristidae	*Ichnopus spinicornis* Boeck, 1861	1	1
Arthropoda*	Malacostraca	Bodotriidae	*Iphinoe serrata* Norman, 1867	23	18
Arthropoda*	Malacostraca	Bodotriidae	*Iphinoe tenella* Sars, 1878	3	2
Arthropoda*	Malacostraca	Bodotriidae	*Iphinoe trispinosa* (Goodsir, 1843)	26	15
Arthropoda*	Malacostraca	Isaeidae	*Isaea montagui* Milne-Edwards, 1830	15	6
Arthropoda*	Malacostraca	Ischyroceridae	*Ischyrocerus anguipes* Krøyer, 1838	1	1
Arthropoda*	Malacostraca	Isopoda n.i.	Isopoda n.i.	2	1
Arthropoda*	Malacostraca	Janiridae	*Jaera (Jaera)* cf. *albifrons* Leach, 1814	1	1
Arthropoda*	Malacostraca	Janiridae	Janiridae n.i.	1	1
Arthropoda*	Malacostraca	Larva n.i.	Larva n.i.	10	7
Arthropoda*	Malacostraca	Aoridae	*Lembos* sp.1	37	25
Arthropoda*	Malacostraca	Aoridae	*Lembos* sp.2	7	3
Arthropoda*	Malacostraca	Lysianassidae	*Lepidepecreum longicornis* (Bate and Westwood, 1862)	1	1
Arthropoda*	Malacostraca	Corophiidae	*Leptocheirus hirsutimanus* (Bate, 1862)	5	4
Arthropoda*	Malacostraca	Corophiidae	*Leptocheirus pectinatus* (Norman, 1869)	19	9
Arthropoda*	Malacostraca	Corophiidae	*Leptocheirus pilosus* Zaddach, 1844	9	4
Arthropoda*	Malacostraca	Corophiidae	*Leptocheirus* sp.	1	1
Arthropoda*	Malacostraca	Corophiidae	*Leptocheirus tricristatus* (Chevreux, 1887)	1	1
Arthropoda*	Malacostraca	Mysidae	*Leptomysis lingvura* (G. O. Sars, 1866)	2	2
Arthropoda*	Malacostraca	Leucothoidae	*Leucothoe incisa* (Robertson, 1892)	18	13
Arthropoda*	Malacostraca	Leucothoidae	*Leucothoe lilljeborgi* Boeck, 1861	2	1
Arthropoda*	Malacostraca	Polybiidae	*Liocarcinus navigator* (Herbst, 1794)	5	3
Arthropoda*	Malacostraca	Polybiidae	*Liocarcinus pusillus* (Leach, 1816)	3	3
Arthropoda*	Malacostraca	Liljeborgiidae	*Listriella* sp.1	1	1
Arthropoda*	Malacostraca	Liljeborgiidae	*Listriella* sp.2	2	2
Arthropoda*	Malacostraca	Lophogastridae	*Lophogaster typicus* M. Sars, 1857	1	1
Arthropoda*	Malacostraca	Lysianassidae	*Lysianassa insperata* (Lincoln, 1979)	3	2
Arthropoda*	Malacostraca	Lysianassidae	*Lysianassa plumosa* Boeck, 1871	2	1
Arthropoda*	Malacostraca	Inachidae	*Macropodia linaresi* Forest and Zariquiey Alvarez, 1964	2	2
Arthropoda*	Malacostraca	Maeridae	*Maera* cf. *loveni* (Bruzelius, 1859)	3	2
Arthropoda*	Malacostraca	Maeridae	*Maera grossimana* (Montagu, 1808)	6	2
Arthropoda*	Malacostraca	Maeridae	*Maera grossimana* (Montagu, 1808)	4	1
Arthropoda*	Malacostraca	Maeridae	*Maera loveni* (Bruzelius, 1859)	11	7
Arthropoda*	Malacostraca	Melitidae	*Maerella tenuimana* (Bate, 1862)	4	4
Arthropoda*	Malacostraca	Corophiidae	*Medicorophium minimum* (Schiecke, 1978)	7	6
Arthropoda*	Malacostraca	Corophiidae	*Medicorophium runcicorne* (Della Valle, 1893)	1	1
Arthropoda*	Malacostraca	Megalopa n.i.	Megalopa n.i.	19	10
Arthropoda*	Malacostraca	Megaluropidae	*Megaluropus agilis* Hoeck, 1889	10	6
Arthropoda*	Malacostraca	Photidae	*Megamphopus brevidactylus* Myers, 1976	2	1
Arthropoda*	Malacostraca	Photidae	*Megamphopus cornutus* Norman, 1869	13	12
Arthropoda*	Malacostraca	Melitidae	*Melita hergensis* Reid, 1939	2	2
Arthropoda*	Malacostraca	Melitidae	*Melita* sp.	1	1
Arthropoda*	Malacostraca	Melphidippidae	*Melphidippella macra* (Norman, 1869)	1	1
Arthropoda*	Malacostraca	Phoxocephalidae	*Metaphoxus fultoni* (Scott, 1890)	11	5
Arthropoda*	Malacostraca	Aoridae	*Microdeutopus anomalus* (Rathke, 1843)	13	6
Arthropoda*	Malacostraca	Aoridae	*Microdeutopus armatus* Chevreux, 1886	3	1
Arthropoda*	Malacostraca	Aoridae	*Microdeutopus* sp.	3	1
Arthropoda*	Malacostraca	Aoridae	*Microdeutopus versiculatus* (Bate, 1856)	14	2
Arthropoda*	Malacostraca	Corophiidae	*Monocorophium acherusicum* (Costa, 1853)	2	2
Arthropoda*	Malacostraca	Oedicerotidae	*Monoculodes carinatus* (Bate, 1857)	6	4
Arthropoda*	Malacostraca	Cirolanidae	*Natatolana* sp.	1	1
Arthropoda*	Malacostraca	Nebaliidae	*Nebalia* cf. *strausi* Risso, 1826	10	3
Arthropoda*	Malacostraca	Callianassidae	*Necallianassa truncata* (Giard and Bonnier, 1890)	14	12
Arthropoda*	Malacostraca	Pinnotheridae	*Nepinnotheres pinnotheres* (Linnaeus, 1758)	1	1
Arthropoda*	Malacostraca	Opisidae	*Normanion sarsi* Stebbing, 1906	3	1
Arthropoda*	Malacostraca	Atylidae	*Nototropis falcatus* (Metzer, 1871)	2	2
