Oficina de Doctorat
UNIVERSITAT POLITÈCNICA DE CATALUNYA

DISTRIBUTION OF SOFT-BOTTOM POLYCHAETES ASSEMBLAGES AT DIFFERENT SCALES IN SHALLOW WATERS OF THE NORTHERN MEDITERRANEAN SPANISH COAST

Letzi Graciela Serrano Samaniego

Rafael Sardá Borroy

Barcelona, June 2012

Oficina de Doctorat
UNIVERSITAT POLITÈCNICA DE CATALUNYA

DISTRIBUTION OF SOFT-BOTTOM POLYCHAETES ASSEMBLAGES AT DIFFERENT SCALES IN SHALLOW WATERS OF THE NORTHERN MEDITERRANEAN SPANISH COAST

Doctorate dissertation

To obtain the Doctoral Degree in Marine Sciences
Marine Sciences Doctoral Program UPC-UB-CSIC
Developed in the Marine Engineering Laboratory
(Laboratori d'Enginyeria Marítima, LIM/UPC)
and in the Center for Advance Studies of Blanes
(Centre d’Estudis Avançats de Blanes-CEAB)

By

Letzi Graciela Serrano Samaniego

Dissertation supervisor:

Rafael Sardá Borroy, CEAB-CSIC

June 2012

Barcelona, Spain

To my dear family:

- *My dearly husband: Carlos I love you.*

My beloved kids

  - *Carlos*
  - *Letzy*
  - *Yenia*
  - *Kelsy*

DISTRIBUTION OF SOFT-BOTTOM POLYCHAETES ASSEMBLAGES AT DIFFERENT SCALES IN SHALLOW WATERS OF THE NORTHERN MEDITERRANEAN SPANISH COAST

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

I am very grateful to the program “Becas de Excelencia Profesional” IFARHU-SENACYT research grant of Panama government by allow me develop the doctoral studies in Marine Sciences program (UPC-UB-CSIC). And Universidad Autónoma de Chiriquí and Universidad de Panama by hold my employed during these years.

Thanks to my thesis director Rafael Sardà Borroy “Rafa” by the wise advises dedication and valuable helping during all this years and who collaboration was very important for ending this thesis just in time. Rafa without your help it was not possible. Thanks you so much. To Joao Gil for helping to resolve some doubts in the polychaetes identification and bibliography. Also I want to thanks to technician Gustavo Carreras for his helping with some sorting and samples weighed. I am in debt to David March Morla for the valuable helping with all maps. Also was appreciative the bibliography given by Dany Martin. I am very grateful to Genoveva Comas, secretary of the Laboratori d'Enginyeria Marítima, LIM/UPC, by the fast and efficient diligent, and to Conxita Avila, Cruz Palacín, Vicente Gracia and Rafa Sardá again, by the following to thesis ante-project.

Also I wish give my grateful to the staff of Center d’Estudis Avançats, Carmela Bosca, Gemma Peña, Ramón Coma, Angel Luque, and Rafa for the helping and bear me through these years. Thanks to Helena Barrios who was library for some years and now David Alenya. Also I want to show my grateful to cleaner ladies Ana, Maricarmen and Emilia by the moment gathered and by their good mood.

I am indebted with my friends Chiara Romano, Francesco Pittito, Guillermo de Mendoza, Carlos Rivera and specially to Juan Pablo Lozoya by their helping during these years. Also, thankful to Sergi Taboada and Carlo Tidu by their help and comment.

Also thankful to all my Ceab-mate and friends, I do not add more names because I could miss some people, and it is not my intention, but I want to express, all of you will have a placed in my heart. I am glad for all gathered moment, I do not forget them.

And finally I want to express especially, my sincere gratitude and feeling to my dear family, who in all moment were my put up with this enterprise, so I also ask apologies by the time consuming, it is my owed whit them. All of them assisting me in every steps of my work, sometimes doing a coarse sorting of samples, or with housework, or do not disturbed me while I work and bear me some bad mood, by to encourage me and also cheer me up. My eternity loved, to my husband Carlos Quiroz, my son Carlos and my daughters Letzy, Yenia and Kelsy Quiroz. I too wish to thank to my relative and my relative-in low by their confidence to my. To all of them, thanks so much.

Letzy

June 2012, Blanes, Spain.

SUMMARY

Soft-bottom polychaete assemblages inhabiting shallow waters of the northern Mediterranean Spanish coast were studied with the objective to elucidate its present structure, distribution and diversity at different scales and with different degree of anthropogenic pressure. Samples were obtained at different depths along the coast between the border of the Spanish-French border to the vicinity of Valencia. Four different studies are presented.

In the Barcelona case study, we revisited an station 20 years after cessation of impact due to sewage discharges. By 2008, we found benthic recovery and clear increase in complexity and diversity. It changed from an assemblage 98 % dominated by a C. capitata complex to an assemblage dominated by M. fragilis, C. capitata, and O. hartmanni. We found more species and more diversity in trophic groups, whereas the abundance and biomass values were clearly reduced by almost two and one order of magnitude, respectively. Although, as silt-clay content in sediments improved, diminishing from 95 to 25 %, as well as PCBs and PAHs during the period, their metal content was still very high. This situation may inhibit their full recovery to normal conditions.

In the Alt Empordà case study, we revisited 42 sampling sites, previously sampled by French scientists in 1970-72. Using the same methodologies we found the Bay of Roses polychaete assemblages belonging to the LFS and LSM communities described by Labrune et al. (2007), a decrease in the number of species and individuals at the shallowest assemblages and similar numbers for the deepest one. D. arietina dominate fine sand sediments while L. latreilli did the same in sandy mud sediments. In the northeastern part of the Cap de Creus, the number of species and individuals were similar to those described by Desbruyères et al. (1972-73) and other notable differences in species composition were registered.

In the regional scale case study, 59 sampling sites were considered in 22 inshore-offshore transects located at depth gradient (10, 20 and 30 m) of the LFS community (Labrune et al., 2007), along the North-western Mediterranean portion of coast between the French border and the Valencia City. The spatial distribution, diversity of polychaetes shows maximal and minimal densities and diversities related to other areas of the Mediterranean Sea. Polychaete assemblages found in it study were similar to establish in the vicinity of Gulf of Lions and other areas of the Mediterranean Sea, although in this case, our results do not reveals linked to granulometric parameters, it was related to depth.

Finally, a mesoscales survey have been carried out analizing samples from the mouth of the Rhone River (France) to the vicinity of Valencia (Spain), obtained from the LFS community. Polychaete assemblages found at the Littoral sands of the North-western Mediterranean are clearly described by the large presence of D. arietina and O. fusiformis both in abundance and biomass, being this more acute in the stations sample at the Gulf of Lions. In sites where coarse sand sediments were found, near rocky shores or highly dynamic deltas, the LFS community was replaced by the Littoral Coarse Sands community (LCS).The Polychaete fauna was well represented along the Mediterranean Spanish coast. We found an important number of the species that constitute the pool of polychaete species inhabiting shallowest sites of the Western mediterranean. Their heterogeneity, diversity, and species richness could range between low to high, depend on size and composition of sediment, depth, submarine topography and human pressure at localities which it inhabit. The structure and distribution of polychaetes assemblages could be related to other factors besides the factors mentioned above, as nutrient availability closed to river discharges or other top-down and bottom-up biotic factors.

INTRODUCTION

Polychaetes as a zoological model

Common generalities about Polychaetes

Among the marine invertebrates, Polychaetes occur in a wide range of habitats and they occupy all depths on every kind of bottom, from rocky bottoms to muddy sediments (Knox *et al.* 1977), from interstitials sands (Núñez *et al.* 2001), estuarine environments (Díaz and Schaffner 1990) or tide marks (Dexter 1969, 1992) until the abyssal plains (Cosson-Sarradin *et al.* 1998; Fiege *et al.* 2000), even they can be found in extreme environments such as hydrothermal vents (Blake and Hilbig 1990). Polychaetes are among the most dominant organisms, both in terms of abundance and biomass, and also often in diversity (Knox *et al.* 1977; Grassle and Maciolek 1992; Hutchings 1998). They have an extraordinary range of ways of living; they may be free living, i.e. crawling on the surface, among stones and algae, buried in the bottom material and swimming; or they may be sedentary, i.e. living in tubes or burrows (Knox *et al.* 1977). They also might by in whales falls bones (Smith and Baco 2003; Dahlgren *et al.* 2004; Glover *et al.* 2005). Although basically they are marine organisms, even you can find organisms adapted to live in fresh water sediment (Hartman 1959; Foster 1972); and less common, atypical polychaetes habitats include subterranean waters, the hyporheic zone of rivers and plant container habitats (Viéitez *et al.* 2004; Williams 2004; Glasby and Timm 2008). In addition, they can become specialized symbionts, from parasites to mutualists, living in association with many marine taxa, including other polychaetes (Martin and Britayev 1998).

Polychaetes are critical in marine food chains, as important prey for many crustaceans, mollusks, fish, wading birds and other organisms, and as predators in their own right. Polychaetes play a major role in the breakdown, subduction and incorporation of organic matter into sediments and their aeration. Due to their ubiquitous distribution, the species composition of polychaetes in a benthic community can indicate the ‘health’ of that community; increasingly, polychaetes are useful pollution indicators (Beesley *et* *al.* 2000). Some species as serious fouling organisms or as pests of commercial shellfish like suspended oyster *Crassostrea gigas* cultures (Mazouni *et al.* 2001) or harbours and other marine structures (Cinar *et al.* 2008). Moreover, some polychaetes have been used by human consume, mainly those known as "palolo" worms (Thorpe *et al.* 2000).

Polychaetes are also economically important by the growing commercial activities and the international market for polychaete species that are dug up or farmed, mainly for being used as fishing bait (Watson *et al.* 2007) and as a food item in aquaculture, with the implied risk of introducing foreign species and associated pathogens or other non-native organisms in the wild (Gambi *et al.* 1994; Olive 1994). Others polychaetes contains toxins or venom glands in some groups i.e. Amphionomidae, *Glycera*, *Metaxypsamma*, and the fact that other groups are chemically defended, opens the possibility of new investigations and applications in pharmacology and medicine (Martin *et al.* 2000).

SYSTEMATICS

The first description of a polychaete accepted for taxonomic purposes was done by Linne in 1758; he recognized the class Vermes for soft-bodied worm-like organisms. Vermes contained, in addition to organisms now recognized as polychaetes and clitellates, also various mollusks and a few crustaceans, nematodes, sea urchins, starfish and cnidarians (Fauchald and Rouse 1997). Other descriptive and classificatory work of great importance were done by Cuvier *et al.* (1817); Lamarck (1818). This phase of annelid classification terminated with Audouin and Milne-Edwards (1834) giving a major overview of the French fauna; the only new name of importance introduced in the higher classification was Errantia; previously named 'Antenneed or 'Dorsibranchiata', to be a companion-term to Sedentaria (Fauchald and Rouse 1997).

In 1850, Grube was first recognized polychaetes as a uniform group. He presented a new classification of the Annelida (as Annulata). The order Appendiculata contained all groups which today are still called polychaetes and *Tomopteris* was placed in a separate order, Gymnocopa. *Peripatus*, at that time, it also was considered an annelid and was placed in the order Onychophora, as did Audouin & Milne Edwards in 1834. The order

Oligochaeta contained earthworms and related taxa, and the order Discophora contained the leeches. Thus, Grube, for the first time, separated both clitellate groups from the polychaetes (Fauchald and Rouse 1997; Beesley *et al.* 2000). Later Quatrefages (1865), divided worms into two series, ‘Vers dioique’ and ‘Vers monoique’. The polychaetes were all included in the Annelides, like ‘sedentaries’ polychaetes were recognized as having distinctly regionalized bodies as thorax and abdomen; and ‘errantes’ as lacking such regions. Lately, in 1878 Hatschek added the Archiannelida, a group as a separate class to include two families, Polygordiidae and Dinophilidae. Besides Hatschek divided the polychaetes into two groups, Cirrifera and Acirra and he used the presence or absence of these cirri as unique features for one of his main groups (Cirrophora vs. Acirra) (Fauchald and Rouse 1997).

Before the nineties, the single most commonly used system was derived from Quatrefages (1865), as codified in widely used monographs by (Fauvel 1923, 1927); Day (1967). The concepts of Errantia and Sedentaria were used even when the authors complained about the inadequacies of the system (Fauchald and Rouse 1997). Dales (1977) re-stated his finding that the stomodaeal modifications are of major importance for understanding polychaete phylogeny, and that other features, also considered in his earlier publications such as nephridia, musculature and chaetae, add importantly to phylogenetic interpretation. Pettibone (1963) presented a key to the class Polychaeta leading directly to families, without reference to orders, but she later (1982) recognized 25 orders, including one for each of the five traditional ‘archiannelidan’ and 6 superfamilies. Fauchald (1977) included 17 orders; his diagnoses did not emphasis on any single morphological feature, but showed a preference for features of the anterior end for major subdivisions.

After the controversy about systematics of Annelida, Rouse and Fauchald (1995) have suggested, it should not be used unless relationships within the Articulata are resolved to show it is a monophyletic taxon. They also recommended taxon name Articulata, originally formulated to include the Annelida and Arthropoda by Cuvier, and is defined as the clade stemming from the first ancestor to show repetition of homologous body structures derived by teloblastic growth with a pygidial growth zone (segmentation) and longitudinal muscles broken into bands. Additionally Fauchald and Rouse (1997), demonstrated the historical background for the current unsatisfactory state of systematics of the polychaetes by the lack of consistent morphological information as major source of uncertainty. They also showed Polychaeta is a monophyletic taxon, but there is no evidence of a sister group for the Clitellata among the polychaetes. They also pointed out that Pogonophora are members of the Polychaeta. On the other hand, McHugh (2000) uses the sequence of a nuclear gene, elongation factor-1, for phylogenetic analysis by the parsimony and neighbour joining methods, but there is no evidence for a monophyletic Polychaeta; instead, placement of the clitellates, pogonophorans and echiurans within the polychaete clade is supported, rendering the Polychaeta paraphyletic taxon. In the same way Westheide *et al.* (1999), based on Hennigian reasoning, and their character weighting is based on diverse, mainly functional considerations, i.e. they taked into account habitats, body size, reproductive biology and the fossil record. Their annelid tree shows the Clitellata as a highly evolved monophylum and the polychaetes as paraphyletic. Special emphasis is placed on the demonstration that the Clitellata are of terrestrial origin. Thus, a future approach that uses morphological and molecular data in combination for the analysis of higher-level annelid relationships, but this will also require further studies on particular issues at lower taxonomic levels (Rousset *et al.* 2007).

The current number of accepted polychaete species is around 9000, though several thousand more have been named and considered invalid (Rouse and Pleijel 2001). The Mediterranean polychaete fauna currently includes 1122 species (of this 946 polychaete species are known from the western Mediterranean), grouped in 452 genera belonging to 72 families (Coll *et al.* 2010), without sort such of them in cosmopolitan or endemics species like (Arvanitidis *et al.* 2002). Keeping in mind this trend, I will refer to different polychaete family level for practical comparative purposes, taking into account 72 groups of polychaetes, the ones showed by Rouse and Fauchald (1997).

Morphology

The body varies greatly in form, depending on life mode and substratum type, i.e. whether the polychaete is errant, crawling, burrowing, sedentary, tube-dwelling, or pelagic (Pettibone 1982). These worms vary in length from less than 1 mm in some interstitial forms to over 3 m (some Eunicidae, Onuphidae) and may live from a few weeks to several years (Beesley *et al.* 2000). The number of segments may be few and limited or many and unlimited. New segments develop immediately in front of the pygidium (Pettibone 1982).

The polychaete body consists of three basic regions: the presegmental region is derived from the episphere, prototroch and the area surrounding the mouth in the larvae and makes up the prostomium and peristomium (the head) in the adult worm (Beesley *et al.* 2000). The head consists of the preoral prostomium, which contains the cerebral ganglia and bears the most important sense organs (Day 1967). It may be in the form of a simple lobe or furnished with various appendages, including a pair of ventral palps and frontal dorsal, or occipital antennae; sometimes simple eyespots or a pair of well-developed stalked eyes are present (Alciopidae, Polyodontidae). The peristomium, enclosing the ventral mouth, may be formed of one to several fused segments which often lack parapodia and setae and are furnished with a variable number of tentacular or peristomial cirri. The prostomium and peristomium may be more or less fused, and are furnished with a pair of long grooved tentacular palps, ciliated nuchal organs, and a median caruncle extending posteriorly from the prostomium. In the sedentary or tube-dwelling forms, the prostomium may be indistinct and more or less hidden by other structures, such as numerous oral tentacles (Terebellidae, Ampharetidae), enlarged flattened setae or paleae (Amphictenidae, Sabellariidae), or an enlarged branchial plume (Sabellidae, Serputidae). Usually, each segment following the peristomium is provided with paired parapodia in the form of fleshy lateral outgrowths bearing bundles of setae. When present, the parapodia are uniramous or biramous (dorsal notopodium and ventral neuropodium), and each is supported by a short rod or aciculum. In the burrowing and sedentary forms, the rami may be in the form of low ridges (tori) provided with rows of acicular hooks or minute setae or uncini. The setae are particularly varied, slender or stout, smooth or dentate, and simple or compound, with basal stems and distal blades of various types. The parapodia may bear accessory structures, such as dorsal and ventral cirri, dorsal scalps (Aphroditacea), flattened lobes or ligules (Nereididae), flattened plates or lamellae (Nephtyidae, Spionidae), or filiform or branched branchiae (Eunicidae). The pygidium, containing the dorsal anus, may be simple or may be provided with cirri or flattened plates (Pettibone 1982).

The epidermis of the body wall is often furnished with ciliated cells which form ciliated tracts and bands; they may set up currents of water, aiding in respiration, and bringing food-laden water and selected particles for tube construction to the mouth. In addition to the circular and longitudinal muscles of the body wall, there may be oblique and transverse muscles, complicated musculature associated with the tentacles and proboscis, and prominent parapodial and setal muscles. The circular muscle layer may be reduced or absent. Slow crawling movement is carried out by the parapodial muscles, rapid crawling and swimming by the parapodia and by undulations of the body which use the well-developed longitudinal muscle bundles. Burrowing may involve two types of anchors; the penetration anchor is a dilation of the upper part of the body that holds the worm against the burrow when the distal region is elongated by contraction of the circular or transverse muscles; this is followed by dilation of the distal region, forming the terminal anchor, which allows contraction of the longitudinal muscles to move the worm into the substrate. The two types of anchors are applied alternately until burial is complete. Polychaetes with elongate narrow bodies and poorly developed parapodia swim by means of undulations which pass along the body and exert a backward thrust against the water in a complex three-dimensional spiral motion or a lateral sinusoidal movement. Irrigation currents are often produced in burrowing and tube-dwelling polychaetes by muscular means, such as undulations of the body in a dorsoventral plane, or pistonlike swellings which pass up or down the body (Pettibone 1982).

Feeding Strategies

Fauchald and Jumars (1979) proposed a consistent conceptual framework to test hypotheses on the sympatric occurrence of congeners with limited morphological differentiation. Their polychaete feeding guilds were established based on a set of relations among food particle size and composition, the mechanisms involved in food capture and ingestion, and motility patterns associated with the feeding itself. Secondarily, the ingestion and assimilation efficiencies and the size or volume of the area necessary for the survival of a given organism would be involved. But currently, analyses of polychaete assemblages do not generally use the complete conceptual framework elaborated by them, i.e. (microphagous and microphagous), which in turn can be subdivided in 5 submodes and 12 subgroups formed according to feeding morphology of each mode. They were combined with the three components of feeding motility to form 22 feeding guilds that are biologically acceptable. The most used feeding schemes generally divide the fauna into five or six trophic categories (omnivores, herbivores, carnivores, filter feeders, surface deposit feeders and burrowers) (Pagliosa 2005). On the other hand, Beesley *et al.* (2000) have summarized this strategies with no implication of phylogenetic relationships, but are useful for ecological purposes, they following schema given by (Fauchald and Jumars 1979) as:

1. Raptorial feeding (Carnivorous, Herbivorous and Omnivorous): this group, all macrophagous polychaetes, included polychaetes with eversible muscular ventral or muscular axial pharynx, to seize food items (often with jaws or teeth) like Eunicida and Phyllodocida, the two groups use its jaws to either seize live animals (carnivorous), tear off pieces of algae (herbivorous) or to grasp dead and decaying matter (scavengers). Some of the raptorial groups, such Phyllodocidae, lack jaws and use their eversible pharynx to capture prey. Members of Onuphidae family have burrowing lives mode, emerge to seek their prey where waves break. They have powerful jaws and feed on small to medium-sized invertebrates as well as drift algae.
2. Deposit-feeders (non-selective): the majority of groups using this method have a simple ventral or axial buccal organ. Some arenicolids and maldanids live in relatively permanent burrows or tubes and feed on the continuous raining of sand or mud falling around the burrow. Others, such as orbiniids, which do not have permanent burrows or tubes, move about the sediment, eating it as they tunnel. In sediments the amount of nutritional value varies; shallow-water mud deposits tend to contain high densities of non-selective deposit-feeders. The total organic matter in such areas can be as low as 1-2% and most deposit-feeders have to eat continually.
3. Surface deposit-feeder (selective): some deposit-feeders do not ingest haphazardly, but use their palps or buccal organs to sort organic material from sediment particles of a particular size range, typically the smaller one. As smaller particles have a great surface area to volume ratio than large particles, they carry more food proportionately per weight ingested. Hence, it is more

efficient to eat smaller particles than a random selection of various-sized particles. Selective deposit-feeders usually live in tubes.

4. Filter feeders: polychaetes filter-feeder, filter suspended particles from the water column. These polychaetes live in some sort of tube. The best known are sabellids serpulids and some chaetopterids. Sabellids and serpulids have elaborate palps in the form of tentacular crowns. A funnel is formed as the crown is expanded out of the tube. On each radiole cilia beat and create a current in the surrounding water. This current passes through the radioles into the funnel, swirls around its base and then passes upwards and outwards. Then food particles are trapped on small brnaches of the radioles, termed pinnules, and carries into groove by cilia. The ciliary current transports the particles towards the base of the radioles where the material is sorted. Small particles are swallowed. But large ones are diverted from the muth and dropped into the awater. Othes species sort the particles into three sizes; mid-sized particles are used in construction of the tube (Beesley *et al.* 2000).