Arthropoda*	Pycnogonida	Nymphonidae	Nymphonidae n.i.	2	1
Arthropoda*	Malacostraca	Lysianassidae	*Orchomene massiliensis* Ledoyer, 1977	1	1
Arthropoda*	Malacostraca	Lysianassidae	*Orchomenella nana* (Kroyer, 1846)	17	6
Arthropoda*	Ostracoda	Ostracoda n.i.	Ostracoda n.i.	9	1
Arthropoda*	Malacostraca	Maeridae	*Othomaera othonis* (Milne-Edwards, 1830)	50	15
Arthropoda*	Malacostraca	Paguridae	*Pagurus cuanensis* Bell, 1846	1	1
Arthropoda*	Malacostraca	Paguridae	*Pagurus excavatus* (Herbst, 1791)	1	1
Arthropoda*	Malacostraca	Caprellidae	*Pariambus typicus* (Krøyer, 1884)	6	5
Arthropoda*	Malacostraca	Parthenopidae	*Parthenope massena* (Roux, 1830)	1	1
Arthropoda*	Malacostraca	Cyproideidae	*Peltocoxa brevirostris* (Scott and Scott, 1893)	1	1
Arthropoda*	Malacostraca	Oedicerotidae	*Perioculodes longimanus* (Bate and Westwood, 1868)	12	9
Arthropoda*	Malacostraca	Aristiidae	*Perrierella audouiniana* (Bate, 1857)	4	2
Arthropoda*	Malacostraca	Crangonidae	*Philocheras bispinosus bispinosus* (Hailstone, 1835a)	10	5
Arthropoda*	Malacostraca	Crangonidae	*Philocheras sculptus* (Bell, 1847 [in Bell, 1844-1853])	1	1
Arthropoda*	Malacostraca	Crangonidae	*Philocheras trispinosus* (Hailstone in Hailstone and Westwood, 1835)	1	1
Arthropoda*	Malacostraca	Photidae	*Photis longicaudata* (Bate and Westwood, 1862)	11	7
Arthropoda*	Malacostraca	Photidae	*Photis longipes* (Della Valle, 1893)	12	6

Phyllum	***Class***	***Family***	***Species name***	***A***	***O***
Arthropoda*	Malacostraca	Caprellidae	*Phtisica marina* Slabber, 1769	16	10
Arthropoda*	Malacostraca	Polybiidae	*Polybius henslowii* Leach, 1820	3	2
Arthropoda*	Malacostraca	Oedicerotidae	*Pontocrates altamarinus* (Bate and Westwood, 1862)	3	2
Arthropoda*	Malacostraca	Oedicerotidae	*Pontocrates arenarius* (Bate, 1858)	5	5
Arthropoda*	Malacostraca	Processidae	*Processa canaliculata* Leach, 1815 [in Leach, 1815-1875]	3	2
Arthropoda*	Malacostraca	Processidae	*Processa edulis crassipes* Nouvel and Holthuis, 1957	3	2
Arthropoda*	Malacostraca	Processidae	*Processa modica modica* Williamson in Williamson and Rochanaburanon, 1979	2	2
Arthropoda*	Malacostraca	Processidae	*Processa nouveli holthuisi* Al-Adhub and Williamson, 1975	5	4
Arthropoda*	Malacostraca	Melitidae	*Psammogammarus caecus* Karaman, 1955	31	13
Arthropoda*	Malacostraca	Pseudocumatidae	*Pseudocuma (Pseudocuma)* cf. *longicorne* (Bate, 1858)	1	1
Arthropoda*	Malacostraca	Scalpellidae	*Scalpellum scalpellum* (Linnaeus, 1767)	1	1
Arthropoda*	Malacostraca	Mysidae	*Schistomysis* cf. *ornata (*G.O. Sars, 1864)	1	1
Arthropoda*	Maxillopoda	Archaeobalanidae	*Semibalanus balanoides* (Linnaeus, 1758)	1	1
Arthropoda*	Malacostraca	Ischyroceridae	*Siphonoecetes (Centraloecetes) kroyeranus* Bate, 1856	1	1
Arthropoda*	Malacostraca	Ischyroceridae	*Siphonoecetes (Centraloecetes) striatus* Myers and McGrath, 1979	5	5
Arthropoda*	Malacostraca	Stenothoidae	*Stenothoe marina* (Bate, 1856)	2	2
Arthropoda*	Malacostraca	Stenothoidae	*Stenothoe valida* Dana, 1852	2	1
Arthropoda*	Malacostraca	Apseudidae	Tanaidacea n.i.	25	10
Arthropoda*	Malacostraca	Upogebiidae	*Upogebia* cf. *stellata* (Montagu, 1808)	1	1
Arthropoda*	Malacostraca	Urothoidae	*Urothoe elegans* (Bate, 1857)	5	4
Arthropoda*	Malacostraca	Urothoidae	*Urothoe grimaldii* Chevreux, 1895	7	4
Arthropoda*	Malacostraca	Urothoidae	*Urothoe marina* (Bate, 1857)	10	3
Arthropoda*	Malacostraca	Urothoidae	*Urothoe pulchella* (Costa, 1853)	30	11
Arthropoda*	Malacostraca	Oedicerotidae	*Westwoodilla caecula* (Bate, 1857)	6	6
Arthropoda*	Malacostraca	Xanthidae	*Xantho pilipes* A. Milne-Edwards, 1867	1	1
Arthropoda*	Malacostraca	Zoe n.i.	Zoe n.i.	6	6
Arthropoda**	Insecta	Chironomidae	Chironomidae n.i.	1	1
Arthropoda**	Insecta	Insecta n.i.	Insecta n.i.	1	1
Chaetognatha	Chaetognatha	Chaetognatha	Chaetognatha n.i.	58	25
Chordata	Leptocardii	Branchiostomidae	*Branchiostoma lanceolatum* (Pallas, 1774)	25	11
Chordata	Actinopterygii	Callionymidae	*Callionymus lyra* Linnaeus, 1758	1	1
Cnidaria	Anthozoa	Anthozoa n.i.	Anthozoa n.i.	12	4
Cnidaria	Cnidaria	Cnidaria	Cnidario n.i.	40	10
Cnidaria	Anthozoa	Edwardsiidae	*Edwardsia claparedii* (Panceri, 1869)	85	21
Cnidaria	Anthozoa	Edwardsiidae	Edwardsidae n.i.	2	2
Cnidaria	Anthozoa	Haloclavidae	*Peachia cylindrica* (Reid, 1848)	2	2
Cnidaria	Anthozoa	Pennatulidae	*Pennatula phosphorea* Linnaeus, 1758	2	1
Echinodermata	Ophiuroidea	Amphiuridae	*Amphipholis squamata* (Delle Chiaje, 1828)	30	16
Echinodermata	Ophiuroidea	Amphiuridae	*Amphiura chiajei* Forbes, 1843	77	21
Echinodermata	Ophiuroidea	Amphiuridae	*Amphiura filiformis* (O.F. Müller, 1776)	44	26
Echinodermata	Crinoidea	Antedonidae	*Antedon bifida* (Pennant, 1777)	1	1
Echinodermata	Asteroidea	Asterinidae	*Asterina gibbosa* (Pennant, 1777)	1	1
Echinodermata	Echinoidea	Brissidae	*Brissopsis lyrifera* (Forbes, 1841)	2	2
Echinodermata	Crinoidea	Crinoidea n.i.	Crinoidea n.i.	2	1
Echinodermata	Echinoidea	Loveniidae	*Echinocardium* cf. *mortenseni* Thiéry, 1909	2	2
Echinodermata	Echinoidea	Loveniidae	*Echinocardium cordatum* (Pennant, 1777)	9	5
Echinodermata	Echinoidea	Loveniidae	*Echinocardium flavescens* (O.F. Müller, 1776)	2	2
Echinodermata	Echinoidea	Echinocyamidae	*Echinocyamus pusillus* (O.F. Müller, 1776)	168	34
Echinodermata	Holothuroidea	Cucumariidae	*Ekmania* sp.	1	1
Echinodermata	Holothuroidea	Phyllophoridae	*Havelockia inermis* (Heller, 1868)	1	1
Echinodermata	Holothuroidea	Holothuroidea n.i.	Holothuroidea n.i.	1	1
Echinodermata	Holothuroidea	Synaptidae	*Labidoplax digitata* (Montagu, 1815)	11	7
Echinodermata	Crinoidea	Antedonidae	*Leptometra celtica* (M'Andrew and Barrett, 1858)	1	1
Echinodermata	Holothuroidea	Cucumariidae	*Leptopentacta* cf. *tergestina* (M. Sars, 1857)	5	3
Echinodermata	Holothuroidea	Synaptidae	*Leptosynapta inhaerens* (O.F. Müller, 1776)	3	2
Echinodermata	Holothuroidea	Synaptidae	*Leptosynapta* sp.	1	1
Echinodermata	Holothuroidea	Cucumariidae	*Ocnus lacteus* (Forbes and Goodsir, 1839)	8	2
Echinodermata	Ophiuroidea	Ophiactidae	*Ophiactis balli* (W. Thompson, 1840)	3	2
Echinodermata	Ophiuroidea	Ophiuridae	*Ophiocten affinis* (Lütken, 1858)	2	2
Echinodermata	Ophiuroidea	Ophiocomidae	*Ophiopsila annulosa* (M. Sars, 1859)	1	1
Echinodermata	Ophiuroidea	Ophiocomidae	*Ophiopsila aranea* Forbes, 1843	2	2
Echinodermata	Ophiuroidea	Ophiotrichidae	*Ophiothrix fragilis* (Abildgaard, in O.F. Müller, 1789)	85	33
Echinodermata	Ophiuroidea	Ophiuridae	*Ophiura albida* Forbes, 1839	5	3
Echinodermata	Ophiuroidea	Ophiuridae	*Ophiura ophiura* (Linnaeus, 1758)	3	2
Echinodermata	Echinoidea	Spatangidae	*Spatangus purpureus* O.F. Müller, 1776	1	1
Echinodermata	Echinoidea	Spatangidae	*Spatangus* sp.	1	1
Echinodermata	Echinoidea	Strongylocentrotidae	*Strongylocentrotus pallidus* (G.O. Sars, 1871)	2	2
Echinodermata	Holothuroidea	Phyllophoridae	*Thyone* cf. *fusus* (O.F. Müller, 1776)	1	1
Echiura	Echiuroidea	Echiuridae	*Thalassema thalassemum* (Pallas, 1766)	14	10
Mollusca	Bivalvia	Semelidae	*Abra alba* (W. Wood, 1802)	150	37
Mollusca	Bivalvia	Semelidae	*Abra nitida* (Müller, 1776)	7	5
Mollusca	Bivalvia	Semelidae	*Abra prismatica* (Montagu, 1808)	7	5
Mollusca	Bivalvia	Semelidae	*Abra* sp.	1	1
Mollusca	Polyplacophora	Acanthochitonidae	*Acanthochitona fascicularis* (Linnaeus, 1767)	2	1
Mollusca	Gastropoda	Acteonidae	*Acteon tornatilis* (Linnaeus, 1758)	1	1
Mollusca	Bivalvia	Pectinidae	*Aequipecten opercularis* (Linnaeus, 1758)	3	2
Mollusca	Bivalvia	Arcidae	*Anadara polii* (Mayer, 1868)	7	7
Mollusca	Gastropoda	Scissurellidae	*Anatoma crispata* (Fleming, 1828)	2	1
Mollusca	Bivalvia	Tellinidae	*Angulus fabula* (Gmelin, 1791)	31	14
Mollusca	Bivalvia	Tellinidae	*Angulus pygmaeus* (Lovén, 1846)	95	24
Mollusca	Bivalvia	Anomiidae	*Anomia ephippium* Linnaeus 1758	3	3

Phyllum	***Class***	***Family***	***Species name***	***A***	***O***
Mollusca	Scaphopoda	Dentaliidae	*Antalis vulgaris* (da Costa, 1778)	3	3
Mollusca	Aplacophora	Aplacophora	Aplacophora sp.1	35	17
Mollusca	Aplacophora	Aplacophora	Aplacophora sp.2	6	2
Mollusca	Gastropoda	Aporrhaidae	*Aporrhais pespelecani* (Linnaeus, 1758)	6	2
Mollusca	Bivalvia	Arcidae	*Arca* sp. 1	2	2
Mollusca	Bivalvia	Arcidae	*Arca* sp. 2	1	1
Mollusca	Bivalvia	Arcidae	*Arca tetragona* Poli, 1795	11	5
Mollusca	Bivalvia	Tellinidae	*Arcopagia balaustina* (Linnaeus, 1758)	1	1
Mollusca	Bivalvia	Tellinidae	*Arcopagia crassa* (Pennant, 1777)	2	2
Mollusca	Bivalvia	Astartidae	*Astarte borealis* (Schumacher, 1817)	2	1