THE MEDITERRANEAN SEA

Oceanographic features

The Mediterranean Sea is a mid-latitude semi-enclosed sea, or almost isolated oceanic system. Many processes which are essential to the general circulation of the world ocean also occur within the Mediterranean, either identically or analogously (Malanotte-Rizzoli 2001; Robinson *et al.* 2001). The Mediterranean Sea (Fig. 1) is a marginal basin connected with the Atlantic Ocean via the Strait of Gibraltar (Astraldi *et al.* 1999). Therein, The Mediterranean Sea exchanges water, salt, heat, and other properties with the North Atlantic Ocean. The North Atlantic is known to play an important role in the global thermohaline circulation, as the major site of deep- and bottom-water formation for the global thermohaline cell (conveyor belt) which encompasses the Atlantic, Southern, Indian, and Pacific Oceans. The salty water of Mediterranean origin may affect water formation processes and variabilities and even the stability of the global thermohaline equilibrium state (Robinson *et al.* 2001). Besides the Mediterranean Sea is formed by two principal sub-basins (the Western and the Eastern Mediterranean) both connected by the Sicily Strait. As the Eastern and the Western Mediterranean, in their turn, enclose several regional seas that are also separated by straits and channels. It constitutes choke points where may observed the exchange of water masses and related properties internally between all the sub-basins and externally between the Mediterranean and the world ocean. The most important strait and channel are: the Corsica and the Balearic Channels, which control the meridional fluxes of the Western Mediterranean Sea; the Sardinia Channel, which forms the eastern boundary of the western Mediterranean basin; the Otranto Strait, through which are conveyed the exchanges between the Adriatic Sea with the rest of Mediterranean; and the Cretan Arc Straits, which is the interface between the Aegean Sea and the Eastern Mediterranean Basin (Astraldi *et al.* 1999). Thus the Mediterranean circulation is forced by water exchange through the straits, by wind stress, and by buoyancy flux at the surface due to freshwater and heat fluxes (Robinson *et al.* 2001).

The circulation on all the Mediterranean sea have been well explained by Millot (1989); (1999) and Malanotte-Rizzoli (2001). Circulation in the Western Mediterranean follows three main ways:

a) An upper thermocline circulation, the ‘Modified Atlantic Water’ MAW name used by Millot (1999) to refer to the surface water all over the Mediterranean Sea, which forms a 100–200 m layer characterized by salinities that increase, due to evaporation and mixing, from ;36.5 at Gibraltar to 38.0–38.3 in the north of the Western Mediterranean Sea, and by a mean temperature, below the mixed layer, of usually 14–15 ºC.
b) Other intermediate layer circulation with Levantine Intermediate Water (LIW) pathways. The LIW, which the highest temperature could be 14.5 ºC and 38.7 salinity at 200 m depth along the Sicilian strait, but also a cooler than 14.0 ºC and denser than 0.1, water with approximately the same salinity at the bottom along the Tunisian slope.
c) The latest one is considered deep thermohaline circulation with Western Mediterranean dense and deep waters (WMDW) pathways. This water mass

formed during the winter, mainly in the Gulf of Lions, and generally characterized by values of 12.75–12.80 ºC and 38.44–38.46 salinity content.

This water mass (MAW) in the Alboran Sea describes a quasi-permanent anti-cyclonic gyre in the west and a more variable circuit in the eastern Alboran. Further east, the MAW is gathered in the strong meandering Algerian current, whose instabilities lead to the formation of anti-cyclonic eddies (diameter nearly 50-100 km) alongside the Algerian coast. These eddies grow in size; some may detach from the coast and drift into the interior of the Balearic Sea. There is also a quasi-stationary cyclonic path of MAW around the Balearic Sea leading to the formation of the Western Corsican Current west of Corsica. In the Tyrrhenian Sea, another steady cyclonic path of MAW, intrudes into Northern Ligurian Sea, where it joins the Western Corsican Current generating a return south-west ward flow along the Italian, French, and Spanish coasts, towards the Alboran Sea, called the Northern Current. The latest shows strong seasonal variability, becoming more intense and narrower in wintertime when it develops intense meanders, and splits into multiple branches in the southern Balearic Sea.

The LIW circulation emerges from the Sicily Straits into the Western Mediterranean in the intermediate layer, 200-600 depth. LIW follows a cyclonic route all around the Tyrrhenian Sea, and splits into two branches at the northern tip of Corsica. One branch enters directly into the Ligurian Sea, the second circulates around Sardinia and Corsica, merges with the previous branch and successively flows cyclonically around the Balearic Sea. This major LIW branch enters the Gulf of Lions, where it plays a crucial role in preconditioning the winter convective cell of WMDW located here. WMDW has been observed to form in the Gulf of Lions basically every year, under winter episodes of cold, dry Mistral wind blowing from France. Here the mixed, ventilating chimney (around 100 km in diameter) can reach 2000 m depth. However, the mean LIW pathway is still controversial.

The WMDW follows a circuitous cyclonic route that leads it throughout the Balearic and Tyrrhenian Seas. The deep WMDW flow is obviously affected by topography. In the Tyrrhenian Sea, the WMDW joins the Tyrrhenian Dense Water present in the deep layers. At Gibraltar, upwelling of WMDW occurs, mixing with the overlying LIW, and contributing (what it is believed to be a small proportion) to the outflow from Gibraltar into the northern Atlantic.

The Mediterranean Sea is a marine biodiversity hot spot. Spatial patterns showed a general decrease in biodiversity from northwestern to southeastern regions following a gradient of production, with some exceptions and caution due to lack of information of the biota along the southern and eastern edges. Biodiversity was also generally higher in coastal areas and continental shelves, and decreases with depth. Temporal trends indicated that overexploitation and habitat loss have been the main human drivers of historical changes in biodiversity. Currently, habitat loss and degradation, followed by fishing impacts, pollution, climate change, eutrophication, and the establishment of alien species are the most important threats to the whole taxonomic groups (Coll *et al.* 2010). Now, the new Marine Environmental Policy of the European Union, the Marine Strategy Framework Directive (MSFD), aims to achieve a good environmental status (GEnS) and the sustainable use of marine ecosystems, using the ecosystem approach as its basic reference framework (DIRECTIVE_2008/56/EC). This policy contained 11 descriptors have been identified for the achievement of GEnS, following European guidelines on the interpretation and application of the biological diversity descriptor as the first one on the list: “Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions”. When this descriptor is analyzed, the recommended levels of ecological organization for the assessment include species state, habitat/community state, landscape state and, finally, the entire ecosystem state (Cochrane *et al.* 2010). These authors also recommended a pragmatic, risk-based selection of biodiversity components using surrogates to assess the biodiversity state of a particular region. In addition, the use of the predominant habitat/community types, the ecotypes of the mobile species group, and the species and habitats listed under Community legislation and international conventions was suggested.

THESIS STRUCTURE

The studies about macrobenthic distribution that includes polychaetes faunal in the Mediterranean Sea were done by (Pérès and Picard 1964) in infralittoral (limit zone compatible with seagrasses) and and circalittoral zone (limit zone compatible with photophilic algae). Similarly were important the surveys done by Guille (1970, 1971) in the French Catalonian border and Desbruyères *et al.* (1972-73) in the Gulf of Roses. Gili *et al.* (1987), studied several types of bottom between 5-80 m, along Catalonian coast. About polychaetes I can mention the studies by Capaccioni-Azzati (1987); Martin *et al.* (1990); (Afonso-Carrillo *et al.* 1992; Pinedo *et al.* 2000) in Alfaques bay. In Barcelones area (Méndez 1996). Over dynamic aspect of macrofauna (Sardá *et al.* 1995). And over dynamic of some polychaete species Grémare *et al.* (1998) on *D. arietina* and Pinedo *et al.* (2000) over *O. fusiformis.* Other surveys dealing aspect that includes polychaetes are those associated with wastewater discard (Ros *et al.* 1992; Cardell-Corral 1996; Cardell *et al.* 1999; Serrano *et al.* 2011) and/or organic enrichment (Méndez *et al.* 1997).

The main objectives of this study are focused on elucidate:

1. How the soft-bottom Polychaete Fauna is distributed and structured in shallow waters alongside the Spanish Northern Mediterranean coast?
2. What are the main soft-bottom Polychaete assemblages found at the Littoral Fine Sands Community in the Spanish Northern Mediterranean coast?
3. What are the conditioning factors that allow the structure and distribution of the Polychaete Fauna in shallow waters?
4. How the Polychaete Fauna vary in a regional scale from the mouth of the Rhone River (France) to the vicinity of the Valencia city (Spain)?

The information presented in the following chapters could be considered as a baseline study to assess the state of the coastal zone, taking into account that this region underneath strong human pressures.

The thesis is organized taking into account different spatial scales of Polychaetes faunal distribution in shallow waters: a local scale, a sub-regional one, a large regional scale and the last one, analizing a mesoscale distribution. Most of the presented data is based on the Littoral Fine Sands Community (Labrune *et al.* 2006, 2007); the characteristic community that dominates shallow waters from 10 to 25-30 m in the Nort western

Mediterranean Sea. All of the analysis carried out in this Thesis are based on samples taken during the framework of different scientific projects (SPIO, MeVaPlaya-II, INTERFASE, REDIT-I, REDIT-II and INDEMARES). The thesis is structured in four chapters detailed below:

- ➢ Chapter 1: a local scale survey:
    - ✓ A polychaete-dominated community in the NW Mediterranean Sea, 20 years after cessation of sewage discharges. In this chapter, one sampling station surrounded by intense human activities was chosen, off the city of Barcelona. The spatial effects of past wastewater discharges in the region were analyzed by Ros *et al.* (1992); Méndez (1996); Cardell *et al.* (1999) on a single station at 20 m depth. After 20 years, after long time cessation of discharges, the station was revisited for assessment. The main goals of this investigation were:
        - To assess the changes observed in benthic communities during these years.
        - To calculate the secondary production of this community through time, relating these values to sewage discharges, water quality and sediment improvement.
- ➢ Chapter 2: a sub-regional spatial scale:
    - ✓ Long-term comparison of Polychete assemblages within soft-bottoms off the Alt Empordà (North western Mediterranean coast). Alt Empordà case study, was chosen because this area is more pristine, despite of the economic activity generated by leisure activities, which currently is not considerable, but which activity plus the pressures by artisanal and industrial fisheries activities could finally contribute the which degradation of the marine environment due to over-frequentation of visitors. Thus, the polychaete fauna at a large number of stations in the Gulf of Roses and the northern part of the "Cap de Creus" are revisited 30 years after a French oceanographic campaign carried out in 1970-72 using similar methodologies. The main goals of this investigation were:

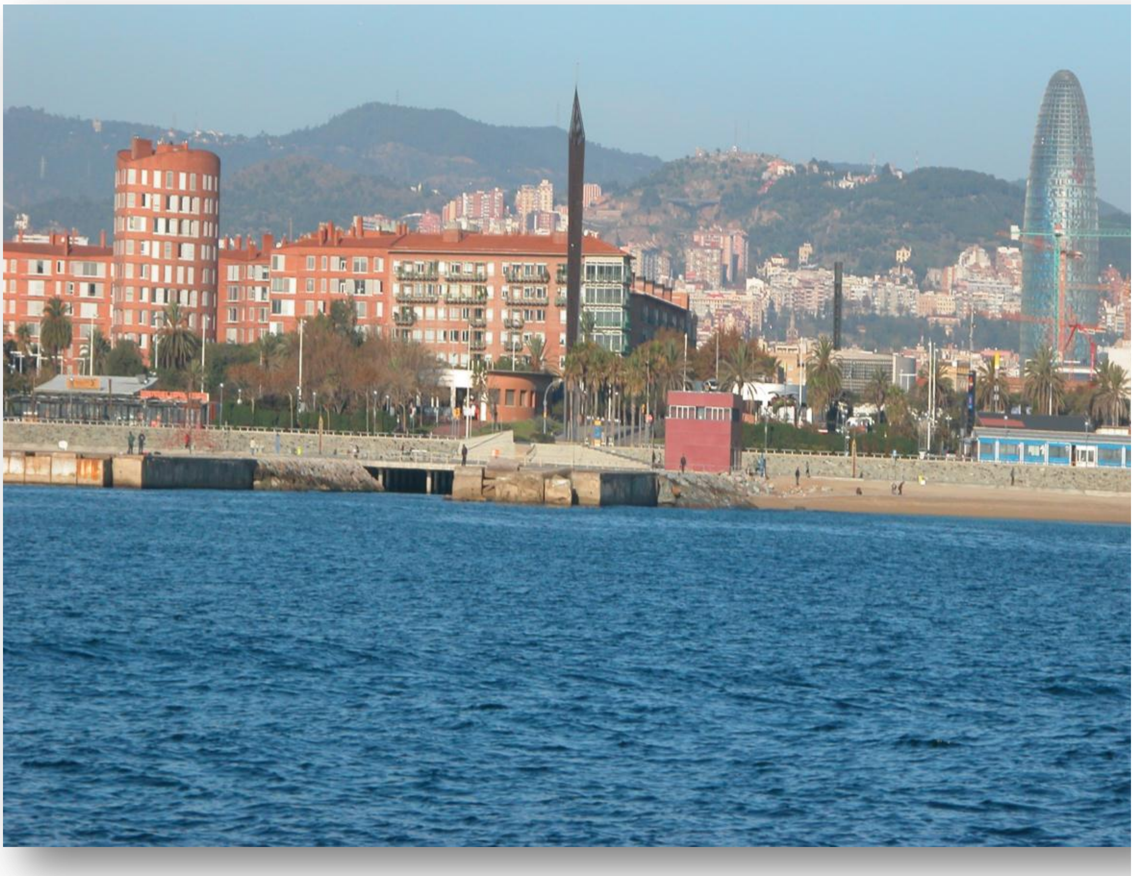
        - To assess the present status of soft-bottom communities in two areas of the “Cap de Creus” region and to make a long-term comparison with old data obtained for these habitats..
        - To update the distributional pattern of polychaetes in the area of the “Cap de Creus” analyzing its relationship with the main environmental parameters.

- ➢ Chapter 3: a regional spatial scale:
    - ✓ Assessment of soft-bottom polychaete sassemblages in the Northern Mediterranean Spanish coast. This chapter benefits from a regional oceanographic campaign carried out by a Spanish-French co-operation financed by the French CNRS, the REDIT-II campaign. In this campaign shallow soft-bottom environments were sampled from the locality of Portbou (Gerona) to the vicinity of the Valencia city. The main goals of this study were:
        - To describe the regional pool of polychaete species inhabiting shallow soft-bottom environments throughout the observed region.
- ➢ Chapter 4: a mesoscale analysis:
    - ✓ Chapter 4. Assessment of soft-bottom polychaete assemblages in the Littoral Fine Sand (LFS) community based on a mesoscale survey: from the mouth of the Rhone river (France) to the vicinity of Valencia (Spain). In this later chapter, we are making a comparison between the different soft-bottom polychaete assemblages found through two oceanographic campaigns (REDIT-I and REDIT-II) at shallow waters (10 and 20 m depth) of the Gulf of Lions and the Northern MNediterranean Spanish coast. The main goals of this investigation were:
        - To describe the distribution patterns of soft-bottom polychaete species throughout the observed region.
        - To identify the relationship between polychaetes assemblages and its main environmental parameters, as well as to get some biomass and productivity estimates.

- To address the suitability of using particular indicators derived of this analysis for the Descriptor 1 of Good Environmental Status (GEnS).

Chapter 1

A polychaete-dominated community in the NW Mediterranean Sea, 20 years after cessation of sewage discharges



CHAPTER 1

A POLYCHAETE-DOMINATED COMMUNITY IN THE NW MEDITERRANEAN SEA, 20 YEARS AFTER CESSATION OF SEWAGE DISCHARGES

ABSTRACT

Benthic recovery following cessation of wastewater discharges in shallow soft-bottom environments off Barcelona was assessed by revisiting an old sampling site in 2008 that had been studied when the impacts of such discharges were more acute (1987-88). In 1987-88, sediments were highly polluted by organic matter and inorganic contaminants. Although the amount of silt-clay in the sediments diminished from 95% to 25% during the intervening twenty year period and significant improvements were observed in the content of PCBs and PAHs, their metal content was still very high. However, the benthic community currently showed a clear increase in complexity and diversity. It changed from an assemblage that was 98% dominated by the *Capitella capitata* complex to an assemblage dominated by *Mediomastus fragilis*, *Capitella capitata*, and *Ophryotrocha hartmanni*. By 2008, more species were found and there was increased representation from different trophic groups, whereas the abundance and biomass values were clearly reduced by almost two and one order of magnitude, respectively. Mean annual density evolved from 385,261 ind. m^{-2} with a mean annual biomass of 12.75 g dry wt m^{-2} in 1987-88, to 8,155 ind. m^{-2} and 0.94 g dry wt m^{-2} in 2008. Using a regression model that allowed comparability between both sets of data, secondary production of the community was reduced from 207.7 g dry wt m^{-2} y^{-1} in 1987-88 to 8.0

g dry wt m^{-2} y^{-1} in 2008. The organic input decreased but the metal concentration present in the sediments may inhibit their full recovery to normal conditions.

INTRODUCTION

Human beings have significantly altered benthic habitats throughout the world's environments. From the many kinds of pollution and ecosystem alterations produced by humans, excess of organic matter is probably the most universal and documented impact affecting marine benthic communities, which occurs principally as sewage but also includes other types of waste (Gray 1981). In addition, sewage discharges through pipelines and outfalls can also contain hazardous metals that can contribute to the pollution of the marine environment (Valiela 2006; Halpern *et al.* 2008). To follow the effects of such kinds of disturbance, as well as the recovery potential of local communities, the use of the marine benthos has been employed as an indicator of environmental changes due to its long life span, sensitive stages, and reduced motility (Pearson & Rosenberg 1978; Warwick & Clarke 1994).

Benthic infaunal communities are organized structurally, numerically and functionally in relation to organic enrichment gradients. Changes in soft-bottom communities due to organic enrichment were modeled by Pearson & Rosenberg (1978) and Rhoads & Germano (1986) and the model has been demonstrated elsewhere. This model established that spatial and temporal changes occurred when heavy or moderate inputs of organic enrichment were introduced into the marine environment. Organic discharges into confined bodies of water frequently lead to the well-known symptoms of eutrophication, resulting, in the most extreme cases, in a total lack of oxygen and the presence of hydrogen sulphide in the sediment, with a corresponding absence of fauna. With increasing distance from a point source discharge there is a corresponding recovery in sediment characteristics and benthic faunal communities. This model is consistent with benthic spatial distributions and temporal responses of the benthos to sewage discharges in open coastal waters (Swartz *et al.* 1986). These changes always show the same patterns that consist basically of decreases in diversity, dominance by opportunistic species, and reduction in the mean size of the dominant species. However, following such events, the communities typically undergo a period of change, often referred to as succession, which ends with a return to the same faunal composition as the pre-impacted state (Rosenberg *et al.* 2002). Pearson & Rosenberg (1978) showed in parallel studies from Scotland, where environmental disturbance increased, and Sweden, where the conditions improved after pollution abatement, that the benthic community structure was similar under similar degrees of disturbance even when the succession of these communities changed in different directions.

The relationships between organic enrichment and benthic productivity have been well documented in the past (Heip 1992). As populations of pioneering species with high rates of increase are the basic responders to organic enrichment, these organisms may enhance secondary production of benthic habitats (Rhoads *et al.* 1978). Although secondary production can integrate information about dynamics in stressed ecosystems with high energy flux, secondary production has not been computed as a response to these sources of environmental disturbances, and few data are available (Steimle *et al.* 1990; Méndez *et al.* 1997).

The Mediterranean basin has particular oceanographic characteristics (relatively shallow, semi-enclosed and with limited natural water exchanges) and it is experiencing heavy demographic, urban and industrial pressures on its coastal areas (Tolosa *et al.* 1997; Bianchi & Morri 2000). The metropolitan area of Barcelona is one of the most active urban environments in the South of Europe and is comprised of 33 municipalities. The flow of raw materials, water and energy that takes place every day in such a socio-ecological system helps to maintain economical activities on but also produces a large volume of waste, such as sewage. A total of 3.2 million inhabitants live in this area and they produce large amounts of urban and industrial wastewaters that are primarily treated and discharged at high rates into the marine environment. During the last two decades, following the introduction of the European environmental policy on water quality (CIS_WFD 2005), waste water discharges treated in the region have drastically improved in quality, and the amount of organic pollution has been highly reduced. This improvement may have also produced a change in the marine benthic communities inhabiting the coastal region following alleviation of the pressure that organic matter previously exerted on them.

In this article, the results obtained during two surveys carried out at the same sampling station, off the city of Barcelona, are presented. These two surveys were separated by twenty years. Additional data on the spatial effects of past wastewater discharges in the region can be seen in Ros & Cardell (1992); Cardell (1996) and Cardell *et al.* (1999). Data presented in this article will be compared against seasonal data obtained from a reference station included in the MacroBen database (Vanden Berghe *et al.* 2009) representing the shallow soft-bottom environments along the Catalan coast. By using these results, the main goals of this article were: a) to assess the changes observed in benthic communities during these years, and b) to calculate the secondary production of this community with time, relating these values to sewage discharges, water quality and sediment improvement.

MATERIAL AND METHODS

Study site

The article is based on samples collected from a single sampling site. This sampling station was located off the Barcelona municipal area (NE, Spain) in a soft-bottom environment at a depth of 20 m (Figure 1). Although at that depth, shallow soft-bottom non-vegetated areas from the Western Mediterranean are commonly inhabited by the medium to fine-sand community represented by *Spisula subtruncata* (*sensu* Pérès & Picard 1964), in the case of Barcelona, these habitats have been receiving the pressures and effluents from the city for hundreds of years, which in turn have produced a change in their physical and chemical properties. The sampling station was first widely affected by the city’s non-treated effluents, then, in the last century, by the waste water treatment plant facilities installed during the 1970s, and, more recently, by the new updated and modernized Besòs waste water treatment plant. A monthly sampling procedure was carried out at this station in 1987-88. After twenty years, the station was revisited and sampled again to detect any changes and to relate those changes with the improvement in the city's depuration of its waste-waters.