Mollusca	Bivalvia	Astartidae	*Astarte sulcata* (da Costa, 1778)	2	2
Mollusca	Bivalvia	Pinnidae	*Atrina fragilis* (Pennant, 1777)	3	3
Mollusca	Bivalvia	Thyasiridae	*Axinulus croulinensis* (Jeffreys, 1847)	1	1
Mollusca	Bivalvia	Arcidae	*Bathyarca pectunculoides* (Scacchi, 1835)	10	4
Mollusca	Gastropoda	Mangeliidae	*Bela brachystoma* (Philippi, 1844)	1	1
Mollusca	Gastropoda	Mangeliidae	*Bela decussata* (Locard, 1892)	2	2
Mollusca	Gastropoda	Mangeliidae	*Bela fuscata* (Deshayes, 1835)	9	6
Mollusca	Gastropoda	Mangeliidae	*Bela* sp.	1	1
Mollusca	Bivalvia	Kelliidae	*Bornia geoffroyi* (Payraudeau, 1826)	2	1
Mollusca	Gastropoda	Caecidae	*Caecum* sp.	77	9
Mollusca	Gastropoda	Caecidae	*Caecum subannulatum* de Folin, 1870	6	3
Mollusca	Gastropoda	Calyptraeidae	*Calyptraea chinensis* (Linnaeus, 1758)	17	11
Mollusca	Bivalvia	Cuspidariidae	*Cardiomya costellata* (Deshayes, 1833)	9	7
Mollusca	Gastropoda	Carditidae	*Centrocardita aculeata* (Poli, 1795)	1	1
Mollusca	Polyplacophora	Chaetopleuridae	*Chaetopleura (Chaetopleura) angulata* (Spengler, 1797)	2	2
Mollusca	Bivalvia	Veneridae	*Chamelea gallina* (Linnaeus, 1758)	10	6
Mollusca	Bivalvia	Veneridae	*Chamelea striatula* (da Costa, 1778)	25	11
Mollusca	Polyplacophora	Chitonidae	*Chiton (Rhyssoplax) olivaceus* Spengler, 1797	1	1
Mollusca	Gastropoda	Pyramidellidae	*Chrysallida indistincta* (Montagu, 1808)	1	1
Mollusca	Bivalvia	Veneridae	*Clausinella brogniarti* (Payraudeau, 1826)	4	2
Mollusca	Bivalvia	Veneridae	*Clausinella fasciata* (da Costa, 1778)	17	10
Mollusca	Bivalvia	Veneridae	*Coracuta* sp.	2	2
Mollusca	Bivalvia	Corbulidae	*Corbula gibba* (Olivi, 1792)	118	36
Mollusca	Gastropoda	Drilliidae	*Crassopleura maravignae* (Bivona Ant. in Bivona And., 1838)	3	2
Mollusca	Bivalvia	Cuspidariidae	*Cuspidaria rostrata* (Spengler, 1793)	8	5
Mollusca	Gastropoda	Cylichnidae	*Cylichna cylindracea* (Pennant, 1777)	27	10
Mollusca	Bivalvia	Pectinidae	*Delectopecten vitreus* (Gmelin, 1791)	1	1
Mollusca	Bivalvia	Astartidae	*Digitaria digitaria* (Linnaeus, 1758)	53	9
Mollusca	Bivalvia	Ungulinidae	*Diplodonta rotundata* (Montagu, 1803)	11	7
Mollusca	Bivalvia	Veneridae	*Dosinia exoleta* (Linnaeus, 1758)	1	1
Mollusca	Bivalvia	Veneridae	*Dosinia lupinus* (Linnaeus, 1758)	37	21
Mollusca	Gastropoda	Hydrobiidae	*Ecrobia truncata* (Vanatta, 1924)	6	1
Mollusca	Bivalvia	Pharidae	*Ensis* sp.	1	1
Mollusca	Bivalvia	Montacutidae	*Epilepton clarkiae* (Clark W., 1852)	1	1
Mollusca	Bivalvia	Semelidae	*Ervilia castanea* (Montagu, 1803)	16	1
Mollusca	Gastropoda	Eulimidae	*Eulima glabra* (da Costa, 1778)	6	5
Mollusca	Gastropoda	Naticidae	*Euspira pulchella* (Risso, 1826)	52	19
Mollusca	Bivalvia	Pectinidae	*Flexopecten glaber* (Linnaeus, 1758)	1	1
Mollusca	Gastropoda	Fasciolariidae	*Fusinus rostratus* (Olivi, 1792)	1	1
Mollusca	Scaphopoda	Fustiariidae	*Fustiaria rubescens* (Deshayes, 1825)	53	23
Mollusca	Bivalvia	Psammobiidae	*Gari costulata* (Turton, 1822)	29	12
Mollusca	Bivalvia	Psammobiidae	*Gari tellinella* (Lamarck, 1818)	50	5
Mollusca	Bivalvia	Mytilidae	*Gibbomodiola adriatica* (Lamarck, 1819)	1	1
Mollusca	Gastropoda	Trochidae	*Gibbula magus* (Linnaeus, 1758)	1	1
Mollusca	Gastropoda	Trochidae	*Gibbula* sp.	16	5
Mollusca	Gastropoda	Trochidae	*Gibbula varia* (Linnaeus, 1758)	1	1
Mollusca	Gastropoda	Carditidae	*Glans trapezia* (Linnaeus, 1767)	1	1
Mollusca	Bivalvia	Glycymerididae	*Glycymeris glycymeris* (Linnaeus, 1758)	42	12
Mollusca	Bivalvia	Glycymerididae	*Glycymeris nummaria* (Linnaeus, 1758)	3	1
Mollusca	Bivalvia	Astartidae	*Goodallia triangularis* (Montagu, 1803)	32	4
Mollusca	Bivalvia	Veneridae	*Gouldia minima* (Montagu, 1803)	58	22
Mollusca	Polyplacophora	Hanleyidae	*Hanleya hanleyi* (Bean in Thorpe, 1844)	1	1
Mollusca	Bivalvia	Hiatellidae	*Hiatella arctica* (Linnaeus, 1767)	7	7
Mollusca	Gastropoda	Iravadiidae	*Hyala vitrea* (Montagu, 1803)	1	1
Mollusca	Gastropoda	Hydrobiidae	*Hydrobia acuta neglecta* Muus, 1963	4	3
Mollusca	Bivalvia	Mytilidae	*Jolya martorelli* (Hidalgo, 1878)	1	1
Mollusca	Gastropoda	Trochidae	*Jujubinus* sp.	2	2
Mollusca	Bivalvia	Kelliida	*Kellia suborbicularis* (Montagu, 1803)	2	2
Mollusca	Bivalvia	Montacutidae	*Kurtiella bidentata* (Montagu, 1803)	122	11
Mollusca	Bivalvia	Cardiidae	*Laevicardium crassum* (Gmelin, 1791)	13	6
Mollusca	Bivalvia	Lasaeidae	Lasaeidae n.i.	3	3
Mollusca	Polyplacophora	Leptochitonidae	*Leptochiton algesirensis* (Capellini, 1859)	8	3
Mollusca	Polyplacophora	Leptochitonidae	*Leptochiton alveolus* (M. Sars MS, Lovén, 1846)	1	1
Mollusca	Polyplacophora	Leptochitonidae	*Leptochiton asellus* (Gmelin, 1791)	1	1
Mollusca	Polyplacophora	Leptochitonidae	*Leptochiton cancellatus* (Sowerby, 1840)	40	13
Mollusca	Bivalvia	Lasaeidae	*Lepton squamosum* (Montagu, 1803)	2	1
Mollusca	Bivalvia	Limidae	*Limaria loscombi* (G.B. Sowerby I, 1823)	1	1
Mollusca	Bivalvia	Limidae	*Limatula subovata* (Monterosato, 1875)	57	7
Mollusca	Bivalvia	Mytilidae	*Lioberus agglutinans* (Cantraine, 1835)	1	1
Mollusca	Bivalvia	Lucinidae	*Loripes lucinalis* (Lamarck, 1818)	1	1
Mollusca	Bivalvia	Lucinidae	*Loripes* sp.	7	1
Mollusca	Bivalvia	Lucinidae	*Lucinoma borealis* (Linnaeus, 1758)	1	1

Phyllum	***Class***	***Family***	***Species name***	***A***	***O***
Mollusca	Gastropoda	Naticidae	*Lunatia fusca* (Blainville, 1825)	1	1
Mollusca	Bivalvia	Lyonsiidae	*Lyonsia norwegica* (Gmelin, 1791)	1	1
Mollusca	Bivalvia	Tellinidae	*Macoma balthica* (Linnaeus, 1758)	2	1
Mollusca	Bivalvia	Tellinidae	*Macoma* sp.	2	2
Mollusca	Bivalvia	Mactridae	*Mactra* sp.	4	1
Mollusca	Bivalvia	Mactridae	*Mactra stultorum* (Linnaeus, 1758)	3	2
Mollusca	Gastropoda	Mangeliidae	*Mangelia* sp.	4	3
Mollusca	Gastropoda	Eulimidae	*Melanella doederleini* (Brusina, 1886)	1	1
Mollusca	Gastropoda	Eulimidae	*Melanella frielei* (Jordan, 1895)	3	1
Mollusca	Gastropoda	Eulimidae	*Melanella polita* (Linnaeus, 1758)	4	4
Mollusca	Bivalvia	Veneridae	*Mercenaria mercenaria* (Linnaeus, 1758)	1	1
Mollusca	Gastropoda	Columbellidae	*Mitrella minor* (Scacchi, 1836)	1	1
Mollusca	Bivalvia	Mytilidae	*Modiolus barbatus* (Linnaeus, 1758)	3	3
Mollusca	Bivalvia	Mytilidae	*Modiolus* sp.	1	1
Mollusca	Bivalvia	Tellinidae	*Moerella donacina* (Linnaeus, 1758)	20	12
Mollusca	Gastropoda	Triphoridae	*Monophorus perversus* (Linnaeus, 1758)	2	1
Mollusca	Bivalvia	Montacutidae	*Montacuta phascolionis* Dautzenberg and Fischer H., 1925	7	5
Mollusca	Bivalvia	Mytilidae	*Musculus subpictus* (Cantraine, 1835)	3	1
Mollusca	Bivalvia	Lucinidae	*Myrtea spinifera* (Montagu, 1803)	17	14
Mollusca	Bivalvia	Lucinidae	*Mytella* sp.	1	1
Mollusca	Gastropoda	Nassariidae	*Nassarius elatus* (Gould, 1845)	8	4
Mollusca	Gastropoda	Nassariidae	*Nassarius incrassatus* (Strøm, 1768)	3	2
Mollusca	Gastropoda	Nassariidae	*Nassarius ovoideus* (Locard, 1886)	2	1
Mollusca	Gastropoda	Nassariidae	*Nassarius reticulatus* (Linnaeus, 1758)	28	14
Mollusca	Bivalvia	Nuculidae	*Nucula nitidosa* Winckworth, 1930	53	19
Mollusca	Bivalvia	Nuculidae	*Nucula* sp.	3	1
Mollusca	Bivalvia	Nuculanoida	*Saccella commutata* (Philippi, 1844)	65	29
Mollusca	Gastropoda	Muricidae	*Ocenebra erinaceus* (Linnaeus, 1758)	1	1
Mollusca	Gastropoda	Pyramidellidae	*Odostomia* sp.	2	2
Mollusca	Gastropoda	Pyramidellidae	*Ondina* sp.	1	1
Mollusca	Bivalvia	Pectinidae	*Palliolum incomparabile* (Risso, 1826)	17	8
Mollusca	Bivalvia	Pectinidae	*Palliolum tigerinum* (O. F. Müller, 1776)	9	5
Mollusca	Bivalvia	Pandoridae	*Pandora inaequivalvis* (Linnaeus, 1758)	2	1
Mollusca	Bivalvia	Cardiidae	*Parvicardium minimum* (Philippi, 1836)	1	1
Mollusca	Bivalvia	Cardiidae	*Parvicardium pinnulatum* (Conrad, 1831)	5	3
Mollusca	Bivalvia	Cardiidae	*Parvicardium scabrum* (Philippi, 1844)	11	5
Mollusca	Bivalvia	Cardiidae	*Parvicardium* sp.	5	2
Mollusca	Bivalvia	Pharidae	*Pharus legumen* (Linnaeus, 1758)	4	4
Mollusca	Bivalvia	Pharidae	*Phaxas pellucidus* (Pennant, 1777)	50	17
Mollusca	Gastropoda	Philinidae	*Philine aperta* (Linnaeus, 1767)	5	5
Mollusca	Gastropoda	Philinidae	*Philine* cf. *quadrata* (S. Wood, 1839)	2	1
Mollusca	Gastropoda	Philinidae	*Philine punctata* (Adams J., 1800)	10	3
Mollusca	Bivalvia	Veneridae	*Pitar rudis* (Poli, 1795)	9	4
Mollusca	Gastropoda	Rissoidae	*Plagyostila asturiana* Fischer P. in de Folin, 1872	1	1
Mollusca	Gastropoda	Raphitomidae	*Raphitoma flavida* (Monterosato, 1884)	1	1
Mollusca	Gastropoda	Retusidae	*Retusa truncatula* (Bruguière, 1792)	4	4
Mollusca	Gastropoda	Ringiculidae	*Ringicula auriculata* (Ménard de la Groye, 1811)	7	1