During the first period of the study (1987-88), sediments off Barcelona city received effluents from different sources. The Besòs treatment plant had primary sludge treatment (half of this was solid suspended material) of over 4.10^5 m^3 day^{-1}, that was sent through a 4 km pipeline from the shore to a depth of 56 m (Figure 1a), with wastewater discharged via an outlet pipe just 600 m long (Ros & Cardell 1992; Cardell 1996; López-Sánchez *et al.* 1996). In addition, another important untreated sewage discharge flowed mainly through the mouth of the Besòs River (3.10^5 m^3 day^{-1}) (Figure 1d), and the rest of the sewage inputs of the city were depurated in the Bogatell treatment plant (8.10^4 m^3 day^{-1}) that discharged directly on the shoreline (Figure 1b,c). The sampling site was located to the south of these three inputs and received their inflow directly due to the prevailing NE-SW direction of the coastal currents in this geographical area (Font & Miralles 1978).

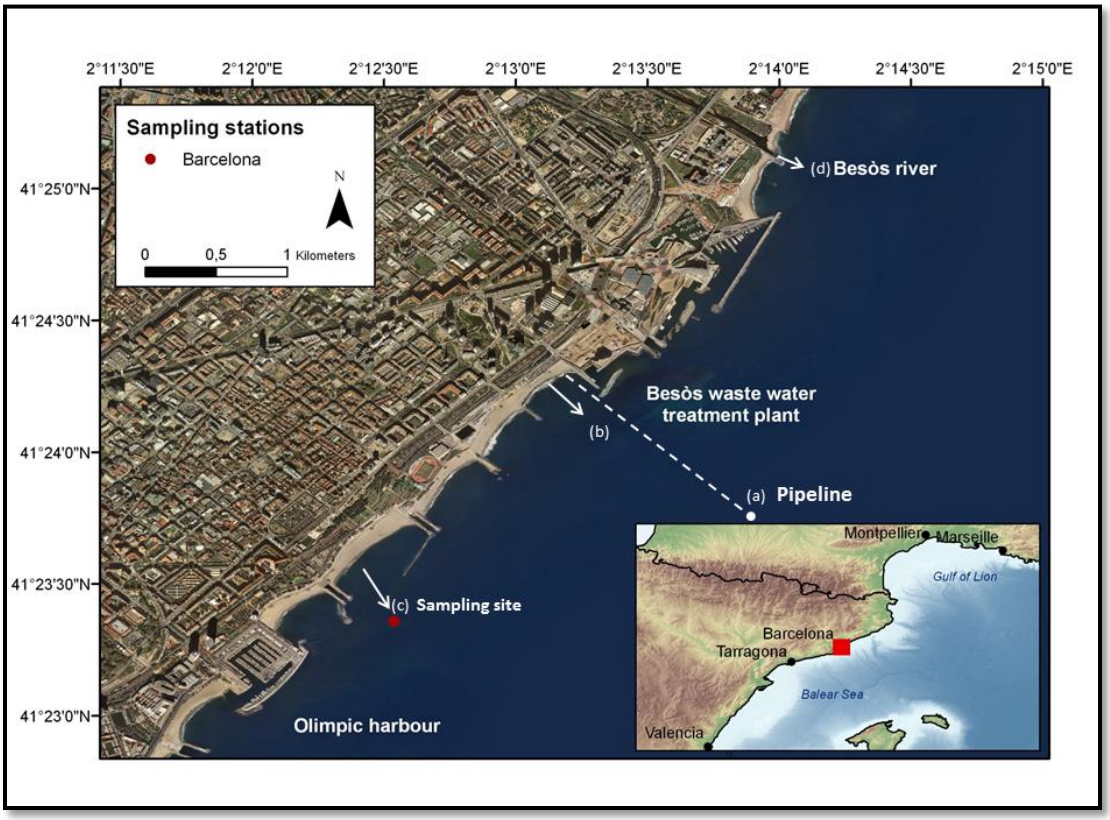


Figure 1. Map of the study area showing the sampling station.

During the 1990s, the Besòs treatment plant was remodelled with new compact technologies (expanding the biological treatment process) to meet the standards required by the European Union to which Spain was incorporated in 1986. Today, the plant treats the sewage water for an area with a population of 1.6 million inhabitants, comprising the municipalities from Barcelona (75%), Sant Adrià de Besòs, Santa Coloma de Gramanet, Badalona, Montgat and Tiana. It is a very large plant (one of the biggest in the world), with a rated flow of over 6.10^5 m^3 day^{-1} for an equivalent population of about 3 million inhabitants. The effluent from the new plant flows into the sea at a depth of 45 m through a subsea pipeline 2,900 m long (2.1 m diameter). Previous outlets and the Bogatell plant have been closed and the water flowing through the mouth of the Besòs River has been highly depurated, so the organic enrichment impacts on the benthic habitats living in the area of the sampling station have been drastically reduced.

The variability of climatic and hydrographic conditions of the littoral is typical of temperate zones, and the surface seawater temperature has been shown to range between 11-12 ºC and 25-26 ºC (Amengual *et al.* 1988; Cebrián *et al.* 1996). The freshwater regime depends on the Besòs River increasing its flow during autumn and spring. It is combined with intermittent heavy discharges (pulses) after storm periods. Planktonic gross primary production peaks during late winter in this area (Estrada 1980; Satta *et al.* 1996). All these factors mentioned above were important to the understanding of the dynamics and regulation of the biological benthic secondary production.

Sampling and laboratory procedures

The station was sampled monthly from September 1987 to September 1988 during the course of the SPIO project, and then, after 20 years, the same station was sampled again in June and November 2008. These months were selected as sampling time points as it had been shown (Sardá *et al.* 1995; 1999) that abundance average are comparable with the annual abundance average of the entire year when monthly sampling is carried out. Sediment samples were collected using 0.1 m^2 and 0.06 m^2 Van Veen grabs, respectively. Three grabs were taken for the analysis of benthic infauna and one for sedimentological analyses, although in 2008 only a 0.06 m² Van Veen grab was used. The grabs were able to penetrate 30 cm into the sediments. No biogenic structures were seen on the bottom of the grab samples. Samples were immediately sieved on a 500-μm mesh and the fauna retained were fixed in 5% formaldehyde. Polychaete species were later identified to the lowest practical taxonomic level and counted. Individual species biomass was determined as dry weight.

During the first sampling (1987-88), selected individuals from representative size categories for the most important species were measured through a binocular microscope equipped with a camera lucida and digitizing tablet. They were then dried (24 h at 70 ºC) and their biomass was obtained as dry weight ($g \cdot m^{-2}$). Using this data, regressions of width vs. dry weight were computed for each major species found and they were used to convert width to biomass (Sardá *et al.* 1999). In 2008, biomass was obtained as wet weight. For comparison purposes, all the data given in this article are expressed in dry weight using, where necessary, the dry weight (17.6%) from wet weight conversion factor calculated for polychaetes in Rumohr *et al.* (1987). Organisms were classified into five trophic groups according to the classical literature (Fauchald & Jumars 1979): filter feeders; mixed (filter and surface-deposit feeders); surface-deposit feeders; subsurface-deposit feeders; and carnivores/omnivores.

Within different research projects, the structure and dynamics of a shallow soft-bottom macroinfaunal assemblage of the medium- to fine-sand sediment community of *Spisula subtruncata* was investigated (Sardá *et al.* 1999). This station has been incorporated into the MacroBen database (Vanden Berghe *et al.* 2009) as a reference point due to the five year data series obtained there. In this current study, its observed dynamics and parameters were compared against those registered on the Barcelona coast at the sampling site.

During 1987-88, the samples obtained for sedimentological analysis were frozen immediately, stored until analyzed, and then defrosted and dried in the laboratory. Metal content was analyzed by flame atomic absorption using a Perking-Elmer 460 spectrophotometer (Palanques & Diaz, 1994). The polychlorinated biphenyl PCB and polycyclic aromatic hydrocarbon PAH contents were obtained by gas chromatography. The samples collected in 2008 were sent to an accredited laboratory for metals analysis, whereas PCBs and PAHs were analyzed using standard techniques.

Measurement methods and secondary production estimates

In 1987-88, secondary production of the two most important contributors for biomass in the assemblage, *Capitella capitata* and *Malacoceros fuliginosus*, was studied by conventional direct production estimates. The maximum thoracic width was used as a size estimate in order to measure growth and to identify generations in the populations of both species of polychaetes. Size measurements were carried out through a stereo microscope using a camera lucida and a digitalizing tablet. For the two species, a thoracic width (TW, mm) versus dry weight (DW, mg) regression was calculated to obtain the biomass of the different specimens:

C. capitata: $DW = 0.32\ TW^{2.57}$, $R^2=0.88$

M. fuliginosus: $DW= 1.22\ TW^{1.35}$, $R^2=0.71$

Secondary production was estimated by the Hynes method (Hynes & Coleman 1968; Hamilton *et al.* 1969; Benke 1979) following the formula given by (Menzie 1980):

$$P = \left[\sum_{j=1}^{i} i(N_j - N_{j+1})(w_j * w_{j+1})^{0.5} \right] * \frac{12}{CPI}$$

where N_j and N_{j+1} are average numbers of individuals of class j and j+1, $w_j * w_{j+1}$ is the geometric mean of the dry weight of two successive size classes, *i* is the number of size classes and *CPI* is the cohort production interval. The *CPI* (a correction for development times shorter or longer than a year) may be inferred from shifts in size distribution throughout the year or from clearly defined emergence periods when independent growth studies under controlled conditions are lacking (Benke 1993). The population dynamics data for both species were used to analyze their cohort production intervals. For these analyses, all organisms of both species were classified into three age classes (recruiters, juvenile, and adults). For *C. capitata*, the recruiters were considered as the individuals included in the lowest size-class measured for the population (maximum thoracic width less than 200 µm), and, according to Tsutsumi (1990) and Tsutsumi *et al.* (1990), adults (reproductive organisms) were considered as all the individuals with a maximum thoracic width greater than 500 µm. For *Malacoceros fuliginosus*, and following the same patterns, recruiters were considered as all the individuals with a maximum thoracic width of less than 300 µm, and adults as those with a thoracic width greater than 1000 µm, according to Day & Wilson (1934) and Guerin (1975).

For the remainder of the macroinfaunal species, an approximate estimate of secondary production was obtained by compiling the average monthly standing stock. Increases in biomass which occurred from one sampling date to the next were added together. Production estimates compiled in this fashion yielded similar values to most of the values calculated from empirical models (Sardá, 1997).

During samples taken in 2008, and with the purpose of comparing present data with the historical data obtained in 1987-88, secondary production of polychaetes was obtained following a regression model developed by Brey (1990):

$$\mathrm{Log}_{10}\mathrm{P} = -\,0.018 + 1.022 * \log_{10}\mathrm{B} - 0.016 * \log_{10}\mathrm{W}$$

where **P** is the secondary production [g (dry weight) m^{-2} a^{-1}]; **B** is the mean biomass of dry weight ($g \cdot m^{-2}$); and **W** the mean dry weight (g).

The *P/B* ratio was calculated because it could reflect the metabolism and life cycle of species in a community population. In this case, the following allometric equation was used:

$$\mathrm{P} = (\mathrm{B}/\mathrm{A})^{0.73} * \mathrm{A}$$

where **A** is the abundance, **B** is the biomass, **B/A** is the mean body size and 0.73 is the average exponent of the regression of annual production on body size for macrobenthic invertebrates (Brey 1990; Warwick *et al.* 2010).

Computation of indices for the analyzed benthic assemblages

Macroinfaunal data were used for the computation of different univariate indices: Species richness, Shannon-Wiener index (*H'),* Margalef index *(d*), and Simpson index (1-λ'). Together with ABC plots, these indices were computed using the Primer© 6 software package (version 6.1.6) (Warwick 1986).

Several indices based on ecological groups (measuring disturbance of the benthic community) were also computed: AMBI, M-AMBI (Borja *et al.* 2000; 2003; Borja & Muxika 2005; Borja & Mader 2008) and PAMBI, and all data were transformed using the square root, fallowing Warwick *et al.* (2010). All analyses were performed with the AMBI index software (version 4.1) (Borja & Mader 2008). AMBI accounts for the relative abundance of several ecological groups of species (corresponding to different levels of sensitivity/tolerance) in a sample, and ranges between 0 and 6. Low AMBI values are associated with the dominance of sensitive species and thus high quality environments, whereas high AMBI values are associated with the dominance of tolerant species and thus low quality environments. In this study, the PAMBI was also calculated as it has recently been shown to be more robust, besides being ecologically and functionally much more relevant (Warwick *et al.* 2010). The root-transformed species production data was employed for both study periods.

RESULTS

Sedimentology

The sediment characteristics of the sampled site during the two periods analyzed are shown in Table 1. The content of silt-clay in the sediments decreased from 95% (1987-

88) to 25% (2008). As a consequence, the granulometrical typology of the sampling station varied from being representative of a clear muddy environment to characterizing a silty-sand enriched environment. In addition, the organic carbon content of the sediments was reduced by half. The cessation of wastewater discharges at shallow depths in the region was mainly responsible for this sedimentological change by the reduction of the flow of suspended solid materials onto the bottoms.

Table I. Sediment characteristics and pollutant indicators.

Sediment Granulometry (%)	**1988**	**2008**
Gravel (>2 mm)	0.60	3.22
Very coarse sand (1 > 2 mm)		0.30
Coarse sand (0.71 > 1 mm)		0.26
Medium sand (0.5 > 0.71 mm)	4.80	0.21
Fine sand (0.125 > 0.5 mm)		17.36
Very fine sand (> 0.063 mm < 0.125 mm)		53.50
Silt-clay (< 0.063 mm)	94.50	24.96
Total Organic Carbon (TOC) (C)		2.90
Pollutant Indicators (mg/kg)		
Cadmium (Cd)	5-10	<1
Copper (Cu)	46-175	210
Chrome (Cr)	n.a.	490
Nickel (Ni)	n.a.	30
Lead (Pb)	405-521	280
Zinc (Zn)	n.a.	540
Mercury (Hg)	4-9	56
Polychlorinated biphenyls (PCBs)	808	<0.07
Polycyclic aromatic hydrocarbons (PAHs)	318	<0.16

(n.a.; data not available)

During 1987-88, the analyzed sediments contained a high organic content and were heavily polluted by hazardous metals, PCBs and PAHs (Table I). However, besides the higher rates of organic matter and inorganic pollutants, hypoxia was never observed in the overlying water during the study period. After spending a considerable amount of money on waste-water improvement, effluents were treated to a higher degree and the discharge was reduced drastically. However, the analysis carried out in 2008 showed that the sediments were still far from being completely clean and in a normal condition. Although significant improvements were observed in the content of PCBs and PAHs, the sediments were still highly polluted due to their metal content. Local sources, other than the wastewater discharge, were probably responsible for this metal contamination imprint.

Community structure and dynamics

The faunal composition of the benthic samples that were analyzed in the period 1987-88 showed a poorly structured community with a relatively small number of species (Table II). The species found at the sample site included 38 species of polychaetes as the major group of fauna, followed by 10 species of bivalves, and a few cumacean, amphipod and prosobranch individuals. No other faunal groups were observed. Polychaetes were by far the most important group, constituting 99% of the mean annual density (385,261 ind. m^{-2}), and 71% of the mean annual biomass (12.75 g m^{-2}). The mean annual diversity of this altered benthic community, calculated by the different diversity indices computed, was very low (Table III).

There was a seasonal pattern in total macroinfaunal abundance and biomass (Figure 2). Abundance increased gradually from September to a maximum during July (750,000 ind. m^{-2}). Following this early summer peak, there was a sharp decrease through the summer. A one-way ANOVA of the abundance data revealed significant seasonal differences (F statistic= 41.57, $p<0.01$). The seasonality for biomass values was less pronounced than that of abundance (Figure 2). Two main peaks were detected during the year, with an early initial peak during February, and another one in June. These peaks were clearly attributed to the seasonal dynamics of the main contributor species.

Table II. Species composition with mean annual macroinfaunal abundance (ind. m-2) and biomass (g dry wt m-2) for the two periods analyzed.

		1988					**2008**				
TG	**SPECIES**	**Abundance ind. m^{-2}**	**%**	**Biomass g m^{-2}**	**%**	**Biomass Rank**	**Abundance ind. m^{-2}**	**%**	**Biomass g m^{-2}**	**%**	**Biomass Rank**
SS	*Capitella capitata*	378,101	98.14	10.0273	78.7	1	1,094	13.42	0.0098	1.0	17
S	*Malacoceros fuliginosus*	2,546	0.66	1.7412	13.7	2	-	-	-	-	
S	*Spio decoratus*	1,684	0.44	0.2158	1.7	4	-	-	-	-	
C	*Exogone (Exogone) verugera*	851	0.22	0.0080	0.1		11	0.14	0.0002	0.0	
SS	*Mediomastus fragilis*	611	0.16	0.2484	1.9	3	1,411	17.30	0.0455	4.9	4
S	*Pseudopolydora antennata*	463	0.12	0.0524	0.4	8	14	0.17	0.0027	0.3	30
C	*Ophryotrocha hartmanni*	422	0.11	0.0039	0.0		847	10.38	0.0043	0.5	28
SS	*Heteromastus filiformis*	83	0.02	0.0548	0.4	7	-	-	-	-	
S	*Aonides oxycephala*	77	0.02	0.0415	0.3	10	3	0.03	0.0010	0.1	
S	*Dipolydora coeca*	68	0.02	0.0081	0.1		203	2.49	0.0134	1.4	12
S	*Prionospio malmgreni*	65	0.02	0.0067	0.1		-	-	-	-	
C	*Neanthes caudata*	56	0.02	0.0288	0.2	11	-	-	-	-	
S	*Poecilochaetus serpens*	30	0.01	0.0026	0.0		128	1.57	0.0084	0.9	18
SS	*Lagis koreni*	21	0.01	0.0090	0.1		8	0.10	0.0046	0.5	27
SS	*Notomastus latericeus*	18	0.01	0.0226	0.2	12	611	7.49	0.2769	29.7	1
C	Nereididae	15	0.00	0.0037	0.0		-	-	-	-	
C	*Podarkeopsis capensis*	15	0.00	0.0004	0.0		-	-	-	-	

		1988					2008				
TG	**SPECIES**	**Abundance ind. m^{-2}**	**%**	**Biomass g m^{-2}**	**%**	**Biomass Rank**	**Abundance ind. m^{-2}**	**%**	**Biomass g m^{-2}**	**%**	**Biomass Rank**
C	*Sigambra parva*	15	0.00	0.0021	0.0		300	3.68	0.0119	1.3	14
S	*Prionospio cirrifera*	12	0.00	0.0006	0.0		33	0.41	0.0009	0.1	
C	*Nephtys hombergii*	12	0.00	0.0101	0.1		3	0.03	0.0020	0.2	33
S	*Parapionosyllis minuta*	9	0.00	0.0002	0.0		-	-	-	-	
C	*Phyllodoce mucosa*	9	0.00	0.0006	0.0		-	-	-	-	
C	*Harmothoe antilopes*	9	0.00	0.0138	0.1		-	-	-	-	
F	*Lanice conchilega*	9	0.00	0.0632	0.5	6	-	-	-	-	
S	*Spiochaetopterus costarum*	6	0.00	0.0190	0.1		-	-	-	-	
C	Pilargidae	6	0.00	0.0213	0.2		-	-	-	-	
C	Phyllodocidae	6	0.00	0.0000	0.0		-	-	-	-	
S	*Sphaerosyllis pirifera*	6	0.00	0.0001	0.0		-	-	-	-	
C	*Aponuphis bilineata*	6	0.00	0.0092	0.1		-	-	-	-	
C	*Harmothoe* sp.	6	0.00	0.0012	0.0		-	-	-	-	
C	*Glycera unicornis*	6	0.00	0.0432	0.3	9	128	1.57	0.1325	14.2	2
SS	Cirratulidae	3	0.00	0.0726	0.6	5	-	-	-	-	
S	*Armandia cirrhosa*	3	0.00	0.0000	0.0		-	-	-	-	
F	*Polycirrus* sp.	3	0.00	0.0000	0.0		-	-	-	-	
M	*Owenia fusiformis*	3	0.00	0.0124	0.1		8	0.10	0.0007	0.1	
C	*Goniada maculata*	3	0.00	0.0003	0.0		-	-	-	-	
C	Hesionidae	3	0.00	0.0002	0.0		-	-	-	-	
C	*Lumbrineris nonatoi*	3	0.00	0.0005	0.0		-	-	-	-	
C	*Lumbrineris latreilli*	-	-	-	-		275	3.37	0.0637	6.8	3
S	*Spiophanes bombyx*	-	-	-	-		467	5.72	0.0316	3.4	5
C	*Goniada emerita*	-	-	-	-		36	0.44	0.0282	3.0	6
S	Spionidae	-	-	-	-		0	0.00	0.0213	2.3	7
SS	*Euclymene oerstedi*	-	-	-	-		31	0.37	0.0172	1.8	8
SS	*Aricidea (Aricidea) pseudoarticulata*	-	-	-	-		114	1.40	0.0153	1.6	9
C	*Phyllodoce laminosa*	-	-	-	-		19	0.24	0.0144	1.5	10
S	*Magelona wilsoni*	-	-	-	-		461	5.65	0.0138	1.5	11
S	*Scoloplos (Scoloplos) armiger*	-	-	-	-		86	1.06	0.0127	1.4	13
S	*Spio filicornis*	-	-	-	-		656	8.04	0.0119	1.3	15
C	*Aponuphis brementi*	-	-	-	-		36	0.44	0.0101	1.1	16
C	*Sthenelais boa*	-	-	-	-		11	0.14	0.0069	0.7	19
C	*Eunice vittata*	-	-	-	-		8	0.10	0.0064	0.7	20
C	*Scoletoma emandibulata mabiti*	-	-	-	-		14	0.17	0.0061	0.7	21
C	*Glycera alba*	-	-	-	-		31	0.37	0.0055	0.6	22
SS	*Monticellina dorsobranchialis*	-	-	-	-		114	1.40	0.0054	0.6	23
S	*Aricidea (Acmira) catherinae*	-	-	-	-		69	0.85	0.0050	0.5	24
S	*Prionospio fallax*	-	-	-	-		122	1.50	0.0049	0.5	25
SS	*Pherusa eruca*	-	-	-	-		8	0.10	0.0047	0.5	26
C	*Eteone syphodonta*	-	-	-	-		3	0.03	0.0035	0.4	29
S	*Levinsenia* sp.	-	-	-	-		128	1.57	0.0025	0.3	31
C	*Pilargis verrucosa*	-	-	-	-		6	0.07	0.0022	0.2	32
C	*Micronephthys stammeri*	-	-	-	-		86	1.06	0.0018	0.2	34
C	*Sigalion mathildae*	-	-	-	-		3	0.03	0.0017	0.2	35
SS	*Peresiella clymenoides*	-	-	-	-		81	0.99	0.0017	0.2	36
C	*Ophiodromus pallidus*	-	-	-	-		22	0.27	0.0014	0.2	37
M	*Chone acustica*	-	-	-	-		114	1.40	0.0014	0.1	38
S	*Paradoneis lyra*	-	-	-	-		103	1.26	0.0010	0.1	
S	*Paradoneis armata*	-	-	-	-		58	0.72	0.0008	0.1	
C	*Malmgreniella castanea*	-	-	-	-		22	0.27	0.0007	0.1	
C	*Lumbrineris impatiens*	-	-	-	-		19	0.24	0.0004	0.0	
S	*Aricidea* sp.	-	-	-	-		3	0.03	0.0004	0.0	
S	*Scolelepis tridentata*	-	-	-	-		8	0.10	0.0004	0.0	
C	*Nephtys hystricis*	-	-	-	-		6	0.07	0.0003	0.0	
S	*Amage gallasii*	-	-	-	-		56	0.68	0.0003	0.0	
C	*Mysta picta*	-	-	-	-		17	0.20	0.0002	0.0	
C	*Ceratonereis (Composetia) hircinicola*	-	-	-	-		8	0.10	0.0001	0.0	
C	*Phyllodoce rosea*	-	-	-	-		11	0.14	0.0001	0.0	
SS	*Chaetozone setosa*	-	-	-	-		11	0.14	0.0001	0.0	
S	*Armandia polyophthalma*	-	-	-	-		3	0.03	0.0001	0.0	
F	*Vermiliopsis labiata*	-	-	-	-		6	0.07	0.0001	0.0	
S	*Sphaerosyllis taylori*	-	-	-	-		11	0.14	0.0000	0.0	
C	*Leonnates glauca*	-	-	-	-		3	0.03	0.0000	0.0	
S	*Aricidea capensis bansei*	-	-	-	-		3	0.03	0.0000	0.0	
S	*Parapionosyllis brevicirra*	-	-	-	-		3	0.03	0.0000	0.0	
S	*Brania arminii*	-	-	-	-		6	0.07	0.0000	0.0	

		1988					2008				
TG	**SPECIES**	**Abundance ind. m^{-2}**	**%**	**Biomass g m^{-2}**	**%**	**Biomass Rank**	**Abundance ind. m^{-2}**	**%**	**Biomass g m^{-2}**	**%**	**Biomass Rank**
	Polychaeta	-	-	-	-			0.00	0.1121	12.0	
	TOTAL	**385,261**	**100**	**12.75**	**100**		**8,158**	**100**	**0.9337**	**100**	

TG (Trophic Groups)

During this initial period, the community was clearly dominated by opportunistic species. The main contributor to the abundance (97%) and biomass (55%) was due to the *Capitella capitata* complex (Table II), since the general dynamics of this altered community mirrored the dynamics of *C. capitata*. The average density of *C. capitata* ranged from 38,864 ind. m^{-2} in September 1987 to 742,653 ind. m^{-2} in July 1988. On the other hand, the average biomass of the species ranged from 0.59 g dry wt m^{-2} in September to 19.08 g dry wt m^{-2} in June. However, two clear peaks of biomass were observed during the year, which was the opposite of that observed for the abundance values. The bivalve *Loripes lacteus* contributed 4.1 g dry wt m^{-2} to the mean annual biomass of the community (23%), while the spionid polychaete *Malacoceros fuliginosus* added 1.7 g dry wt m^{-2}. These two species, together with *C. capitata*, were clearly considered the three key species in this community at that time (Table II). The dynamics of both species of polychaetes had similar increasing densities until a peak in late spring-early summer. On the other hand, *L. lacteus* showed a different behavior with annual peaks of density through the winter. As a consequence of the previously mentioned faunal composition, the biomass of the community was dominated by subsurface-deposit feeders (58%), followed by filter-feeders (25%), and surface-deposit feeders (12%). The rest of the trophic groups were clearly less important.

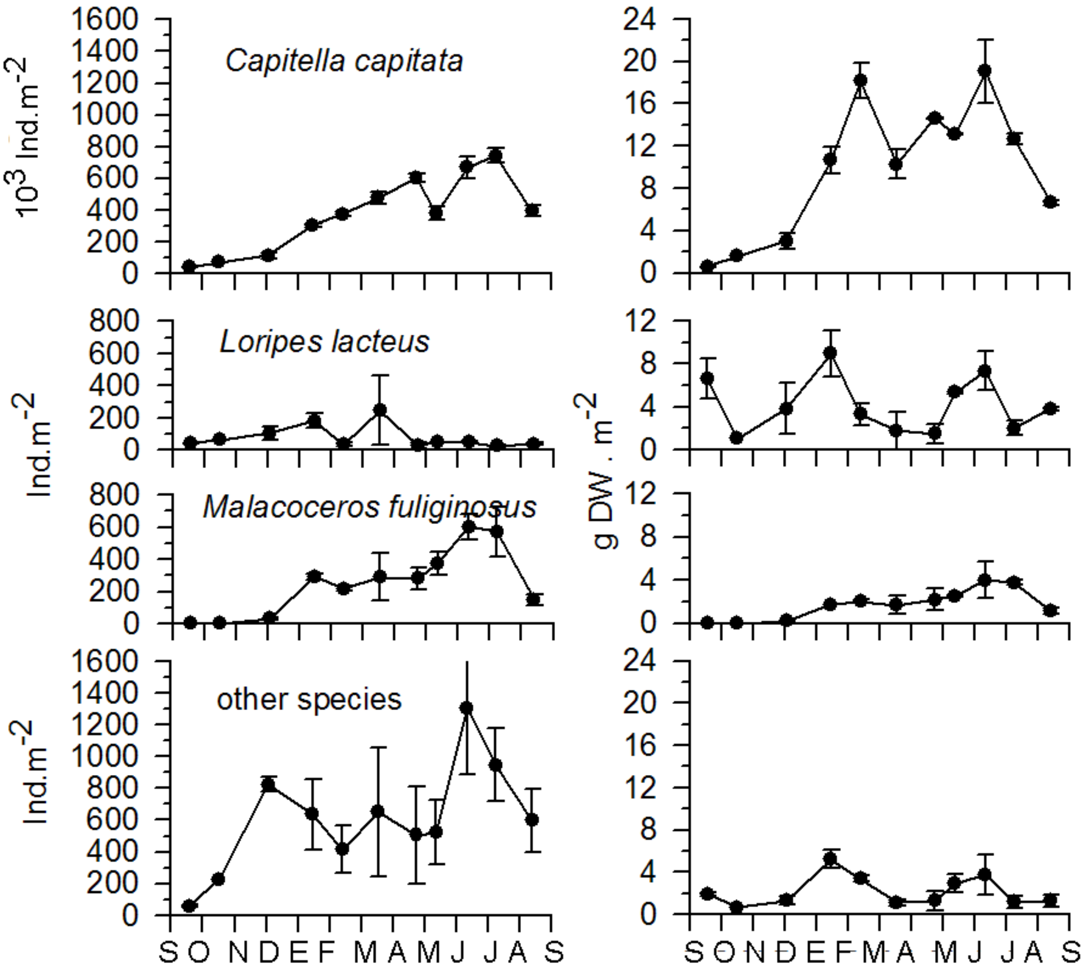


Figure 2. Seasonal abundance (left-hand graphs) and biomass data (right-hand graphs) of key species at the studied station (September 1987 to September 1988).

Twenty years after the cessation of the high inputs of wastewater discharges into these shallow soft-bottom environments, a clear increase was observed in the complexity of the studied assemblage. In 2008, more species (60 species of polychaete), higher diversity values and increased representation of different trophic groups were found (Table II). During these 20 years, the assemblage that was 98% dominated in abundance by a *Capitella capitata* complex changed to an assemblage dominated by *Mediomastus* *fragilis* (17.3%), *Capitella capitata* complex (13.4%), and *Ophryotrocha hartmanni* (10.4%) with a clear increase in diversity (Table III). Concerning biomass values, other species, such as the capitellid *Notomastus latericius* (29.7%), the glycerid *Glycera unicornis* (14.2%) and the lumbrinerid *Lumbrineris latreilli* (6.8%), replaced the highly important *C. capitata* complex (78.7%) over the same period.

Abundance and biomass values were clearly reduced by almost two and one order of magnitude, respectively (Table II). Annual densities of 385,261 ind.$\cdot$m^{-2} with a mean annual biomass of 12.75 g$\cdot$m^{-2} in 1988 decreased to 8,155 ind.$\cdot$m^{-2} in 2008 with an annual biomass of 0.94 g$\cdot$m^{-2}. Mean abundance values obtained in 2008 were a little bit lower than the average value obtained for the reference station in the MacroBen database (10,623 ind. m^{-2}; Sardá *et al.* 1999) (Figure 3). In addition, the mean biomass values obtained in 2008 were also a little bit lower than the average value obtained for the same reference station (2.41 g dry wt m^{-2}; Sardá *et al.* 1999) (Figure 3).

The differences observed between both periods can be seen by the use of k-dominance curves where the biomass and abundance of each species is ranked from highest to lowest and plotted against the cumulative percentage biomass or percentage abundance (Figure 4). In 1987-88, the plots showed how the abundance curve fell clearly above the biomass curve, which is the normal pattern when abundant species are small and rapidly growing, typical of disturbed and enriched communities. By 2008, the plots changed their positions indicating that the previous stress had been reduced.

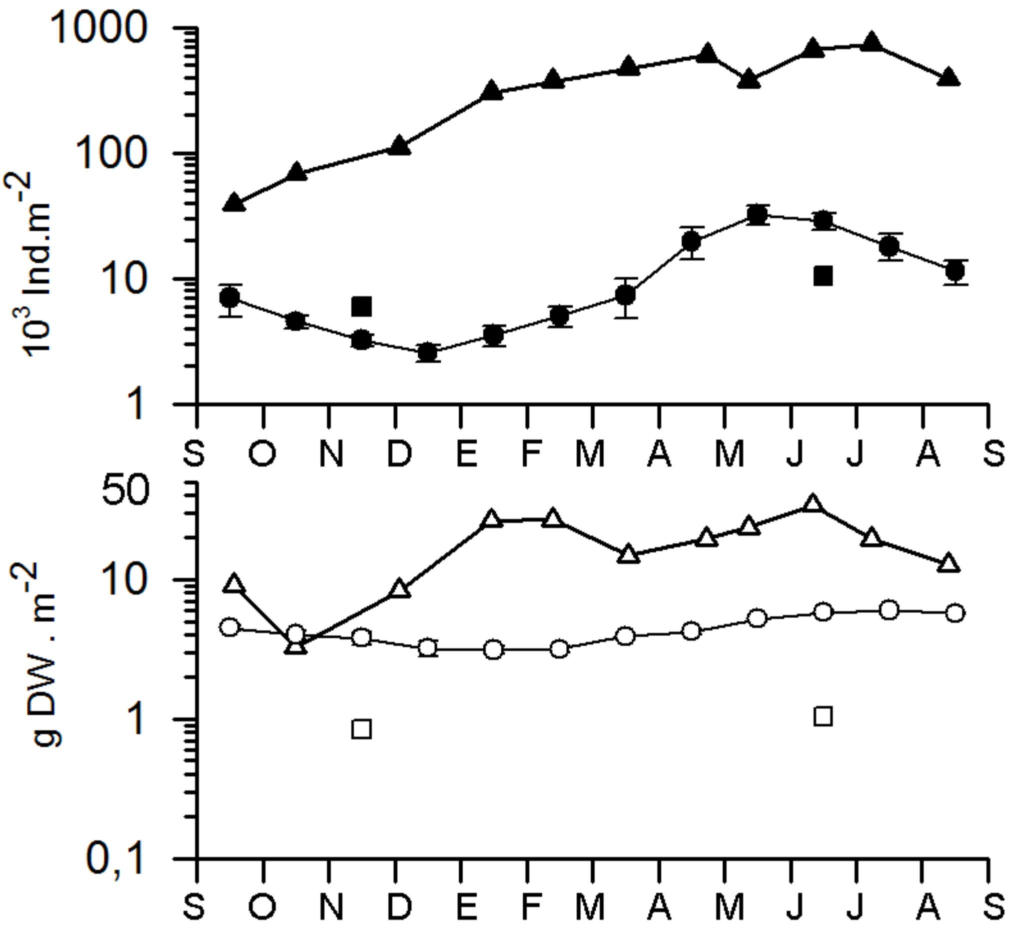


Figure 3. Abundance data (upper graph) and biomass data (lower graph) of the studied series and comparison with the reference station from the MacroBen database. (triangles represent data for 1987-88 from the studied site; squares represent data for 2008 from the studied site and circles are data from the Blanes reference station - pooled data from 1992 to 1996).

AMBI values have been recognized as an efficient tool for detecting changes in benthic communities receiving impacts derived from human activities. AMBI values changed the status of the studied sample station from heavily disturbed to slightly disturbed (Table III). However, the AMBI values were still indicating a major presence of tolerant species rather than sensitive ones. When the PAMBI index was used, the poor status observed in 1987-88 changed to a good status in 2008.

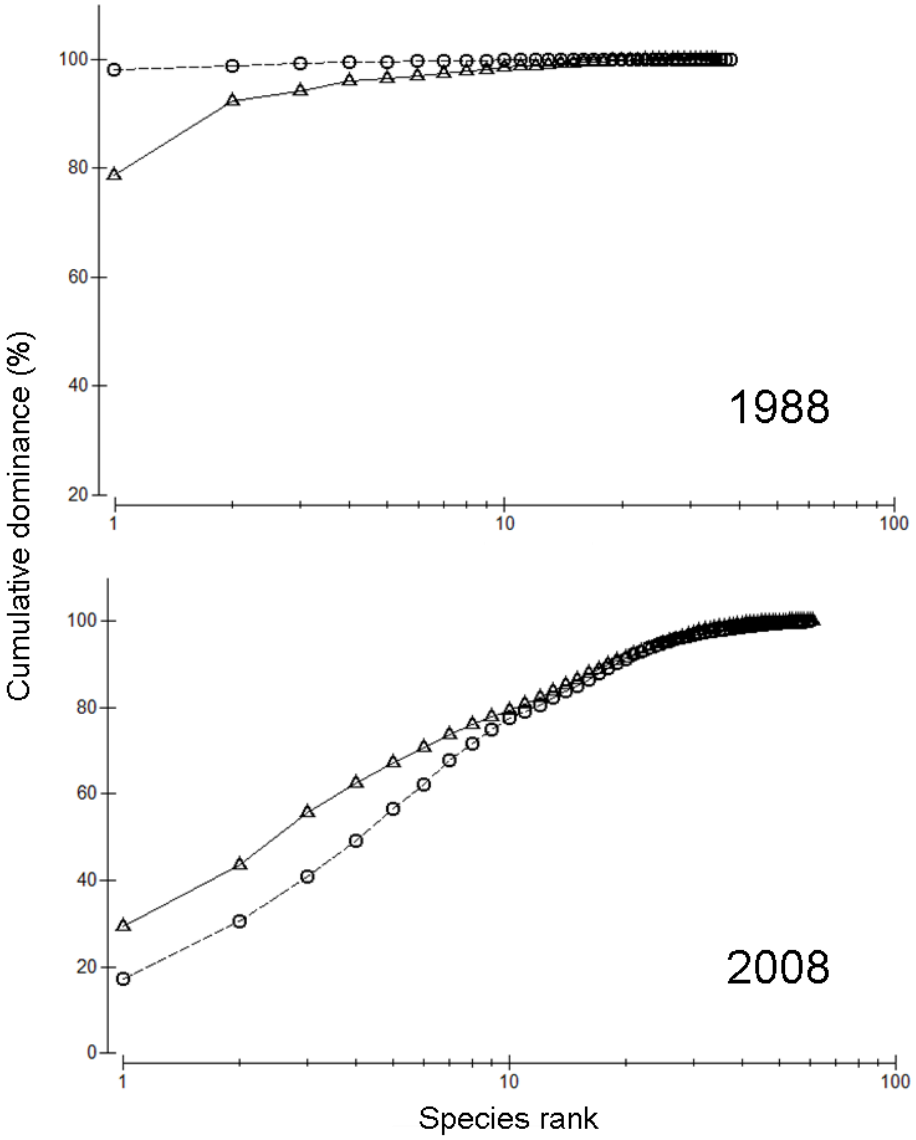


Figure 4. k-dominance curves for abundance (open circles) and biomass (open triangles) of macrofauna inhabiting the studied site during the two periods analyzed.

Table III. Mean annual main community parameters and biotic indices calculated.

	1988	Status	2008	Status
Abundance (ind. m^{-2})	385,261		8,158	
Biomass (g dry weight m^{-2})	12.75		0.93	
Polychaete species	38		60	
Shannon [*H*' $\log_2$] (bits·ind.$^{-1}$)	0.19 ± 0.06		3.91 ± 0.13	
Margalef index [d]	0.85 ± 0.14		4.00 ± 0.36	
Simpson index [1-λ']	0.04 ± 0.01		0.90 ± 0.01	
AMBI (abundance)	5.34 ± 0.14	Heavily disturbed	2.67 ± 0.30	Slightly disturbed
PAMBI (productivity)	4.82 ± 0.80	Bad	2.43 ± 0.21	Good
M-AMBI (abundance)	0.81 ± 0.07	High	0.95 ± 0.06	High

Secondary production

Using the Hynes methodology, in 1987-88, the estimated production for *Capitella capitata* was calculated as 77.8 g dry wt m^{-2} for the average annual cohort, and with a mean annual biomass of 10.03 g dry wt m^{-2} this gave the production to mean biomass ratio (P/B) a value of 7.75. The analysis of the evolution of the *C. capitata* size classes allowed three main generations to be recognized throughout the year (Figure 5). The main recruitment peaks, observed in Figure 4 as the increased percentage presence of recruiters in the populations, were observed in January, March, and July. Following these three peaks of recruitment, the biomass of *C. capitata* increased to a maximum of approximately 20 g dry wt m^{-2}. Using these shifts in size distribution during the year, the *CPI* for the *C. capitata* population (4 months) was estimated as 121.6 days. Consequently, the annual secondary production for the *C. capitata* population in this community would be 233.5 g dry wt m^{-2} $year^{-1}$.

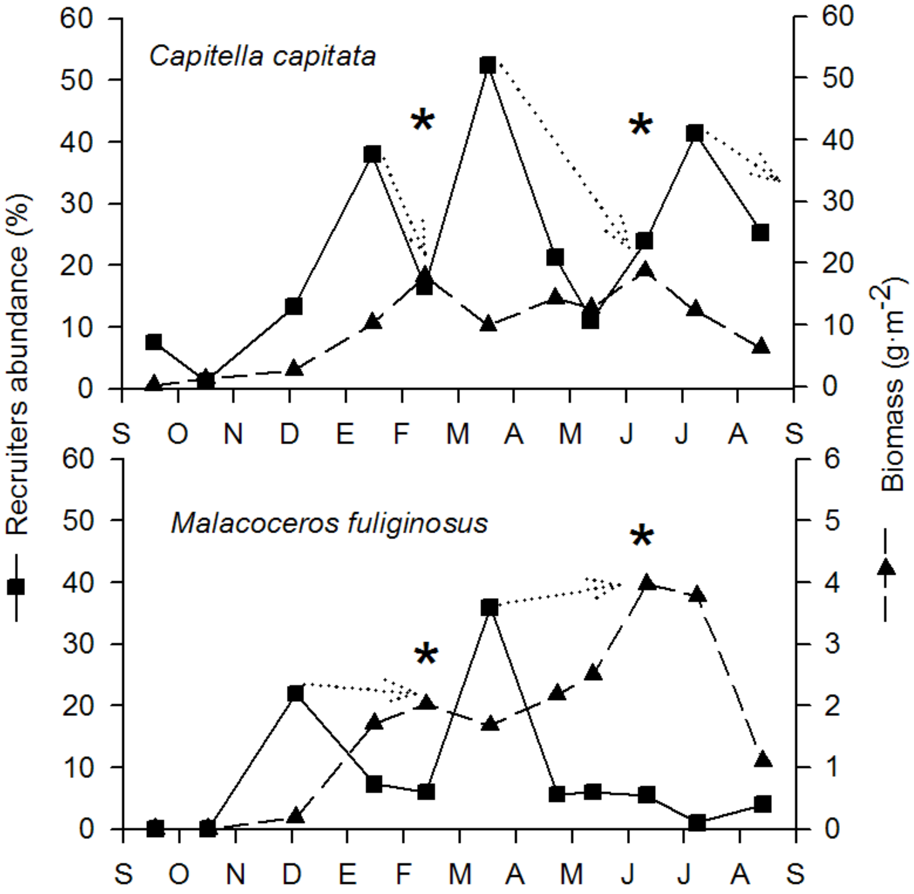


Figure 5. Main recruitment peaks and biomass values for the two main populations during September 1987 and September 1988.

For *Malacoceros fuliginosus*, the production was estimated as 6.7 g dry wt m^{-2}, with a mean annual biomass of 1.74 g dry wt m^{-2}, which resulted in a production to mean biomass ratio (P/B) of 3.85. The analysis of the variation in the size-structure of the population during the year showed two generations with recruitment peaks in December and March. Following these two peaks of recruitment, the biomass increased to approximately 2 and 4 g dry wt m^{-2}, respectively. Using these shifts in size distribution, a *CPI* of 182.5 days (6 months) was estimated for *M. fuliginosus*. This calculation yielded an annual secondary production value for the species of 13.4 g dry wt m^{-2} $year^{-1}$. In the case of *Loripes lacteus*, the population cohorts were able to be identified. Following the production of the cohorts through the year, a secondary production value was obtained for *L. lacteus* of 21.5 g dry wt m^{-2} y^{-1}, with a mean annual biomass value of 4.11 g dry wt m^{-2}. The P/B ratio obtained in this case would be 5.23.