Mollusca	Gastropoda	Ringiculidae	*Ringicula buccinea* (Brocchi, 1814)	1	1
Mollusca	Gastropoda	Ringiculidae	*Ringicula* sp.	1	1
Mollusca	Bivalvia	Gastrochaenidae	*Rocellaria dubia* (Pennant, 1777)	1	1
Mollusca	Bivalvia	Semelidae	*Scrobicularia plana* (da Costa, 1778)	2	2
Mollusca	Gastropoda	Ovulidae	*Simnia* sp.	2	1
Mollusca	Bivalvia	Solecurtidae	*Solecurtus scopula* (Turton, 1822)	1	1
Mollusca	Bivalvia	Mactridae	*Spisula elliptica* (Brown, 1827)	12	7
Mollusca	Bivalvia	Mactridae	*Spisula* sp.	3	2
Mollusca	Bivalvia	Mactridae	*Spisula subtruncata* (da Costa, 1778)	44	16
Mollusca	Bivalvia	Montacutidae	*Tellimya ferruginosa* (Montagu, 1808)	27	20
Mollusca	Bivalvia	Montacutidae	*Tellimya* sp.	2	1
Mollusca	Bivalvia	Tellinidae	*Tellina compressa* Brocchi, 1814	99	28
Mollusca	Bivalvia	Tellinidae	*Tellina distorta* Poli, 1791	3	1
Mollusca	Bivalvia	Tellinidae	*Tellina serrata* Brocchi, 1814	6	3
Mollusca	Bivalvia	Thraciidae	*Thracia papyracea* (Poli, 1791)	2	2
Mollusca	Bivalvia	Thraciidae	*Thracia villosiuscula* (MacGillivray, 1827)	145	29
Mollusca	Bivalvia	Thyasiridae	*Thyasira flexuosa* (Montagu, 1803)	136	26
Mollusca	Bivalvia	Thyasiridae	*Thyasira* sp.	70	18
Mollusca	Bivalvia	Thyasiridae	*Thyasira subovata* (Jeffreys, 1881)	3	1
Mollusca	Bivalvia	Veneridae	*Timoclea ovata* (Pennant, 1777)	30	18
Mollusca	Bivalvia	Cuspidariidae	*Tropidomya abbreviata* (Forbes, 1843)	1	1
Mollusca	Gastropoda	Pyramidellidae	*Turbonilla* sp.	4	4
Mollusca	Gastropoda	Turritellidae	*Turritella communis* Risso, 1826	27	15
Mollusca	Gastropoda	Turritellidae	*Turritella turbona* Monterosato, 1877	23	10
Mollusca	Bivalvia	Veneridae	*Venerupis corrugata* (Gmelin, 1791)	2	1
Mollusca	Bivalvia	Veneridae	*Venus casina* Linnaeus, 1758	8	4
Mollusca	Bivalvia	Veneridae	*Venus* sp.	6	3
Mollusca	Gastropoda	Eulimidae	*Vitreolina curva* (Monterosato, 1874)	1	1
Mollusca	Bivalvia	Yoldiidae	*Yoldiella philippiana* (Nyst, 1845)	5	5
Nematoda	Nematoda	Nematoda	Nematoda n.i.	1709	53
Nemertea	Nemertea	Nemertea	Nemertea n.i.	1611	105
Phoronida	Phoronida	Phoronida	Phoronida n.i.	192	52
Platyhelminthes	Platyhelminthes	Platyhelminthes	Turbellaria n.i.	9	5
Sipuncula	Phascolosomatidea	Aspidosiphonidae	*Aspidosiphon (Aspidosiphon) muelleri muelleri* Diesing, 1851	487	26
Sipuncula	Sipunculidea	Golfingiidae	*Golfingia (Golfingia) elongata* (Keferstein, 1862a)	80	25

Phyllum	***Class***	***Family***	***Species name***	***A***	***O***
Sipuncula	Sipunculidea	Golfingiidae	*Golfingia (Golfingia) vulgaris vulgaris* (De Blainville, 1827)	24	13
Sipuncula	Sipunculidea	Phascolionidae	*Onchnesoma steenstrupii steenstrupii* Koren and Danielssen, 1876	72	20
Sipuncula	Sipunculidea	Phascolionidae	*Phascolion (Phascolion) strombus strombus* (Montagu, 1804)	11	9
Sipuncula	Phascolosomatidea	Phascolosomatidae	*Phascolosoma (Phascolosoma) granulatum* Leuckart, 1828	46	4
Sipuncula	Sipuncula	Sipuncula	Sipuncula n.i.	34	10

Table 3 – Constancy and fidelity indeces per affinity group and their product for the 15 most characteristic species.

Taxa	**Constancy per affinity group**						**Fidelity per affinity group**						**Confidence X Fidelity**					
	A	B	C1	C2	C3	D	A	B	C1	C2	C3	D	A	B	C1	C2	C3	D
Pisione remota (Southern, 1914)	**74.2**						**100**						**74.2**					
Protodorvillea kefersteini (McIntosh, 1869)	**87.1**		6.9	3.4	5.6		**84.6**		6.7	3.3	5.4		**73.7**		0.5	0.1	0.3	
Goniadella gracilis Verril, 1873	**80.6**		6.9	3.4			**88.6**		7.6	3.8			**71.5**		0.5	0.1		
Glycera lapidum Quatrefages, 1865	**90.3**		13.8	10.3	5.6		**75.3**		11.5	8.6	4.6		**68.0**		1.6	0.9	0.3	
Angulus pygmaeus (Lovén, 1846)	**71.0**			3.4			**95.4**			4.6			**67.7**			0.2		
Sphaerosyllis bulbosa Southern, 1914	**77.4**		3.4		11.1	4.8	**8**		3.6		11.5	4.9	**62.0**		0.1		1.3	0.2
Polygordius appendiculatus Fraipont, 1887	**80.6**		10.3	10.3	16.7		**68.3**		8.8	8.8	14.1		**55.1**		0.9	0.9	2.4	
Thracia villosiuscula (MacGillivray, 1827)	**74.2**	7.7	3.4		16.7		**72.7**	7.5	3.4		16.3		**54.0**	0.6	0.1		2.7	
Pulliella sp.	**51.6**						**100**						**51.6**					
Syllis licheri Ravara, San Martín and Moreira, 2004	**54.8**		3.4				**94.1**		5.9				**51.6**		0.2			