By adding together the increases in biomass that occurred from one sample date to the next, the secondary production of the rest of the macroinfaunal component of the community was estimated as 7.95 g dry wt m^{-2} $year^{-1}$. The total secondary production from September 1987 to September 1988 in the entire community was then calculated as 276.3 g dry wt m^{-2} y^{-1} (85% from the *Capitella capitata* complex).

The productivity obtained for the period 1987-88 yielded an annual secondary production of 207.7 g dry wt m^{-2} y^{-1}, which was a little lower than the one obtained by conventional methodologies, whereas, in 2008, this regression model yielded an annual secondary production of only 8.0 g dry wt m^{-2} $year^{-1}$.

DISCUSSION

Wastewater from the Barcelona metropolitan area was discharged for decades through near-shore outfalls off Barcelona itself. Together with the direct effluents discharged by the Besòs River, they were responsible for a profound alteration of the physical and biological composition of the shallow soft-bottom environments. In 1987-88, sediment properties of the benthic assemblage were heavily influenced by the sewage discharges, and high values of organic carbon content and other inorganic pollutants were registered (Amengual *et al.* 1988). These values were essential for the interpretation of the faunal data. In contrast to the earlier conditions, 20 years after cessation of wastewater discharge at shallow depths, muddy sediments were partially washed by the currents, and the recent sediments showed no PCB and PAH pollutants, although metal contamination was still important. The presence of high values of lead, zinc, copper, and nickel suggested that metals were also delivered from other sources rather than only wastewater, such as atmospheric deposition and/or water runoff from the city, as certain metals have become broadly used in several industries and activities, and their concentrations increased accordingly in waters receiving inputs from the land. Therefore, currently, shallow soft-bottom sediments off Barcelona contain less organic carbon but they are still polluted by dangerous concentrations of hazardous metals.

The effects of organic enrichment on benthic dynamics have been widely accepted since the model of Pearson & Rosenberg (1978). At early stages of enrichment, benthic communities tend to increase abundance, biomass and, even, the number of species. However, if enrichment continues, although abundance still increases, biomass and species richness decline (transitional phase) until, finally, at the peak of enrichment, opportunistic species dominate the community, at which point the abundance is very high, biomass increases again and species richness remains very low (polluted phase). In the most extreme cases, with lack of oxygen and the presence of hydrogen sulphide, macrofauna is lost completely. The observations made at the Barcelona station sampled showed a clear move (recovery) from a highly polluted phase to a transitional phase. Nevertheless, twenty years after the removal of the high inputs of wastewater discharges into these shallow soft-bottom environments there were still signs of disturbance, such as the high abundance of some opportunistic species and low biomass values.

The effects of the organic enrichment did not alter the foreseen seasonal cycle of density expected for this area. In terms of abundance, as already described for Northwestern Mediterranean soft-bottom shallow habitats (Sardá *et al.* 1995; 1999), macroinfaunal density increased to a peak in May-June as new recruiters settled into the sediments. Then, a sharp decrease occurred during summer and lower density values were observed through the autumn and winter. In this area, it is generally accepted that autotrophic (mainly phytoplankton) production is the largest organic carbon source for the benthos under normal conditions (Satta *et al.* 1996). In non-enriched conditions, these shallow sublittoral habitats tend to be structurally complex in species composition, showing sporadic appearances of many species and large recruitments of others that are concentrated in shorter periods of the year. As has been observed in the reference station, spring peaks of density normally ranged from 15,000 to 50,000 ind. m^{-2} (Sardá *et al.* 1995). The ecological change due to the sewage outfall led to the sediment being colonized by a very low diversity assemblage mainly comprised of three species, where density values were more than one order of magnitude higher than those calculated for non-enriched shallow communities. However, the seasonal cycle of this modified community was similar to the one observed in a non-impacted community, with the exception that, in this case, the largest organic carbon source originated from man-made activities.

The biomass of the infaunal community affected by the sewage outfall responded differently to that observed for the abundance. In non-enriched communities of the Western Mediterranean, the seasonal pattern of biomass followed roughly that of abundance and only one very predictable biomass peak was observed (Sardá *et al.* 1995; 1999). The annual pattern of biomass in this enriched community showed two main peaks of biomass throughout the year, with the *Capitella capitata* complex being almost entirely responsible for such a seasonal pattern. Mean biomass values of the macrobenthic community decreased by an order of magnitude during these twenty years. In the Northwestern Mediterranean region, shallow, non-vegetated, soft-bottom habitats are, in general, poor in biomass and productivity. Except in the vicinity of large rivers where values up to 18.4 g dry wt m^{-2} have been recorded (the Gulf of Fos, France; Massé, 1972), in enclosed areas or coastal lagoons (157.2 g dry wt m^{-2} for the Camargue area, Massé, 1972; 66.0 g dry wt m^{-2} in the Alfacs Bay, Ebro Delta, Martin *et al.* 2000) or large cities, as in our case study, where biomass and productivity tend to increase, the rest of the values are, in general, small.

Laboratory experiments have shown that, even if food and other environmental conditions are maintained constant, the populations of *Capitella capitata* can have large temporal oscillations (Chesney & Tenore, 1985; Grémare *et al.* 1988). It has been proposed that these oscillations would be due to the achievement of the population carrying capacity by over-exploitation of food and spatial resources. Several authors (Chesney & Tenore, 1985; Grémare *et al.*, 1988, 1989) suggested a density-dependent effect for the decrease in the reproductive output of the species due to the lower availability of food resources by unit of biomass. In our sampling site, it seems that the population of *C. capitata* grew until it reached a biomass of approximately 20 g dry wt m^{-2}, when it suddenly crashed. After the crash, the population recovered rapidly, except during the summer time. In summer, even if recruitment of new individuals was still very high, the survival was clearly reduced and the population declined abruptly. There are at least three possible explanations for this: (1) the decline was due to the development of reducing conditions in the sediments (Tsutsumi, 1990), (2) the absence of sufficient food in quantity and quality to maintain an increased metabolic rate in the species (Charles & Amouroux 1995; Grémare *et al.* 1997, 1998, and (3) other physical disturbances over the sediment. However, no anoxic conditions were observed in the analyzed sediment during the sampled season (Amengual *et al.* 1988), therefore, the depletion of infauna by the development of reducing conditions in the sediments cannot be an explanation. On the other hand, although the quality of the organic input could be lower in the summer its quantity could not be, as shown by the specific conditions of the studied site. Therefore, the crash in the summer could probably be due to a combination of physical conditions, carrying capacity and food, since mixing processes in the water column are greatly reduced when the temperature is high.

Secondary production of the benthic community inhabiting the studied station was drastically reduced by the cessation of wastewater discharges. In 1987-88, direct measurements used to calculate this production yielded accurate results (276.3 g dry wt m^{-2} y^{-1}), and these values were in agreement with those calculated by Méndez *et al.* (1997) at a similar station (1991-92). In 2008, the data obtained did not allow us to use such conventional methodologies, although the use of multiple regressions based on pooled biological data has been shown to be useful (Sardá, 1997). Using the methodology developed by Brey (1990), we were able to obtain a production number in 1987-88 (207.7 g dry wt m^{-2} y^{-1}) not far from that obtained by conventional methodologies, and, moreover, we could compare this data with the one obtained for 2008 (8.0 g dry wt m^{-2} y^{-1}), demonstrating the drastic reduction in secondary production of this community.

During these twenty years, a drastic reduction in wastewater discharges into the shallow soft-bottom environments off Barcelona was reported. However, although pulses of organic matter were highly reduced, sediments were still polluted by metals as a consequence of the multiplicity of human activities that leads to metal loading in the marine environment. The recovery process of the benthic community inhabiting these soft-bottom environments is still under debate. Although the organic input decreased, the metal concentration present in the sediments may inhibit its full recovery to normal conditions. Mirroring the decrease in the organic input, secondary production of the macrofaunal community was also sharply reduced. It is a fact that waste water treatment plants today can greatly reduce the organic outputs of these installations. Nevertheless, we should understand that the marine environment can assimilate a certain quantity of domestic wastes without large adverse changes and, as a result, if metal contamination can also be avoided, some increase in coastal productivity by a bioenhancement factor due to lower level waste water discharges could even be positive.

Chapter 2

Long-term comparison of Polychete assemblages within soft-bottoms off the Alt Empordà (North western Mediterranean coast)

CHAPTER 2

LONG-TERM COMPARISON OF POLYCHETE ASSEMBLAGES WITHIN SOFT-BOTTOMS OFF THE ALT EMPORDÀ (NORTH WESTERN MEDITERRANEAN COAST)

ABSTRACT

Soft-bottom polychaete species present in 42 stations of the “Cap de Creus” region (Northern Mediterranean Spanish coast) who were previously sampled by French scientists in 1970-72 were revisited using similar methodologies during two oceanographic campaigns, both in 2002 (Bay of Roses) and 2009 (northeastern part of the “Cap de Creus”). Five different polychaete assemblages were identified; (a) a littoral surf beach assemblage, (b) a littoral fine sand assemblage, (c) a littoral sandy mud assemblages, (d) a coastal terrigenous mud assemblage, and (e) a detritic sand assemblage. These assemblages were associated to the different platform communities described by Labrune *et al.* (2007). In the Bay of Roses, results showed a decrease in the number of species and individuals at the two shallowest assemblages and registered similar numbers for the deepest one. Species such as *Owenia fusiformis* and *Nephthys hombergii* were clearly less abundant while other species such as *Ditrupa arietina* in fine sand sediments and *Lumbrineris latreilli* in sandy mud sediments clearly have increase their numbers. In the northeastern part of the “Cap de Creus”, the number of species and individuals were similar to those described, by Desbruyères *et al.* (1972-73); however, assemblage’s composition showed notable differences.

INTRODUCTION

The structure and organization of soft-bottom macroinvertebrate communities in the Catalan Sea (North western Mediterranean) was deeply investigated decades ago by French researches of the Banyuls-sur-mer Oceanographic Laboratory through several oceanographic campaigns carried out in the late sixtees and early seventees of the last century (Got *et al*., 1968; Guille, 1970, 1971; Aloïsi & Got, 1972-73; (Desbruyères *et* *al.* 1972-73). These surveys allowed us to understand the sedimentary regime, faunal distribution and their biogeographic and geographic roll alongside the continental slope. These scientists found that faunal distribution was associated mainly to the hydrodynamic and sedimentary regime produced by local climatology. These works has been used as reference states for coastal and platform communities of the Catalan Sea, and allow us today to revisit previous sampled stations making comparisons with the old data such as the one done in the bay of Bayuls-sur-mer (Gremare et al., 1998).

The Northerneast most part of the Spanish Mediterranean coast correspond to the Alt Empordà county (Girona, Spain) comprising the “Cap de Creus” region and the Gulf of Roses. This area has been considered an important zone in the past due to its landscape, submarine topography and fisheries. During last decades, human uses in the area have been characterized by the increasing socioeconomic importance of recreational activities in detriment, in part, to the commercial fishing activities. Even though the economic activity generated by leisure activities in Cap de Creus is not currently considerable, the degradation of the marine environment due to over-frequentation of visitors could finally hit these recreational uses that are vital for the local economy (Lloret and Riera 2008) and it is done on top of the pressures made by artisanal and industrial fisheries activities. Being recognized for its exceptional natural value, the Catalan society has raised awareness to preserve and protect this high ecological important area.

The Cap de Creus was the first maritime-terrestrial park established in Spain under the main legislative act for conservation of the Natural Capital, the Pla d’Espais d’Interès Natural (PEIN) (Catalan Law 12/1985). Protected in 1998, its marine domain represents 2% of the entire protected area. This area joint another important terrestrial protected area in the region, the area of Els Aiguamolls de l’Empordà Natural Park, protected in 1983. As this latest area was not initially thought to protect the marine domain, an enlargement of the park into under the figures of Nature 2000 site was done recently protecting marine waters of the Gulf of Roses. During the last decade, Europe has put special emphasis in the establishment of a marine offshore network of conservation areas under Natura 2000 as a key point for the EU Biodiversity policy to achieve the Convention on Biological Diversity’s target of 20 % Marine Protected Areas by 2020.

The parliament of Spain has now the proposal to host one of this offshore Marine Natura 2000 sites in the region of the "cap de Creus". The protection figure covers around 3000 ha and pretends to be extended to offshore waters comprising shelf, shelf-break and the head of the canyon of the "Cap de Creus". Basically a very large marine-terrestrial area is going to be protected in few months in and off the northern east most county of Catalonia (Spain).

As part of previous ecological studies for the development of the Natura 2000 site, several surveys were carried out to assess the status of its surrounded waters and benthic habitats (Gili *et al.,* 2011; Sardá *et al.,* 2012). This allowed us to establish a long-term comparison with the old data for the area. Regarding benthic soft-bottom macroinvertebrate communities, we used as a work of reference the initial description of the bionomy for this particular coast that can be seen in (Desbruyères *et al.* 1972-73). These authors showed "Cap de Creus" as an important site because it leads a huge modification into the hydrodynamic and sedimentary regime, as north as south part of Cap de Creus. In this survey they found three main large communities: fine sand community with *Spisula subtruncata,* a transitional zone of sand and mud with *Nephtys hombergii* and the last one was a muddy community with *Amphiura filiformis.* The later community was divided in three sub-communities, by the reason of dominant species: mud with *Nucula sulcata*, mud-detritic with *Venus ovata* and detritic with *Auchenoplax crinita*.

The main aim of the present paper was to assess the present status of soft-bottom communities in areas of the "Cap de Creus" region and to evaluate changes observed with old data for these habitats. Specific objectives to reach in this paper are: a) updating the distributional pattern of polychaetes in the area of the "Cap de Creus", b) to identify the relationship between polychaetes assemblages and its main environmental parameters, c) to include measurements of biomass that could give us indications on the productivity of the area, and d) to relate the presence of the main dominant polychaete species found in the Littoral Fine Sand Community with other polychaete communities found in the vicinity. Using such type of data, we have been able to established a comparison after more than 30 years.

MATERIAL AND METHODS

Study sites

The marine area under study comprises the marine environment located off the Alt Empordà County, from the town of Portbou to the town of L'Escala, both in the province of Girona (Figure 1). This area can be divided into three main zones: the area located off "Els Aiguamolls de l'Empordà" Natural Park in the Gulf of Roses, the area located off the "Cap de Creus", and the area located in the northern part of the Cape, off the Marenda region. The climate regime is characterised by the presence of a north-westerly, dry and cold wind "Tramuntana", which induces mixing and upwelling of enriched waters in the area (Lloret *et al.* 2001). The oceanographic conditions are very influenced by the presence of the northern current, which carries to the area nutrients from the river Rhone (Rodríguez Martínez 1982; Estrada 1996), which is the largest freshwater input in the area, whose mouth is situated about 150 km north of the study area and whose catchment basin is about 98,000 km^2 (Lloret and Riera 2008). Wind mixing and river runoff affect not only the productivity of marine species inhabiting the area, but also the human uses that have developed thereby (Lloret *et al.* 2008).

The area has two main morphological entities, the "Cap de Creus" peninsula and the Gulf of Roses. The "Cap de Creus" peninsula is located at the north-western Mediterranean Sea, which comprise the eastern Pyrenees in the region of Catalonia (Alós 1990). Shallow marine bottoms surrounding Cap de Creus are mostly rocky, whereas most deep areas are muddy. In the shallow areas, rocky substratum and the hydro-climatic conditions allow the establishment of productive and varied habitats and biocenosis, such as the coralliferous and infralittoral algal assemblages. In many of its coves, the existence of sandy bottoms allows the development of seagrass meadows (Lloret and Riera 2008). The second morphological entity in the area is the Gulf of Roses, in the southern part of the Cap de Creus (Figure 1). This gulf receives freshwater input from the river Muga, which has a catchment basin of about 15 000 km2 and supports a multispecies fishery carried out by bottom trawlers, purse seiners and by a small-scale fleet using long lines, gill nets and shellfish dredges. Some species have their habitat or spawning area in the Gulf of Roses and are therefore locally fished, e.g. *Donax trunculus* and *Penaeus kerathurus* (Lloret *et al.* 2001).

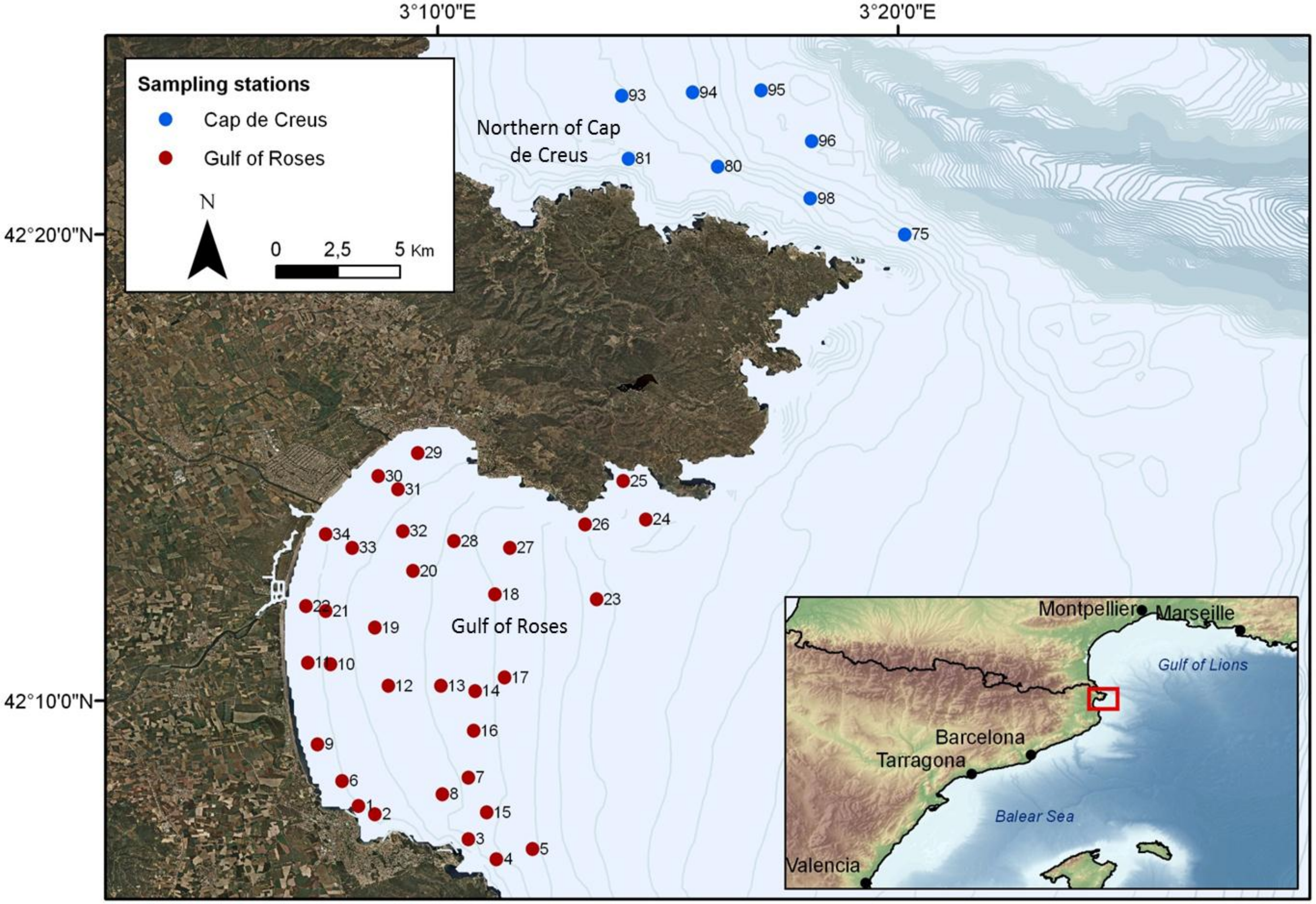


Figure 1. Distribution of the sampling sited tin both sides of Cap de Creus. The blue circles belongs to sampling station to the northern and the red circles belongs to the south (Gulf of Roses).

The sampling effort

The information provided in this paper comes from two different campaigns carried out at two different periods of the past decade in this particular region. The first of these two campaigns was carried out in the Gulf of Roses (Girona, Spain) in January of 2002 while the second one took place in the northern part of the Cap de Creus (Girona, Spain) in July of 2009. In both campaigns, all samples were taken with Van Veen grabs mirroring the sampling strategy and sampled sites done by (Desbruyères *et al.* 1972-73). The idea of both campaigns was to revisit selected sites sampled in this old French survey. As samples in it survey came from different periods of time, we could not take into consideration the seasonal change effect in our analysis. However, for the Gulf of Roses study, sampling took place in January being this the moment of the year in which densities of benthic soft-bottom communities are at the minimum records in the North-western Mediterranean shallow sediments habitats (Sardá et al., 1999), and this can facilitate the comparison besides the seasonal effect.

In the Gulf of Roses study, benthic samples were collected in January 2002 using the Itxasbide boat property of the Consejo Superior de Investigaciones Científicas (CSIC). Data were collected at 34 sites (Figure 1) located on 9 inshore-offshore transects from the town of L'Escala to Cala Montjoi, north of Roses. Another group of benthic samples were obtained for sedimentological analysis in the same campaign allowing us to obtain good sedimentological data from the entire Bay. We repeated the same stations sampled in 1970 between 0 and 60 m depth. Samples were collected with a *van Veen* grab (600 cm^2 opening). At each site, 2 grabs were taken for the analysis of benthic macrofauna, and 1 for granulometric and organic content analysis. Grab samples were sieved first through a 1 mm and, then, through a 0.5 mm screen on the boat, and preserved in buffered formalin. In this paper, we are presenting information on the samples taken with the first mesh (1 mm) that allow us the comparison with the French study.