Malmgreniella ljungmani (Malmgren, 1867)	**77.4**				38.9	4.8	**63.9**				32.1	3.9	**49.5**				12.5	0.2
Hesionura elongata (Southern, 1914)	**51.6**		3.4				**93.7**		6.3				**48.4**		0.2			
Pisione parapari Moreira, Quintas and Troncoso, 2000	**45.2**						**100**						**45.2**					
Gyptis propinqua Marion, 1875	**48.4**				5.6		**89.7**				10.3		**43.4**				0.6	
Prionospio sp.	**51.6**		10.3				**83.3**		16.7				**43.0**		1.7			
Magelona johnstoni Fiege, Licher and Mackie, 2000	3.2	**76.9**	10.3				3.6	**85.0**	11.4				0.1	**65.4**	1.2			
Urothoe pulchella (Costa, 1853)		**69.2**	3.4		5.6			**88.5**	4.4		7.1			**61.3**	0.2		0.4	
Spiophanes bombyx (Claparède, 1870)	22.6	**92.3**	79.3	10.3	5.6	4.8	10.5	**43.0**	36.9	4.8	2.6	2.2	2.4	**39.7**	**29.3**	0.5	0.1	0.1
Angulus fabula (Gmelin, 1791)		**53.8**	17.2	3.4				**72.2**	23.1	4.6				**38.9**	4.0	0.2		
Sigalion mathildae Audouin and Milne Edwards in Cuvier, 1830	6.5	**53.8**	13.8	3.4			8.3	**69.4**	17.8	4.4			0.5	**37.4**	2.5	0.2		
Magelona filiformis Wilson, 1959	3.2	**53.8**	24.1				4.0	**66.3**	29.7				0.1	**35.7**	7.2			
Megaluropus agilis Hoeck, 1889		**38.5**			5.6			**87.4**			12.6			**33.6**			0.7	
Hippomedon denticulatus (Bate, 1857)	9.7	**46.2**		3.4		4.8	15.1	**72.1**		5.4		7.4	1.5	**33.3**		0.2		0.4
Leucothoe incisa (Robertson, 1892)	19.4	**46.2**	3.4				28.1	**66.9**	5.0				5.4	**30.9**	0.2			
Pharus legumen (Linnaeus, 1758)		**30.8**						**100**						**30.8**				
Glycera convoluta Keferstein, 1862		**30.8**	10.3					**74.8**	25.2					**23.0**	2.6			
Scoloplos typicus (Eisig, 1914)	6.5	**38.5**	13.8		5.6	4.8	9.3	**55.7**	2		8.0	6.9	0.6	**21.4**	2.8		0.4	0.3
Chaetozone carpenteri McIntosh, 1911	9.7	**46.2**	3.4	10.3	16.7	19.0	9.2	**43.8**	3.3	9.8	15.8	18.1	0.9	**20.2**	0.1	1.0	2.6	3.4
Bathyporeia elegans Watkin, 1938		**23.1**	3.4					**87.0**	13.0					**20.1**	0.4			
Prionospio fallax Söderström, 1920	9.7	**61.5**	**79.3**	13.8	11.1		5.5	**35.1**	**45.2**	7.9	6.3		0.5	**21.6**	**35.9**	1.1	0.7	
Tellina compressa Brocchi, 1814			**58.6**	24.1	11.1	4.8			**59.4**	24.5	11.3	4.8			**34.8**	5.9	1.3	0.2
Chaetozone gibber Woodham and Chambers, 1994	3.2		**44.8**	3.4	11.1		5.2		**71.6**	5.5	17.7		0.2		**32.1**	0.2	2.0	
Phaxas pellucidus (Pennant, 1777)		23.1	**44.8**					34.0	**66.0**					7.8	**29.6**			
Thyasira flexuosa (Montagu, 1803)	3.2		**51.7**	17.2	5.6	14.3	3.5		**56.2**	18.7	6.0	15.5	0.1		**29.1**	3.2	0.3	2.2
Prionospio aluta Maciolek, 1985			**27.6**						**100**						**27.6**			
Abra alba (W. Wood, 1802)	19.4	30.8	**62.1**	10.3	22.2	4.8	12.9	20.6	**41.5**	6.9	14.9	3.2	2.5	6.3	**25.8**	0.7	3.3	0.2
Poecilochaetus serpens Allen, 1904	9.7		**62.1**	24.1	27.8	33.3	6.2		**39.5**	15.4	17.7	21.2	0.6		**24.5**	3.7	4.9	7.1
Phyllodoce rosea McIntosh, 1877			**24.1**						**100**						**24.1**			
Nephtys hombergii Savigny in Lamarck, 1818		7.7	**48.3**	20.7	16.7	4.8		7.8	**49.2**	21.1	17.0	4.9		0.6	**23.8**	4.4	2.8	0.2
Spio filicornis (Müller, 1776)	45.2	23.1	**55.2**	6.9			34.7	17.7	**42.3**	5.3			15.7	4.1	**23.4**	0.4		
Aricidea (Acmira) catherinae Laubier, 1967	6.5		**41.4**	20.7	5.6		8.7		**55.9**	27.9	7.5		0.6		**23.1**	5.8	0.4	
Aricidea (Aricidea) pseudoarticulata Hobson, 1972			**37.9**	3.4	22.2				**59.6**	5.4	34.9				**22.6**	0.2	7.8	
Pseudopolydora antennata (Claparède, 1869)		7.7	**51.7**	44.8	11.1	4.8		6.4	**43.1**	37.3	9.3	4.0		0.5	**22.3**	16.7	1.0	0.2
Galathowenia oculata (Zachs, 1923)	6.5	15.4	51.7	**89.7**	38.9	14.3	3.0	7.1	23.9	41.4	**18.0**	6.6	0.2	1.1	12.4	**37.1**	7.0	0.9
Pterolysippe vanelli (Fauvel, 1936) sensu Eliason, 1955, emend	3.2	7.7	17.2	**69.0**	38.9		2.4	5.7	12.7	50.7	**28.6**		0.1	0.4	2.2	**35.0**	11.1	
Monticellina heterochaeta Laubier, 1961	12.9		24.1	**86.2**	5	42.9	6.0		11.2	39.9	**23.1**	19.8	0.8		2.7	**34.4**	11.6	8.5

Taxa	**Constancy per affinity group**						**Fidelity per affinity group**						**Confidence X Fidelity**					
	A	B	C1	C2	C3	D	A	B	C1	C2	C3	D	A	B	C1	C2	C3	D
Sarsonuphis bihanica (Intes and Le Loeuff, 1975)	3.2		17.2	**72.4**	11.1	52.4	2.1		11.0	46.3	**7.1**	33.5	0.1		1.9	**33.5**	0.8	**17.5**
Aphelochaeta sp.1	9.7		24.1	**62.1**	16.7	4.8	8.2		20.6	52.9	**14.2**	4.1	0.8		5.0	**32.8**	2.4	0.2
Aplacophora sp.1	6.5		3.4	**41.4**	5.6	4.8	10.5		5.6	67.2	**9.0**	7.7	0.7		0.2	**27.8**	0.5	0.4
Saccella commutata (Philippi, 1844)			24.1	**55.2**	22.2	9.5			21.7	49.7	**2**	8.6			5.2	**27.4**	4.4	0.8
Isolda pulchella Müller in Grube, 1858			13.8	**51.7**	38.9				13.2	49.5	**37.2**				1.8	**25.6**	14.5	
Ampharete finmarchica (M. Sars, 1864)	29.0	23.1	62.1	**100**	100	81.0	7.3	5.8	15.7	25.3	**25.3**	20.5	2.1	1.3	9.8	**25.3**	25.3	**16.6**
Glycera dayi O'Connor, 1987	12.9	7.7	34.5	**55.2**	5.6	4.8	10.7	6.4	28.6	**45.8**	4.6	3.9	1.4	0.5	9.9	**25.2**	0.3	0.2
Terebellides stroemii Sars, 1835	12.9		34.5	**65.5**	5	9.5	7.5		2	**38.0**	29.0	5.5	1.0		6.9	**24.9**	14.5	0.5
Leiocapitella dollfusi (Fauvel, 1936)				**27.6**		4.8				**85.3**		14.7				**23.5**		0.7
Magelona wilsoni Glémarec, 1966			10.3	**41.4**	16.7	4.8			14.1	**56.6**	22.8	6.5			1.5	**23.4**	3.8	0.3
Euchone rubrocincta (Sars, 1862)	6.5				**61.1**		9.5				**90.5**		0.6				**55.3**	
Prionospio multibranchiata Berkeley, 1927	3.2		17.2	3.4	**72.2**	4.8	3.2		17.1	3.4	**71.6**	4.7	0.1		2.9	0.1	**51.7**	0.2
Nematonereis unicornis (Grube, 1840)	6.5			13.8	**61.1**		7.9			17.0	**75.1**		0.5			2.3	**45.9**	
Paralacydonia paradoxa Fauvel, 1913	9.7		6.9	86.2	**100**	33.3	4.1		2.9	36.5	**42.4**	14.1	0.4		0.2	**31.5**	**42.4**	4.7
Eunice vittata (Delle Chiaje, 1828)	45.2	7.7	3.4	75.9	**100**	4.8	19.1	3.2	1.5	32.0	**42.2**	2.0	8.6	0.2	0.1	**24.3**	**42.2**	0.1
Panthalis oerstedi Kinberg, 1856	3.2				**5**	9.5	5.1				**79.7**	15.2	0.2				**39.8**	1.4
Cirrophorus branchiatus Ehlers, 1908		7.7	3.4	3.4	**5**			11.9	5.3	5.3	**77.4**			0.9	0.2	0.2	**38.7**	
Lygdamis muratus (Allen, 1904)	12.9	30.8	3.4	3.4	**66.7**		11.0	26.2	2.9	2.9	**56.9**		1.4	8.1	0.1	0.1	**37.9**	
Parapionosyllis brevicirra San Martin, 1984	3.2			3.4	**5**	9.5	4.9			5.2	**75.5**	14.4	0.2			0.2	**37.8**	1.4
Lumbrineris pinaster (Martins, Carrera-Parra, Quintino and Rodrigues 2012)	9.7	7.7	3.4	10.3	**66.7**	23.8	8.0	6.3	2.8	8.5	**54.8**	19.6	0.8	0.5	0.1	0.9	**36.5**	4.7
Harmothoe antilopes (McIntosh, 1876)	3.2		6.9	10.3	**5**		4.6		9.8	14.7	**71.0**		0.1		0.7	1.5	**35.5**	
Syllis garciai (Campoy, 1982)	61.3			10.3	**72.2**	9.5	4			6.7	**47.1**	6.2	24.5			0.7	**34.0**	0.6
Schistomeringos rudolphii (delle Chiaje, 1828)					**33.3**						**100**						**33.3**	
Notomastus latericeus Sars, 1851	64.5	15.4	34.5	44.8	**88.9**	4.8	25.5	6.1	13.6	17.7	**35.2**	1.9	16.5	0.9	4.7	7.9	**31.2**	0.1
Polydora flava Claparède, 1870	9.7		20.7	31.0	**61.1**		7.9		16.9	25.3	**49.9**		0.8		3.5	7.9	**30.5**	
Sternaspis scutata Ranzani, 1817			3.4			**38.1**			8.3			**91.7**			0.3			**34.9**
Heteromastus filiformis (Claparède, 1864)				3.4	11.1	**33.3**				7.2	23.2	**69.6**				0.2	2.6	**23.2**
Psammogammarus caecus Karaman, 1955	16.1			3.4		**33.3**	30.5			6.5		**63.0**	4.9			0.2		**21.0**
Nephtys incisa Malmgren, 1865			3.4	20.7	5.6	**33.3**			5.5	32.8	8.8	**52.9**			0.2	6.8	0.5	**17.6**
Sarsonuphis bihanica (Intes and le Loeuff, 1975)	3.2		17.2	72.4	11.1	**52.4**	2.1		11.0	46.3	7.1	**33.5**	0.1		1.9	**33.5**	0.8	**17.5**
Ampharete finmarchica (M. Sars, 1864)	29.0	23.1	62.1	100	100	**81.0**	7.3	5.8	15.7	25.3	25.3	**20.5**	2.1	1.3	9.8	**25.3**	25.3	**16.6**
Harpinia antennaria Meinert, 1890	3.2		6.9	27.6	16.7	**38.1**	3.5		7.5	29.8	18.0	**41.2**	0.1		0.5	8.2	3.0	**15.7**
Chaetozone sp. 2	6.5		27.6	13.8	5	**47.6**	4.4		19.0	9.5	34.4	**32.7**	0.3		5.2	1.3	17.2	**15.6**
Glycera unicornis Savigny in Lamarck, 1818	3.2	15.4	31.0	41.4	38.9	**52.4**	1.8	8.4	17.0	22.7	21.3	**28.7**	0.1	1.3	5.3	9.4	8.3	**15.1**
Ninoe armoricana (Glémarec, 1968)			10.3	10.3	5.6	**28.6**			18.9	18.9	10.1	**52.1**			2.0	2.0	0.6	**14.9**
Athanas nitescens (Leach, 1813 [in Leach, 1813-1814])					5.6	**19.0**					22.6	**77.4**					1.3	**14.7**
Ampelisca sp.	16.1	46.2	41.4	79.3	94.4	**71.4**	4.6	13.2	11.9	22.7	27.1	**20.5**	0.7	6.1	4.9	18.0	25.6	**14.6**
Labioleanira yhleni (Malmgren, 1867)		7.7	20.7	31.0	5.6	**38.1**		7.5	20.1	30.1	5.4	**37.0**		0.6	4.2	9.3	0.3	**14.1**
Alpheus cf. glaber (Olivi, 1792)				3.4		**14.3**				19.4		**80.6**				0.7		**11.5**
Paraprionospio pinnata (Ehlers, 1901)	9.7	7.7	24.1	51.7	38.9	**38.1**	5.7	4.5	14.2	30.4	22.8	**22.4**	0.6	0.3	3.4	15.7	8.9	**8.5**