In the Northern part of the Cape study, benthic samples were collected in July of 2009 using another oceanographic boat of the CSIC, in this case the Dolores boat. In this case, data were collected at 8 sites (Figure 1) following the same stations that were done in Desbruyères *et al.* (1972-73). These samples were obtained at depths between 75 and

108 m on two different benthic communities that those sampled in the Bay of Roses; the Terrigenous Coastal Mud community and the Detritic Mud community. Samples were collected with two different *van Veen* grabs (1200 cm^2 and 600 cm^2 opening); obviously data is presented in data by m^2. At each site, 2 grabs were taken for the analysis of benthic macrofauna, and 1 for granulometric analysis. The reference number is it equivalent in the French study of 1972-73. In this case grab samples were sieved through 0.5 mm screen on the boat, and preserved in buffered formalin.

Data analysis and assemblage classification

The organisms retained by the sieve were counted and classified to the lowest possible taxonomic level for polychaetes, bivalves and echinoderms, as well as easily recognized species such as the lancet (*Branchiostoma lanceolatum*). The rest of the taxa were classified only to major groups. Species biomass was determined as dry weight (24 h at 60 °C) except for calcified species, where it was obtained by the loss of weight after ashing (5 h at 450 °C). Following previous work done in the past (Sardá et al., 1999), regressions of length or width vs. dry weight were used for key species such as *Ditrupa arietina* and *Owenia fusiformis*. Organisms were classified into five trophic groups: (F): filter feeders; (M): mixed (filter and surface deposit feeders); (S): surface-deposit feeders; (SS): subsurface-deposit feeders; (C): carnivores/omnivores, using information in Fauchald and Jumars (1979) and (Dauvin and Ibanez 1986).

Organic content of dry sediment was estimated as the loss of weight after ashing. Granulometrical analyses were made using a LS Particle Size Analysis Counter at the Department of Geology of the University of Barcelona. The classification of sediments follows Wentworth (1972) classification for samples taking in 2002. And for samples taking in 2009 (northern Cap de Creus), the analysis were done using a Malvern® Mastersizer 2000 laser microgranulometer, in the Center of advance study of Blanes.

A study on the structure and composition of polychaete assemblages have been carried in both of the studies, the Gulf of Roses and the one in the northern part. In the case of the Gulf of Roses, the use of the same mesh size allows us to make the comparison between our data and the one obtained by the old French survey of 1972-73. The correspondence between clusters of stations determined during the present study of the

Gulf of Roses and the classification proposed by Desbruyères *et al.* (1972-73) was first assessed using two non-parametric MDS based analysis on polychaetes compositions recorded during the present study, and the Desbruyères *et al.* (1972-73) for the three internal communities of the Bay. These analyses were carried out at the lowest taxonomic level, on square-root transformed abundance data and using the Bray Curtis similarity index. We eliminated rare species (presence in less than 10% of the samples) from our analysis. All these analyses were carried out using the Primer© 6 software package (version 6.1.13) (Warwick 1986).

Diversity measures

Ecological indicators based on diversity were measured through the use of different univariate indices: Species richness, Shannon-Wiener index (*H'),* Margalef index *(d*), and Simpson index (1-λ') were computed using the Primer© 6 software package (version 6.1.6) (Warwick 1986).

RESULTS

Gulf of Roses study

A total of 3415 individuals belonging to 137 species of Polychaetes and three species of Sipunculida were identified during the present study in the 68 samples analyzed. This number is a little bit smaller if it is compared with the 173 species obtained in the oceanographic campaign of 1970-72. A list of the species obtained in our study is presented in Table 1.

Table 1. Species list found in the Gulf of Roses study with it abundance and biomass.

	A		B		C	
	Density (ind m^{-2})	Biomass (mg m^{-2})	Density (ind m^{-2})	Biomass (mg m^{-2})	Density (ind m^{-2})	Biomass (mg m^{-2})
Scoletoma impatiens	100	80.5	25	14.0	6	95.0
Ditrupa arietina	64	433.5	0	0.0	2	27.9
Chone duneri	54	219.7	0	0.0	25	8.4
Prionospio caspersi	40	4.5	0	0.0	13	2.1
Nephtys hombergii	35	0.0	8	4.8	23	80.5
Myriochele oculata	33	19.3	0	0.0	38	12.4
Paradoneis armata	15	14.4	0	0.0	4	0.8
Exogone verugera	11	2.3	0	0.0	5	0.4
Glycera rouxi	11	69.4	0	0.0	18	736.6
Scoloplos armiger	8	31.0	4	3.9	9	91.4
POLYCHAETA unident.	8	77.6	4	38.7	15	90.9
Glycera capitata	8	52.1	0	0.0	0	0.0
Mediomastus fragilis	7	1.9	0	0.0	27	7.5
Sigalion squamosum	7	17.9	13	18.4	2	0.7
Glycera convoluta	6	11.1	0	0.0	1	14.3
Owenia fusiformis	6	64.9	4	61.7	6	39.7
Goniada maculata	4	2.2	0	0.0	13	26.2
Nereis zonata	3	1.9	0	0.0	0	0.0
Aricidea capensis bansei	3	0.4	0	0.0	0	0.0
Dipolydora flava	3	2.5	0	0.0	2	1.2
Drilonereis filum	3	3.9	0	0.0	4	18.8
Eunice vittata	3	26.0	0	0.0	5	9.7
Lumbrineris latreilli	3	54.0	0	0.0	180	269.4
Magelona mirabilis	3	8.0	0	0.0	2	0.1
Pseudoleiocapitella fauveli	3	0.9	0	0.0	0	0.0
Polydora caeca	3	2.2	0	0.0	3	1.1
Schistomeringos rudolphii	3	0.6	13	1.9	0	0.0
Arabella iricolor	1	24.0	0	0.0	0	0.0
Lumbricomastus sp.	1	10.0	0	0.0	0	0.0
Caulleriella alata	1	0.0	0	0.0	0	0.0
Chaetozone setosa	1	2.7	0	0.0	8	26.0
Chone infundibuliformis	1	50.2	0	0.0	0	0.4
Clymenura clypeata	1	4.1	0	0.0	13	28.5
Eteone longa	1	0.7	0	0.0	1	250.1
Exogone naidina	1	0.2	0	0.0	16	0.6
Marphysa bellii	1	0.9	0	0.0	2	1.3
Melinna palmata	1	0.6	0	0.0	9	21.0

Notomastus latericeus	1	6.6	0	0.0	38	190.0
Phyllodoce laminosa	1	9.3	0	0.0	1	7.2
Piromis eruca	1	21.4	0	0.0	6	3.9
Spio filicornis	1	0.0	0	0.0	3	3.1
Syllis cornuta	1	0.1	0	0.0	2	1.1
Phascolion strombi	1	0.8	0	0.0	2	1.6
SIPUNCULIDA unident.	1	13.7	0	0.0	4	39.5
Amaeana trilobata	0	0.0	0	0.0	1	3.7
Amage adspersa	0	0.0	0	0.0	1	0.2
Ampharete acutifrons	0	0.0	0	0.0	2	3.1
Amphicteis gunneri	0	0.0	0	0.0	1	0.2
Amphitrite sp.	0	0.0	0	0.0	1	6.0
Aonides oxycephala	0	0.0	0	0.0	2	4.8
Apelochaeta marioni	0	0.0	0	0.0	44	61.3
Aponuphis fauveli	0	0.0	0	0.0	1	1.3
Aponuphis bilineata	0	0.0	4	8.3	17	84.5
Aricidea assimilis	0	0.0	0	0.0	6	4.2
Aricidea sp.	0	0.0	0	0.0	3	1.2
Aricidea suecica	0	0.0	0	0.0	21	7.1
Armandia cirrhosa	0	0.0	0	0.0	4	28.5
Autolytus sp.	0	0.0	0	0.0	0	0.2
Chone sp.	0	0.0	0	0.0	2	0.6
Cirriformia tentaculata	0	0.0	0	0.0	4	11.1
Cirrophorus furcatus	0	0.0	0	0.0	4	141.6
Cirrophorus branchiatus	0	0.0	0	0.0	0	0.0
Cossura soyeri	0	0.0	0	0.0	16	2.9
Dorvillea rubrovittata	0	0.0	0	0.0	1	16.8
Euchone rosea	0	0.0	0	0.0	9	1.1
Euclymene oerstedii	0	0.0	0	0.0	19	32.7
Euclymene robusta	0	0.0	0	0.0	0	0.3
Euclymene sp.	0	0.0	0	0.0	2	6.1
Eulalia parva	0	0.0	0	0.0	0	0.0
Exogone hebes	0	0.0	0	0.0	0	0.1
Fabriciola sp.	0	0.0	0	0.0	2	0.1
Fauvelopsis adriatica	0	0.0	0	0.0	3	2.7
Glycera sp.	0	0.0	4	6.0	2	0.1
Gyptis rosea	0	0.0	0	0.0	1	0.1
Harmothoe sp.	0	0.0	0	0.0	0	0.7
Heteromastus filiformis	0	0.0	0	0.0	1	11.3
Hyalinoecia tubicola	0	0.0	0	0.0	0	0.5
Laetmonice hystrix	0	0.0	0	0.0	0	0.5
Lanice conchilega	0	0.0	0	0.0	0	0.0
Laonice cirrata	0	0.0	0	0.0	2	3.1
Leanira hystricis	0	0.0	0	0.0	1	97.8
Levinsenia gracilis	0	0.0	0	0.0	41	4.0

Lumbrineris sp.	0	0.0	0	0.0	1	0.9
Magelona sp.	0	0.0	0	0.0	1	1.7
Magelona alleni	0	0.0	0	0.0	1	20.1
Magelona filiformis	0	0.0	4	1.7	0	0.0
Magelona minuta	0	0.0	0	0.0	36	5.9
Malacoceros fuliginosus	0	0.0	0	0.0	1	2.9
Micronephtys maryae	0	0.0	0	0.0	3	7.2
Monticellina heterochaeta	0	0.0	0	0.0	25	24.1
Nephtys cirrosa	0	0.0	0	0.0	1	304.7
Nephtys hystricis	0	0.0	13	40.0	12	31.4
Nephtys paradoxa	0	0.0	0	0.0	3	57.4
Nereiphylla sp.	0	0.0	0	0.0	0	0.0
Nerinides cantabra	0	0.0	4	34.7	0	0.2
Nerinides sp.	0	0.0	0	0.0	0	0.6
Notocirrus scoticus	0	0.0	0	0.0	0	53.1
Ophiodromus flexuosus	0	0.0	0	0.0	4	7.1
Orbinia cuvieri	0	0.0	0	0.0	1	3.8
Oriopsis armandi	0	0.0	0	0.0	1	1.5
Paradoneis lyra	0	0.0	0	0.0	4	0.4
Paradoneis sp.	0	0.0	0	0.0	0	2.7
Paralacydonia paradoxa	0	0.0	0	0.0	21	33.1
Parapionosyllis labronica	0	0.0	0	0.0	0	0.1
Paraprionospio pinnata	0	0.0	0	0.0	1	51.9
Pectinaria koreni	0	0.0	0	0.0	1	14.0
Pholoe minuta	0	0.0	0	0.0	0	0.0
Phyllodoce mucosa	0	0.0	0	0.0	1	4.2
Pilargis verrucosa	0	0.0	0	0.0	2	8.0
Pista cristata	0	0.0	0	0.0	2	9.0
Pista maculata	0	0.0	0	0.0	0	0.9
Poecilochaetus serpens	0	0.0	0	0.0	1	5.3
Polycirrus sp.	0	0.0	0	0.0	0	2.6
Praxillella gracilis	0	0.0	0	0.0	5	26.4
Praxillella praetermissa	0	0.0	0	0.0	1	7.6
Praxillella sp.	0	0.0	0	0.0	0	0.2
Prionospio cirrifera	0	0.0	0	0.0	6	1.3
Prionospio malmgreni	0	0.0	0	0.0	41	12.0
Prionospio sp.	0	0.0	0	0.0	2	1.0
Prionospio streenstrupi	0	0.0	0	0.0	1	7.0
Protodorvillea kefersteini	0	0.0	0	0.0	0	0.0
Pseudomalacoceros tridentata	0	0.0	0	0.0	0	0.0
Pseudopolydora antennata	0	0.0	0	0.0	1	8.1
Scolelepis ciliata	0	0.0	0	0.0	0	24.6
Scoletoma emandibulata mabiti	0	0.0	0	0.0	5	13.5
Serpula concharum	0	0.0	0	0.0	2	0.0
Sigambra tentaculata	0	0.0	0	0.0	0	0.0

Sphaerodorum gracilis	0	0.0	0	0.0	0	0.1
Sphaerosyllis ovigera	0	0.0	0	0.0	1	0.1
Sphaerosyllis sp.	0	0.0	0	0.0	2	0.3
Sphaerosyllis taylori	0	0.0	0	0.0	0	0.1
Spiochaetopterus costarum	0	0.0	0	0.0	3	2.3
Spiophanes bombyx	0	0.0	0	0.0	1	4.8
Spiophanes kroyeri	0	0.0	0	0.0	5	0.9
Sternaspis scutata	0	0.0	0	0.0	10	806.9
Sthenelais limicola	0	0.0	0	0.0	1	0.0
Syllis gerlachi	0	0.0	0	0.0	0	0.1
Syllis parapari	0	0.0	0	0.0	4	0.8
Terebellides stroemi	0	0.0	0	0.0	1	7.0
Trichobranchus glacialis	0	0.0	0	0.0	1	4.8
Aspidosiphon muelleri	0	0.0	0	0.0	109	784.1
Total	470	1535.8	100	234.0	1050	5018.6

Using the work carried out in 2002, our multivariate classification technique (MDS ordination of the used matrix derived from transformed data of abundances) divided the stations into three groups of similar species composition (see Figure 2 for its cluster representation). These three assemblages included: (A) a littoral surf beach assemblage, (B) a littoral fine sand assemblage, and (C) and a littoral sandy mud assemblage; matching the different sediment types found in the Gulf of Roses. When this cluster is compared with the one obtained in 1972-73, the stations from the two periods, besides some overlapping, tend to differentiate. The correspondence with the sample aggregation in 1970-72 is shown below:

(1) The littoral surf-beach assemblage (A) and the Littoral find sand assemblage (B) are in correspondence with the "*commonauté des sables fins à Spisula subtruncata*". In 1972-73 both communities were not possible to differentiate.

(2) The littoral sandy mud assemblage (C) correspond to the "*variation des vases sableuses litorales de la sous-communauté des vases à Nucula sulcata*". The previos "*faciès de transition de sables vaseus à Nephthys homergii*" seen in the work of 1972-73 was not possible to differentiate from the other samples of the littoral sandy mud assemblage.

Five of the samples carried out in 2002 were not included in any of these groups (# 18, 23, 3, 6, and 22) being different by themselves or almost defaunated in the case of the shallower ones.

A comparison of the results from the 34 stations for the two sampling periods (1972-73 and 2002) showed some trends towards an increase in the number of individuals but decreasing the number of species, especially in the shallowest communities. We could not see this data from biomass because there was not biomass data reported for 1972-73. Table 2 enclosed general data about these three assemblages.

Table 2. Main (± standard deviation) benthic parameters from the three assemblages identified in the study.

	Surf Beach assemblage	**Fine Sand assemblage**	**Sandy mud assemblage**
Species number	7,5±0,7	15,8±4,8	
Abundance (ind m-2)	100,1±11,8	469,8±250,7	1149,3±936,9
Biomass (mg m-2)	233,5±49,5	782,6±480,6	5025,1±4003,1
Grain size (um)	231,8±32,2	149,3±15,3	32,1±46,5
CaCO3 (%)	16,3±4,2	18,5±2,3	24,5±7,1
Organic matter (% weight)	1,1±0,2	1,1±0,3	2,4±0,9

Sedimentology conditions found in the Gulf of Roses were not too different from those observed in 1972-73. It was characterized by sandy soft-bottom sediments until the depth of around 20 m that they are replace by sandy muds between 20 and 50-60 and later on by muddy habitats.

The Littoral surf beach assemblage

This assemblage is observed from the surf zone of beaches in which sediments can be moved in and out and organisms are subjected to a high physical energy environment; in our case samples obtained above 10 m depth. In 1972-73, sampled stations obtained in this environments could not been separated from the rest of the fine sand community. In 2003, the assemblage only group stations 9 and 11. During the present study we only found 10 species. Total abundances and number of species showed a marked decrease between 1972-73 and 2002 (from 645 to 100 ind. m^{-2}, and from 51 to just 10 species). Table 3 showing a comparison between the two periods.

Table 3. Littoral beach-surf assemblage. Individuals per meter square of the most abundant species (between parentheses the species rank).

Species	**(Desbruyères et al. 1972-73)**	**present study** data 2002
Owenia fusiformis	93(1)	4(6)
Nephtys hombergii	58(2)	8(5)
Prionospio cirrifera	53(3)	---
Magelona mirabilis	50(4)	---
Cirrophorus branchiatus	43(5)	---
Scoletoma impatiens	33(6)	25(1)
Lumbrineris gracilis	33(7)	---
Mediomastus capensis	25(8)	---
Nephtys hystricis	---	13(2)
Sigalion squamosum	---	13(3)
Schistomeringos rudolphi	3	13(4)
Magelona filiformis	---	4(7)
Scoloplos armiger	15	4(8)
Species number	51	10
Number of individuals	645	100

When compared with previous data, observed changes in density were due to the absence of several species that were common in 1972-73 and the drastic decrease in the abundance of *Owenia fusiformis*. From the species present in the community in 1972-73, only *Scoletoma impatiens* seems to be on the same numbers that were obtained in the seventees. Total biomass value for polychaetes was computed as 234 mg dry weight m^{-2} from which the most important contributors were *Owenia fusiformis*, *Nephthys hystricis*, and *Nerinides cantabra* (see Table 3).

The Littoral fine sand assemblage

The evaluation of changes for the typical assemblage of the Littoral fine sand community (LFS) in the Gulf of Roses reported and decrease in the number of individuals but maintaining its number of species (from 1316 to 470 ind m^{-2}, and from 43 to 42 species). Most of the changes that we can see in the comparison between 1972-

73 and 2002 (Table 4) can be related to the decrease in the number of individuals of *Owenia fusiformis* (however we cannot be sure that this could be due to a seasonal effect, may be recruitment patterns in 1972-73) and the appearance of Ditrupa arietina, which was absent from the community in 1972-73 and reached a density of 64 ind m^{-2} in 2002. *Scoletoma impatiens*, as in the previous analyzed assemblage, was the dominant species with similar numbers to which were found in 1972-73.

Table 4. Littoral fine sand assemblage. Individuals per meter square of the most abundant species (between parentheses the species rank).

Species	**(Desbruyères et al. 1972-73)**	**Present study** data 2002
Owenia fusiformis	648(1)	6
Magelona mirabilis	98(2)	3
Lumbrineris gracilis	90(3)	---
Scoletoma impatiens	90(4)	100(1)
Clymenura clypeata	60(5)	1
Chaetozone setosa	54(6)	1
Levinsenia gracilis	26(7)	
Glycera rouxi	22(8)	11(8)
Prionospio cirrifera	23	---
Ditrupa arietina	---	64(2)
Chone duneri	---	54(3)
Prionospio caspersi	17	40(4)
Nephtys hombergii	12	35(5)
Myriochele oculata	10	33(6)
Paradoneis armata	1	15(7)
Species number	43	42
Number of individuals	1316	470

The polychete biomass for the entire assemblage averaged 1335,8 mg dry weight m^{-2}. *Ditrupa arietina* (433,5 mg dry weight m^{-2}) and *Chone duneri* (219,7 mg dry weight m^{-2}) were its main contributors. The case of *Ditrupa arietina* was really notable because it was absent in 1972-73 and in 2002 it can be considered a clear characteristic species of this community, basically there is not individuals in the other two assemblages that were studied in our campaign.

The Littoral sandy mud assemblage

Most of the samples obtained in the study of the Gulf of Roses got together in a particular cluster. This cluster grouped all samples under the Littoral sandy mud (LSM) assemblage in the Gulf. It was the most numerous in number of species, in abundance as well as in biomass. Curiously enough, total abundances and number of species showed very similar numbers from 1972-73 to 2002 (1054 and 1050 ind m^{-2}, and 112 and 120 respectively). Table 5 is showing a comparison between the two periods.

Table 5 Littoral sandy mud assemblage. Individuals per meter square of the most abundant species (between parentheses the species rank).

Species	**(Desbruyères et al. 1972-73)**	**Present study** data 2002
Monticellina heterochaeta	183(1)	25
Prionospio cirrifera	109(2)	6
Levinsenia gracilis	70(3)	41(3)
Lumbrineris latreilli	63(4)	180(1)
Nematonereis unicornis	59(5)	---
Prionospio malmgreni	55(6)	41(4)
Terebellides stroemi	49(7)	1
Paralacydonia paradoxa	35(8)	21
Chaetozone setosa	31	8
Apelochaeta marioni	0-	44(2)
Myriochele oculata	9	38(6)
Notomastus latericius	27	38(7)
Magelona minuta	14	36(8)
Nephtys hystricis	28(8)	23(8)
Prionospio caspersi	---	40(5)
Sternaspis scutata	8	35(6)
Species number	112	120
Number of individuals	1054	1050

The pool of species found in the study of 2012 is similar to the one sampled in 1972-73. However polychaete dominance is in different species been *Lumbrineris latreilli* the one that contributed most on abundance. Together with other species such as *Apelochaeta marioni, Aricidea suecica, Notomastus latericius, Cossura soyeri, Euclymene oerstedii, Levinsenia gracilis, Magelona minuta, Paralacydonia paradoxa, Prionospio malgreni, Sternaspis scutata* and *Monticellina heterochaeta* constituted the most characteristic species in the assemblage. Special attention deserves the presence of the sipunculid

Aspidosiphon muelleri (109 ind. m-2) which also make habitat for other species as *Syllis parapari*.

Sandy mud areas were rich in species and contained comparatively with the other studied assemblages high infaunal biomass (5018,6 mg dry weight m^{-2}). Six species contributed on average more than 200 mg dry weight m^{-2}, *Sternaspis scutata* (806,9 dry weight m^{-2}), the sipunculid *Aspidosiphon muelleri* (784,1 dry weight m^{-2}), *Glycera rouxii* (736,6 dry weight m^{-2}), *Nephthys cirrosa* (304,7 dry weight m^{-2}), *Lumbrineris latreilli* (269,4 dry weight m^{-2}), and *Eteone longa* (250,0 dry weight m^{-2}).

The different stations that in 1972-73 were included in the so called transition facies with *Nephthys hombergii* converged in 2002 under this sandy mud assemblage. *Nephthys hombergii* who gave name to this facies move from 80 ind m^{-2} in 1972-73 to just 8 ind m^{-2} in 2002 while *Magelona mirabilis*, the dominant species in the old work (110 ind m-2) was not collected in these samples in 2002. The most important species in the samples of 2002 that revist the old stations were the polychaetes *Ditrupa arietina* (108 ind m-2), not present in 1972-73 and *Scoletoma emandibulata mabiti* (18 ind m-2) and two species of Sipunculids, *Aspidosiphon muelleri* (167 ind m-2) and *Phascolion strombi* (59 ind m-2).

The ecological indicators based on diversity in the assemblages was summary Table 6, it show that diversity in the Gulf of Roses in general was high, even though the evenness in the Littoral beach-surf assemblage indicated that species do not were equal abundant.

Table 6. Diversity measures in the Gulf of Roses

Type of assemblage	**S**	***d***	**1-λ'**	**H'(log2)**	**J'**
Littoral beach-surf assemblage	44	7.0	0.9	4.1	0.7
Littoral fine sand assemblage	12	2.4	0.9	3.3	0.9
Littoral sandy mud assemblage	128	18.3	0.9	5.3	0.8

In the northern part of the “Cap de Creus” study there were a total of 1492±502 individuals belonging to 176 species in the 8 samples in the northern of Cap de Creus and it biomass was 1.41± 3.71 dry weight m^{-2}. It result were alike to Desbruyères *et al.* (1972-73) found (1146 ind. m^{-2}, 1.43 dry weight m^{-2}) in the detritic mud assemblage. This community was described by Desbruyères *et al.* (1972-73) as a zone with variable proportion of silt-clay percentage, where the fine sands were replaced by coarse sand and gravel. In our analysis this situation was similar. However the terrigenous coastal mud assemblage shows lightly differences in the granulometric characteristic, in its study. It lasted assemblage was described by Desbruyères *et al.* (1972-73) as situated between 50 to 105 m depth and silt-clay percentage content more than 75%. Conversely the silt-clay content were less in our study, it varies between 23 to 54%.

The MDS ordination shows two assemblages in the northern of Cap de Creus but the Anova analysis do not reveal differences between these two assemblages. Then I listed the most important species found in the northern of Cap de Creus in the Table 7.

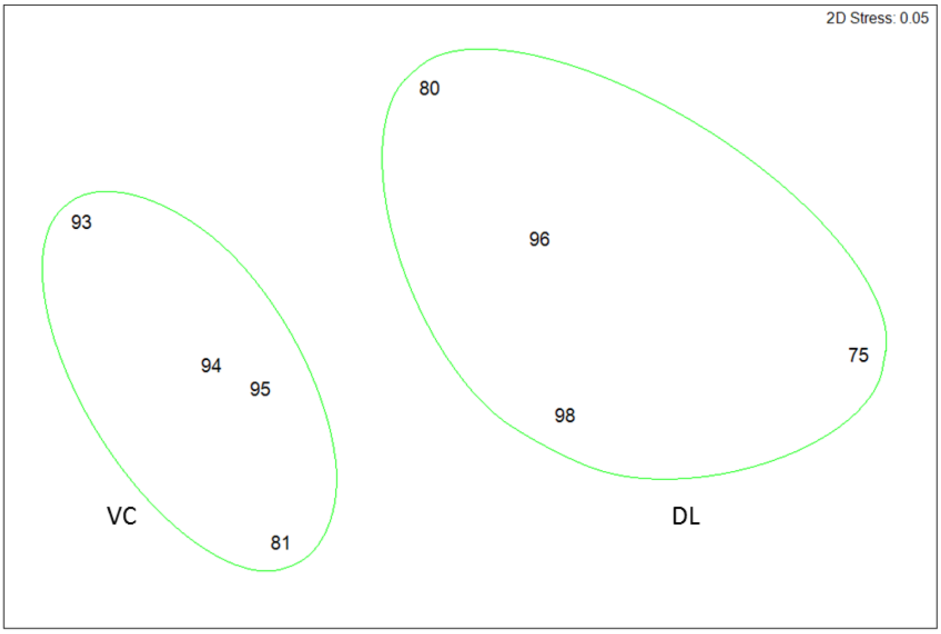


Figure 2. MDS analysis for community found in northern of Cap de Creus. The number corresponds to sampling station.

The species found in the assemblage contained similar pool of species like Desbruyères *et al.* (1972-73) described. But we do not do quantitative comparison because we used other size sieve.

Table 7. Species list of the most important species found in the northern of Cap de Creus.

Species	**Mean**	**Standard Dev.**
Magelona minuta	133	162
Paradoneis lyra	103	102
Monticellina dorsobranchialis	96	72
Galathowenia oculata	66	72
Magelona wilsoni	59	73
Lumbrineris latreilli	57	41
Levinsenia sp.	48	55
Aricidea pseudoarticulata	42	42
Glycera tesselata	39	19
Aphelochaeta marioni	31	37
Paralacydonia paradoxa	30	36
Aricidea assimilis	29	37
Prionospio fallax	27	51
Prionospio cirrifera	26	33
Lumbrineris nonatoi	26	52
Parapionosyllis brevicirra	25	40
Dipolydora armata	24	51
Amphicteis gunneri	23	43
Peresiella clymenoides	22	38
Pseudofabriciola longipyga	21	52
Harmothoe spinifera	20	22
Chrysopetalum debile	17	38
Litocorsa stremma	17	22
Exogone verugera	17	24
Prionospio dubia	17	28
Terebellides stroemii	16	17
Exogone naidina	16	21
Praxillella affinis	15	22
Glycera alba	15	20
Haplosyllis spongicola	15	31
Scoletoma emandibulata mabiti	14	18
Glycinde nordmanni	13	20
Scalibregma inflatum	12	8
Fauveliopsis adriatica	10	16
Melinna palmata	10	9

Some species found in the present study there were not registered in the old work, like the owenid *Galathowenia oculata*, the paranoid *Levinsenia* sp., and the sabellid *Pseudofabriciola longipyga*. Although these species also have been reported in other areas of the Mediterranean Sea (Fitzhugh 1994; Labrune *et al.* 2006; Aguirrezabalaga 2008).

DISCUSSION

Different studies (Pearson et al., 1985; Rosenberg et al., 1987; Gremare et al., 1998) have shown that marked changes in the composition and structure on benthic soft-bottom assemblages are normal when long-term comparisons are made. Seasonal effects, between-years variability, anthropogenic pressures, etc. can serve as explanation. In the analyzed case off the Alt Empordà region we got basically the same results, large changes were observed, both in the Gulf of Roses and the Northern part of the Cape when compared with the old study of (Desbruyères *et al.* 1972-73). The study allow us to compare the situation both in the seventies of last century and in the past decade, a 30 years interval, for 5 different communities of the soft-bottom shallow and platform habitats of the region using polychaete species assemblages to characterize such communities.

In the Gulf of Roses, three natural polychaete species assemblages were distinguished related to grain size, organic content and species composition: (a) the Littoral surf beach assemblage, (b) the Littoral fine sand assemblage, and (c) the Littoral sandy mud assemblage. These three asseemblages have been compared with their situation 30 years ago recognized by Desbruyères *et al.* (1972-73). The results show a reduction of the number of species and densities in the first two shallower assemblages, and similar numbers for the deepest one. In a previous work carried out in the Bay of Banyuls (30 kilometers north of the area of study) by Gremare et al., 1998 carrrying also another long-term comparison of shallow soft-bottom communities several changes were observed. Our observed changes in the Gulf of Roses mirrored the ones described in Banyuls-sur-mer: (1) high reductions of species that, in the past, served to describe communities such as *Nephthys homergii*, *Scoloplos armiger,* and *Notomastus latericius*, and (2) the increased presence of *Ditrupa arietina* which was absent in the old papers.

In addition, in the Gulf of Roses, we have seen a clear reduction in the numbers of the polychaete *Owenis fusiformis* in shallow sandy communities. In the present status, *Ditrupa arietina*, together with *Scoletoma impatiens* are characterizing the Littoral fine sand community, while *Lumbrineris latreilli* and the sipunculid *Aspisosiphon muelleri* characeterizes the sandy mud community.,

The increase of *Ditrupa arietina* in shallow sandy communities of the North western Mediterranean is the most relevant factor shown during last decades. Several papers outlined the fact that the species have been increasing densities during recent years (Medernach, 1996; Gremare *et al*., 1998). *Ditrupa arietina* is preferentially found between 15 and 30 m depth, which mostly correspond to well-sorted fine sands and muddy sands. Both the results of population monitoring and the heterogeneity of population structure at small spatial scale show that the dynamics of this species is unstable. The observed distribution pattern is therefore interpreted as resulting from a response to both wide-scale environmental parameters (accounting for the dramatic increase of the species at a wide geographical scale), and to local environmental factors (accounting for small-scale heterogeneity in population structure) (Gremare *et. al*., 1998a). The phenomenon of this species is not restricted to the area investigated between Banyuls-sur-mer and the Gulf of Roses, this is a phenomenon of regional importance where high densities of the species have been shown all over the North western Mediterranean coast.

There is not clear explanation about why *Ditrupa arietina* have today large populations in those environments. In the past, we observed the inmediate response of the species to sediment alterations following dredging in the Bay of Blanes (Sardá et al., 2000). It looks that on favorable conditions, *Ditrupa arietina* could be able to recruit in large numbers when sediment is altered. Following those works, explanations about the increase of the species were related to sediment instability and the notion of transient sediments Pérès & Picard (1957) and Grémare *et al.* (1998); however, considerations about the life-span of Ditrupa arietina , 1-2 years (Medernach 2000), and the presence of the important species at temporal and spatial scales make difficult to explain the increase of *Ditrupa arietina* just from sediment instability.

Another factor that have been stated to explain why *Ditrupa arietina* increasing numbers, and also can served to explain the decrease of other polychaete species from these assemblages such as *Scoloplos armiger* and *Notomastus latericius* is changes in sediment composition due to the decrease presence of fine particles in the sediment. As Gremare et al., (1998a) pointed out, this is consistent with an increase of resuspension during recent years resulting in a decrease in the sedimentation of fine particles and an increase in the amount of detritus remaining in suspension. The diminution of fine particles as explanation of the recent changes observed in shallow sandy communities could also explain why we have a move from in the trophic composition of polychaete assemblages in the zone from deposit-feeding to filter feedings. The increase of *Ditrupa arietina* is still debatable and other possible explanations should also been tested. *Ditrupa arietina* is a passive filter feeding that recruits in high numbers in early spring (Sardá et al., 1999). The decrease presence of large bivalve populations in shallow sandy environments due to overfishing could have retired from the habitat active filter feeder species able to control and to reduce recruitment of other pioneer species.

Owenia fusiformis is another species for which our study showed large population reductions. Pinedo *et al.* (2000) found that *O. fusiformis* was related to the mouth of the river. They found the highest percentages of densities of *O. fusiformis* in sited close 11% of silt-clay in Bay of Blanes (Spain). Similar result were found by Dauvin and Gillet (1991); Dauvin (1992) in the Bay of Seine, where patches of high densities were associated mainly with percentages of silt-clay >4%.

In the northen part of the Cap of Creus from the two polychaete assemblages studied according to Desbruyères *et al.* (1972-73): (d) the terrigenous coastal mud assemblage, and (e) the detritic mud assemblage show no differences. It could be related the most species composition were present in both assemblages, thus only there were some differences in the abundances distribution. Although, do not in the same magnitude like *Ditrupa arietina,* in the Gulf of Roses, or the same species in the Gulf of Lion (Labrune *et al.* 2006) in the infralittoral zone. This fact also reflects the high diversity found in this zone.

The results of the present study show the occurrence of several changes in the composition and structure of soft-bottom polychaete assemblages in the “Cap de Creus”. Main changes are related to the decrease of *Owenia fusifromis* and the increase of *Ditrupa arietina* in the area, as well as the reduction in numbers of several species that were used to even describe communities in the seventees, species such as *Nephthys hombergii*, *Scoloplos armiger* and *Notomastus latericius*. Both aspects are clearly observed when we compared this data with the one given in Desbruyères *et al.* (1972-73). There is not a clear explanation today about the cause of this change, but due to the regional (mesoscale) importance of these changes, the decrease in fine particles coming to the sea and resuspension mechanisms could be behind this change.

Chapter 3

Spatial distribution and diversity of polychaete faunal in the northern Mediterranean Spanish coast

CHAPTER 3

SPATIAL DISTRIBUTION AND DIVERSITY OF POLYCHAETE FAUNAL IN THE NORTHERN MEDITERRANEAN SPANISH COAST

ABSTRACT

The spatial distribution, diversity of polychaetes and the relationship between polychaetes assemblages and its main environmental parameters were studied along the North-western Mediterranean portion of coast between the French border and the Valencia City REDIT-II campaign. 59 sampling sites were considered in twenty-two inshore-offshore transects located at depth gradient (10, 20 and 30m) in Littoral Fine Sand. I found maximal and minimal densities and diversities related to other areas of the Mediterranean Sea. The faunal assemblages found in it study were similar to establish in the vicinity of Gulf of Lions and other areas of the Mediterranean Sea, although our results do not reveals linked to granulometric parameters.

INTRODUCTION

Biological diversity involves a range of different levels of organisation from the genetic variation between individuals and populations, to species diversity, assemblages, habitats, landscapes and biogeographical provinces (Gray 2000). In Mediterranean Sea, the marine diversity range from 4-25% of the world marine species. Within the metazoans, polychaeta is the second highest group in proportion of species records after the sponges. Thus, Mediterranean Sea is considered a marine biodiversity hot spot (Coll *et al.* 2010). However marine biodiversity have obtained a little attention accorded to its terrestrial counterpart. Even though, historically Mediterranean Sea has been thoroughly studied (Bianchi and Morri 2000). On the other side, the global economy, as mainly effect of human activity, is directly (e.g. food, materials) and indirectly (ecosystem services) dependent on biodiversity (Costello *et al.* 2006), and now the major cause of changes to marine biological diversity, especially in coastal areas (Ellingsen 2001). Currently, following the new European policy, the Marine Strategy Framework (MSFD) (DIRECTIVE_2008/56/EC), the biological diversity at different temporal and spatial scales is a prerequisite as criteria and methodological standards to be evaluated on good environmental status (GEnS) of marine waters.

Studies on polychaetes distribution have done in some areas the Spanish Mediterranean coast by several author like Desbruyères *et al.* (1972-73) in the Catalonian coast. Polychaete distribution and diversity in the Gulf of Lions (Guille 1971; Labrune *et al.* 2006, 2007). Also information over polychaetes distribution on impacted sites by anthropogenic activities have done also by Ros *et al.* (1992); Cardell-Corral (1996); Méndez (1996); Cardell *et al.* (1999) (Serrano *et al.* 2011) in zone closed to Barcelona.

Given that Spain is among the European Countries with the longest coastal zone (Sardá 2001), which includes 4.872 km long, without mention island and northern territories in Africa. Out of these, Mediterranean coast is around the half, 2.058 km long (INE 2008), of Spain whole coast. However the knowing of polychaetes distribution still has several gaps, alongside this coast, being necessary clarify these breaks.

Like Coll *et al.* (2010) showed, polychaetes are one of the most characteristic groups in Mediterranean coastal. It predominance in soft-bottom communities confers to this group a significant importance on the knowing of the mechanisms that control the community dynamics.

The main aim of this study is to describe the polychaetes distribution alongside depth gradient in northern costal in Mediterranean Sea. In this context, the specific objectives of the present study were (1) to describe the distributional pattern of polychaetes for the region, (2) to identify the relationship between polychaetes assemblages and its main environmental parameters.

MATERIAL AND METHODS

Study area

The Western Mediterranean is characterized by its wide continental shelf, by lower salinity and temperature values as well as by higher primary productivity and chlorophyll a concentration values (Arvanitidis *et al.* 2002).

The study area includes around 1000 km of the Spanish Mediterranean coast, comprising Catalonia 699 km and Valencia 454 km. Both of the two coasts with the highest human pressures (Sarda *et al.* 2005; Yepes and Medina 2005). It coast have some important river that discharge flow in Mediterranean sea (Ebro and Llobregat) and other less important (Arnau *et al.* 2004).

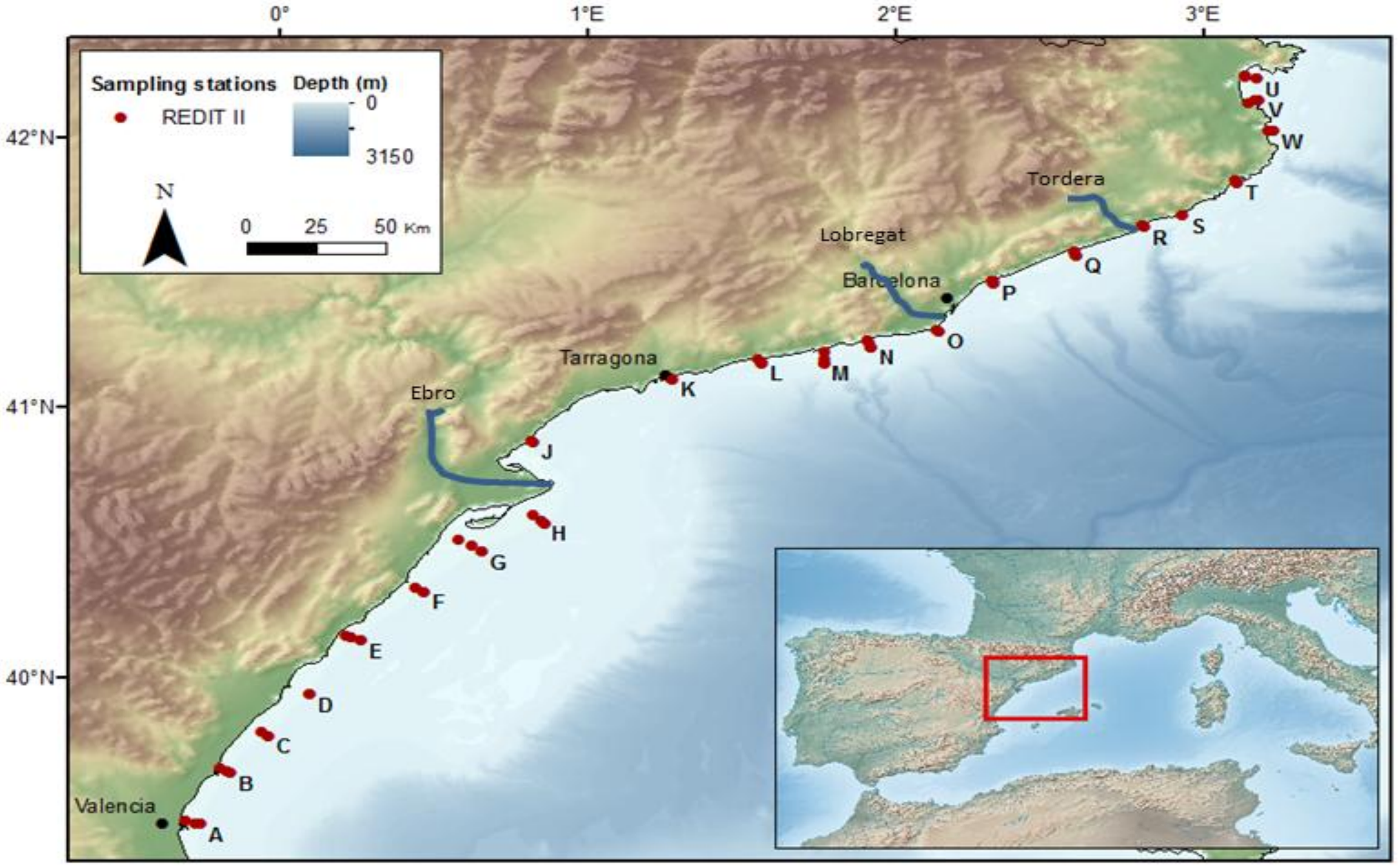


Figure 1. Map of location of the sampling sites and transects alongside the Spanish coast.

Table 1. Geographic coordinates location from sampling sites, granulometry expressed by D50 (µm) and % of silt-clay. The sampling sites were sampled at three depth (10, 20 and 30 meters) in different transect alongside the coast.

Transect	Depth (m)	D50 (µm)	% of silt-clay	Latitude		Longitude	
2U	10	222.4	0.9	42º13'41"	N	03º07'49"	E
2U	20	170.7	3.8	42º13'17"	N	03º08'10"	E
2U	30	135.3	8.3	42º12'52"	N	03º10'13"	E
2V	10	150.9	5.8	42º07'24"	N	03º08'39"	E
2V	20	156.4	3.8	42º07'60"	N	03º09'59"	E
2V	30	110.1	19.6	42º08'05"	N	03º10'34"	E
2W	10	162.3	4.8	42º01'13"	N	03º12'22"	E
2W	20	62.2	50.6	42º01'12"	N	03º12'47"	E
2W	30	62.0	50.6	42º01'12"	N	03º13'19"	E
2T	10	263.4	0.0	41º50'22"	N	03º06'6"	E
2T	20	215.8	4.9	41º50'11"	N	03º06'14"	E
2T	30	136.1	13.5	41º49'51"	N	03º06'18"	E
2S	30	160.2	21.4	41º42'29"	N	02º55'30"	E
2R	10	174.7	1.6	41º40'18"	N	02º47'50"	E
2R	20	243.3	0.0	41º40'14"	N	02º48'3"	E
2R	30	622.1	4.9	41º39'54"	N	02º48'19"	E
2Q	10	529.2	1.3	41º34'34"	N	02º34'35"	E
2Q	20	597.8	0.4	41º34'23"	N	02º34'38"	E
2Q	30	72.4	48.4	41º33'38"	N	02º35'03"	E
2P	10	181.5	3.4	41º28'6"	N	02º18'50"	E
2P	20	127.4	16.9	41º27'58"	N	02º18'37"	E
2P	30	106.3	31.5	41º27'38"	N	02º18'50"	E
2O	10	132.8	8.4	41º17'11"	N	02º07'56"	E
2O	20	98.1	32.2	41º17'3"	N	02º08'1"	E
2O	30	26.9	71.8	41º16'51"	N	02º08'07"	E
2N	10	156.0	1.5	41º14'55"	N	01º54'23"	E
2N	20	44.8	65.0	41º14'19"	N	01º54'42"	E
2N	30	27.0	73.2	41º13'16"	N	01º55'03"	E
2M	10	108.3	6.2	41º12'17"	N	01º46'2"	E
2M	20	456.9	11.7	41º10'50"	N	01º46'1"	E
2M	30	471.7	4.2	41º09'49"	N	01º45'54"	E
2L	10	133.6	5.8	41º10'40"	N	01º33'5"	E
2L	20	67.2	45.6	41º10'12"	N	01º33'38"	E
2L	30	48.6	64.4	40º09'45"	N	01º33'36"	E
2K	10	171.7	0.0	41º06'39"	N	01º15'52"	E
2K	20	159.9	6.7	41º06'29"	N	01º16'7"	E
2K	30	39.8	68.2	41º06'11"	N	01º16'12"	E
2J	20	196.0	25.1	40º52'44"	N	00º48'44"	E
2J	30	547.7	11.8	40º52'25"	N	00º49'16"	E
2H	10	80.7	38.4	40º36'2"	N	00º49'6"	E
2H	20	103.0	24.8	40º35'1"	N	00º50'49"	E
2H	30	15.1	87.3	40º34'15"	N	00º51'20"	E
2G	10	27.4	80.6	40º30'44"	N	00º34'50"	E
2G	20	28.2	82.3	40º29'22"	N	00º37'15"	E
2G	30	11.9	94.0	40º28'04"	N	00º39'17"	E

Transect	Depth (m)	D50 (µm)	% of silt-clay	Latitude		Longitude	
2F	20	62.7	50.2	40º20'4"	N	00º26'15"	E
2F	30	19.4	72.2	40º19'04"	N	00º27'52"	E
2E	10	127.9	5.2	40º09'30"	N	00º12'47"	E
2E	20	92.6	33.8	40º09'6"	N	00º13'51"	E
2E	30	14.3	83.2	40º08'23"	N	00º15'34"	E
2D	30	24.5	61.3	39º56'23"	N	00º05'36"	E
2C	20	94.2	22.0	39º48'2"	N	00º03'44"	W
2C	30	98.2	34.7	39º47'17"	N	00º02'30"	W
2B	10	132.7	3.3	39º39'54"	N	00º11'42"	W
2B	20	99.6	15.2	39º39'25"	N	00º10'38"	W
2B	30	48.8	61.3	39º39'00"	N	00º09'48"	W
2A	10	n.a.	n.a.	39º28'23"	N	00º18'30"	W
2A	20	165.5	28.6	39º27'50"	N	00º16'45"	W
2A	30	48.8	59.4	39º27'43"	N	00º15'33"	W

(n.a.) data no aviable

Sampling and laboratory procedures

Samples were obtained during the course of the REDIT-II (December 1999, on the N.O. Tethys) campaigns, alongside the coast, see Table 1. Geographic coordinates location from sampling sites, granulometry expressed by D50 (µm) and % of silt-clay. The sampling sites were sampled at three depth (10, 20 and 30 meters) in different transect alongside the coast. for detail of geographic coordinates and location. The benthic samples were obtained at 59 stations in 22 inshore-offshore transects (10, 20 and 30 m depths) between the French border and the vicinity of the Valencia city in the area of the North-western Mediterranean coast (Figure 1). Out of these overall sample transects, four of it could not be achieved at 10 m depth (e.g. 2C, 2D, 2F, 2J and 2S) and neither two at 20 m depth (e.g. 2D and 2S), due to technical constraints.

Sediment samples were collected using a 0.1 m² van Veen grab. At each site, 3 grabs were taken for the analysis of benthic macrofauna, and 1 for granulometric analyses. Macrofauna samples were immediately sieved on a 1 mm mesh and the fauna retained were fixed in 5% formaldehyde. At the laboratory, samples were sorted and polychaetes were separated from the remaining fauna. Polychaetes species were later identified to the lowest practical taxonomic level and counted. Unidentified species were only taken into account when they could not be mistaken for other identified species. Data analyses were carried out on data pooled over the three replicated sampling units (Ellingsen 2001).

To examine possible physical habitat characteristics that might be correlated with macrofaunal assemblages, several variables were analyzed for each sampling station. Water depth was recorded from the ship echosounder log at the time of sampling. Granulometric analysis was conducted on fresh sediment using a Malvern® Mastersizer 2000 laser microgranulometer.

Data analysis

Analysis of polychaetes was performed using as univariate measures of diversity species richness (S), the Shannon-Wiener index (*H'*) (log base 2) and the reciprocal of Simpson's index (1-λ') see (Magurran 2004). Following Peet (1974) and Ellingsen (2002) I calling *H'* and 1-λ'as heterogeneity diversity and used labelling of species restricted to a single site 'uniques', species occurring at exactly 2 sites only 'duplicates', species represented by a single individual 'singletons', according to Colwell and Coddington (1994). Also I used multidimensional scaling (MDS) analyses of faunal data. All indices were computed using the Primer$^{©}$ 6 software package (version 6.1.13) (Clarke and Gorley 2006).

Assemblages were performed on previously reduced sets of species in order to limit the noise introduced by the rare species. The elimination of these later species from the analysis was based on general presences on samples sites lower than 10%. Polychaetes assemblages were then elucidated by cluster analysis based on the faunal composition (Bray Curtis similarity, average link grouping). Abundances were square-root transformed to limit the influence of the most dominant taxa. The taxa most responsible for similarities within each cluster of stations on one hand, and for dissimilarities between clusters of stations on the other hand were identified using the SIMPER procedure. All these analyses were carried out using the Primer© 6 software package (version 6.1.13) (Warwick 1986). The relationships between polychaetes heterogeneity diversity and environmental parameters were first assessed by testing for significant correlation between the similarity matrices of polychaetes abundance and (1) depth, (2) silt-clay content using Spearman rank correlation.

RESULTS

Granulometry

The sediment grain size fractions was variable alongside the coast, and mainly the maximum values obtained for median size grain (D50 µm) and percentage of silt-clay (% <63 µm) (Wentworth 1922), were associated with mouth of main river. It values range (D50 µm 622.1 and 94%, respectively) and the minimum values range (D50 µm 11.9 and 0 %), (Table 1). In the same way, at 10 m depth (D50 µm) and percentage of silt-clay (% <63 µm) range (529.2 to 27.4 and 80.6 – 0%) (Figure 2a); at 20 m depth (D50 µm) and percentage of silt-clay (% <63 µm) range (597.8 to 28.2 and 82.3 – 0 %) (Figure 2b) and finally at 30 m depth (D50 µm) and percentage of silt-clay (% <63 µm) range (662.1 to 11.9 and 94 – 4.2%) (Figure 2c).

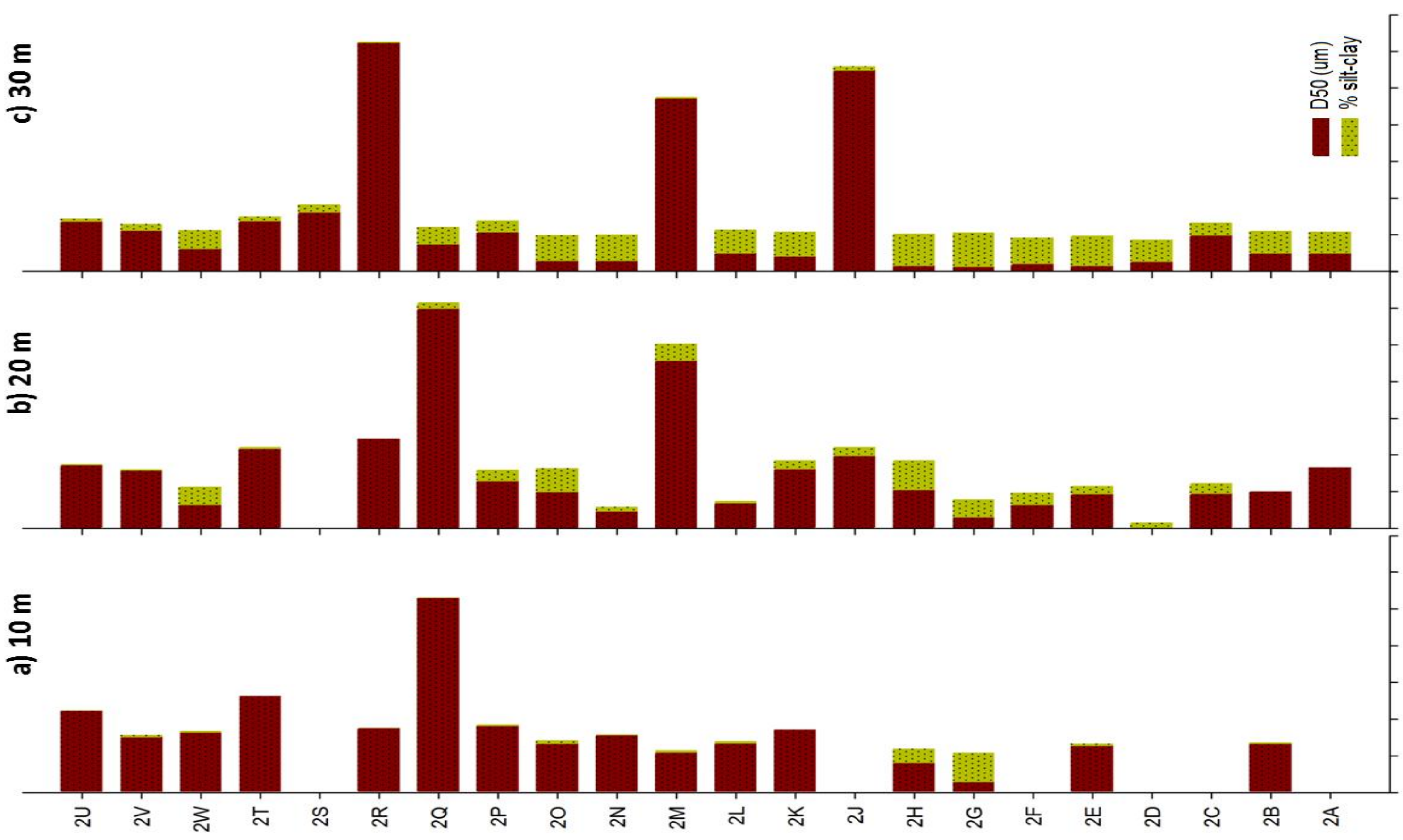


Figure 2. Median size fractions (D50 µm) and percentaje de silt-clay (%<63 µm). a) at 10 m depth. b) 20 m depth. c) 30 m depth.

Species richness, abundances and heterogeneity diversity

Total abundance in the northeast of Spain was 44878 individuals at all 59 sampling station, belonging to 276 Linnaean ranks (e.g. 263 species and 13 morpho-types assigned to family level). It abundance represented a mean density from 761 ± 650 ind. m^{-2}. From all taxa found, there were 47 most important species, *D. arietina* represented 12% (89± 244 ind. m^{-2}), *O. fusiformis* and *M. heterochaeta* denoted 5% each (39 ± 136 ind. m^{-2} and 34 ± 80 ind. m^{-2}, respectively), *L. gracilis* and *A. bilineata* denoted 4% each (33 ± 86 ind. m^{-2} and 29 ± 50 ind. m^{-2}, respectively), *G. oculata, N. latericeus, M. fragilis* and *L. latreilli* indicated 3% each (25 ± 44 ind. m^{-2}, 25 ± 56 ind. m^{-2}, 21 ± 52 ind. m^{-2} and 21 ± 33 ind. m^{-2}, respectively), only 38 species represented at least 2 to 1% in overall zone (Figure 3). Transect with higher abundance was 2O, located near to Delta of Lobregat in Barcelona (1823 individuals) and the lowest abundance was 2E (176 individuals) near to Torrenostra. The higher abundance of *D. arietina* was found in the transect 2U (539 individuals) near to mouth of La Muga river, in the northernmost Spain coast.

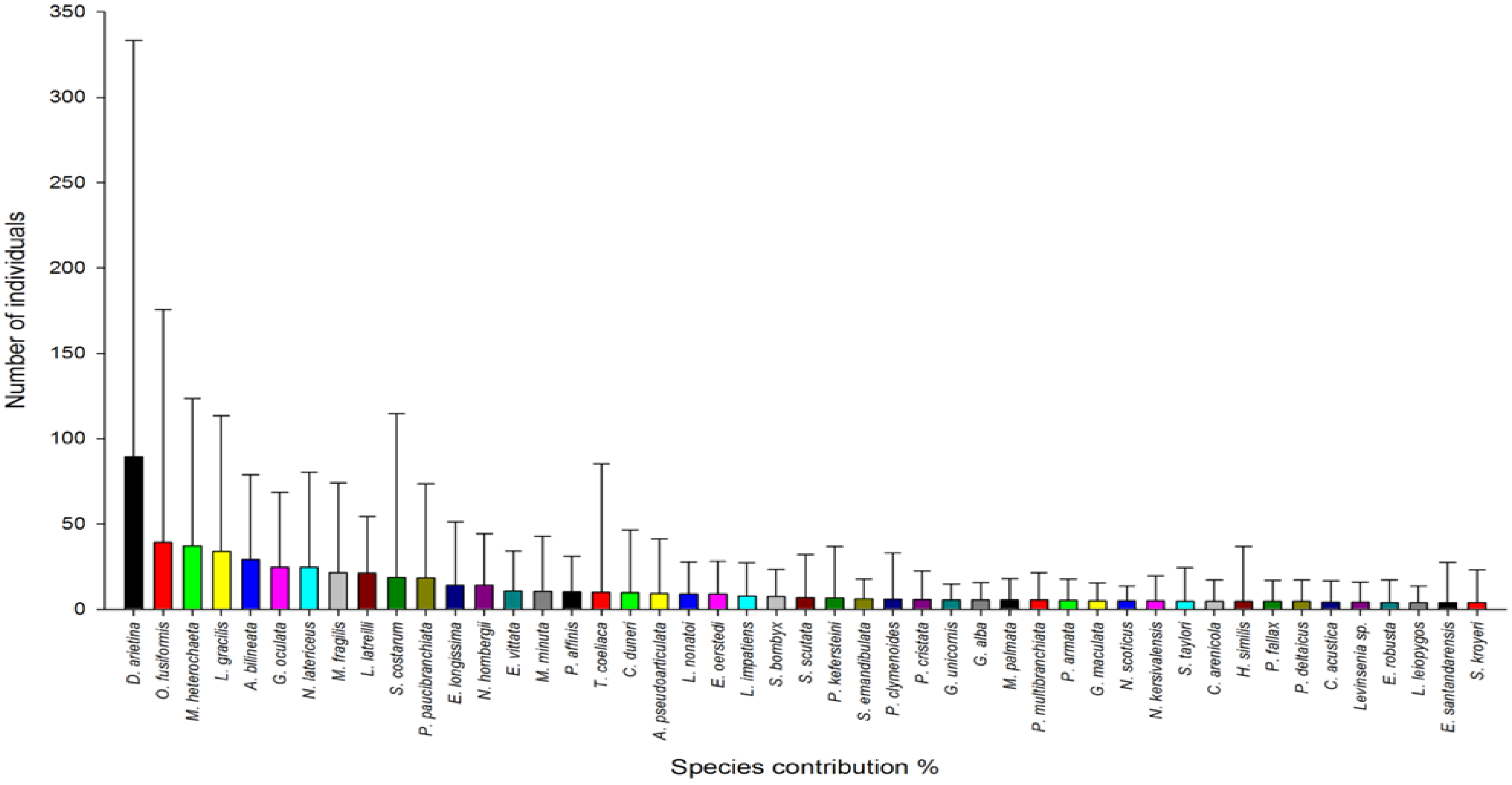


Figure 3. Species contribution vs number of individual of the 47 most important species.

Table 2. Summary of diversity indices in Spanish coast. (S): Species richness, (N): abundance per sampling station, (*d*): Margalef richness, (J’): evenness, (1-λ'): Simpson index.

Transect	depth (m)	S	N	*d*	H'(log2)	J'	1-λ'
2U	10	14	270	2.3	2.8	0.7	0.8
2V	10	18	157	3.4	3.5	0.8	0.9
2W	10	20	560	3.0	2.9	0.7	0.8
2A	10	24	513	3.7	2.9	0.6	0.7
2B	10	28	243	4.9	4.2	0.9	0.9
2E	10	23	317	3.8	2.7	0.6	0.7
2G	10	32	903	4.6	3.6	0.7	0.9
2H	10	49	933	7.0	4.7	0.8	0.9
2K	10	14	80	3.0	3.6	0.9	0.9
2L	10	19	103	3.9	4.0	0.9	0.9
2M	10	20	137	3.9	3.9	0.9	0.9
2N	10	27	700	4.0	2.7	0.6	0.6
2O	10	25	2545	3.1	2.8	0.6	0.8
2P	10	27	790	3.9	3.6	0.7	0.8
2Q	10	15	273	2.5	3.1	0.8	0.8
2R	10	16	203	2.8	3.4	0.9	0.9
2T	10	5	213	0.7	1.1	0.5	0.4
2U	20	26	1290	3.5	1.5	0.3	0.3
2V	20	15	777	2.1	1.1	0.3	0.3
2W	20	46	930	6.6	4.4	0.8	0.9
2A	20	72	2460	9.1	4.7	0.8	0.9
2B	20	20	203	3.6	3.9	0.9	0.9
2C	20	26	373	4.2	4.2	0.9	0.9
2E	20	12	70	2.6	3.4	1.0	0.9
2F	20	56	1193	7.8	4.5	0.8	0.9
2G	20	29	343	4.8	3.6	0.7	0.9
2H	20	21	180	3.9	3.7	0.8	0.9
2J	20	51	633	7.8	4.8	0.8	0.9
2K	20	31	230	5.5	4.4	0.9	0.9
2L	20	55	2567	6.9	4.4	0.8	0.9
2M	20	66	1457	8.9	5.2	0.9	1.0
2N	20	53	890	7.7	4.9	0.9	1.0
2O	20	55	2340	7.0	4.6	0.8	0.9
2P	20	46	1387	6.2	3.7	0.7	0.8
2Q	20	32	437	5.1	4.2	0.8	0.9
2R	20	25	430	4.0	3.1	0.7	0.8
2T	20	44	587	6.7	4.7	0.9	0.9
2U	30	17	593	2.5	0.9	0.2	0.2

2V	30	28	410	4.5	4.3	0.9	0.9
2W	30	34	990	4.8	4.0	0.8	0.9
2A	30	49	1985	6.3	4.4	0.8	0.9
2B	30	39	1150	5.4	4.4	0.8	0.9
2C	30	40	700	6.0	4.7	0.9	0.9
2D	30	42	640	6.3	4.6	0.9	0.9
2E	30	12	140	2.2	3.2	0.9	0.9
2F	30	14	160	2.6	3.2	0.8	0.8
2G	30	15	205	2.6	3.4	0.9	0.9
2H	30	13	335	2.1	2.4	0.6	0.7
2J	30	38	715	5.6	4.0	0.8	0.9
2K	30	26	390	4.2	4.1	0.9	0.9
2L	30	24	485	3.7	3.5	0.8	0.9
2M	30	62	1700	8.2	5.2	0.9	1.0
2N	30	20	345	3.3	3.2	0.8	0.8
2O	30	22	585	3.3	3.8	0.8	0.9
2P	30	31	650	4.6	3.6	0.7	0.8
2Q	30	46	1458	6.2	4.3	0.8	0.9
2R	30	43	1275	5.9	4.4	0.8	0.9
2S	30	38	620	5.8	4.6	0.9	0.9
2T	30	31	1630	4.1	1.7	0.3	0.4

The species richness was highly variable in the zone, range 5 to 72 for sampling site Table 2. The heterogeneity diversity also was variable (range *H'* 0.8 to 3.6 bit ind.$^{-1}$), highest heterogeneity diversity occur at 20 and 30 m depth belongs to transect 2M. The lower heterogeneity diversity occur in two sampling sites (2V20 and 2T10), in sampling site 2V20 where, out of 15 species in this site, *D. arietina* represented 84 % of sampling site (e.g. 653 out of 777 ind. m^{-2}) and 2T10 where, out of 5 species in this site, *D. arietina* represented 78% of sampling site (e.g. 167 out of 213 ind. m^{-2}). Neither of 276 species was found at all sampling station, *A. bilineata* was the most spanned specie (73%) of whole sampling area, this specie was following by *G. oculata* (67%), *L. latreilli* (53%), and *E. vittata and S. costarum* were in (51%) of whole sampling area. Conversely, 77 species (28%) were uniques (restricted to a single site), and 42 species (15%) were restricted to only 2 sites. The uniques had low abundaces, out of these 44 species (57%) were singletons (only 1 individual at sampling site) and 13 species (17%) were doubletons (2 individuals at sampling site).

Table 3. Pairwise Spearman rank correlations between environmental and biotic variables, including *D. arietina* with significant ($p < 0.01$) coefficients in bold face (n for all correlations=59)

	S	N	d	J'	H'(log2)	1-λ'	Depth	D50 (um)	<63%	*D. arietina*
S										
N	**0.79**									
d	**0.97**	**0.64**								
J'	0.03	**-0.42**	0.20							
H'(log2)	**0.80**	0.37	**0.88**	**0.58**						
1-λ'	**0.61**	0.15	**0.72**	**0.76**	**0.94**					
Depth	0.21	0.24	0.17	0.12	0.22	0.16				
D50 (µm)	0.07	0.07	0.07	-0.07	0.01	0.01	-0.34			
<63%	0.19	0.13	0.18	0.16	0.27	0.20	**0.59**	**-0.80**		
D. arietina	0.12	0.18	0.07	-0.27	-0.08	-0.11	0.08	0.27	-0.23	

Exception abundance (N) and evenness (J'), there were positive correlations among heterogeneity diversity measures. see (Table 3). Also there is a positive correlation between percentage of silt-clay and depth. And finally Spearman rank reveals negative correlations between median grain sizes D50 (µm) and percentage of silt-clay.

Spatial distribution and faunal assemblages

The MDS analysis shows a main distributional gradient of species linked to depth alongside the coastal area (Figure 4), and ANOSIM (ANOVA one-way) indicated it differences were significative (Global R): 0.406 (p<0.001).

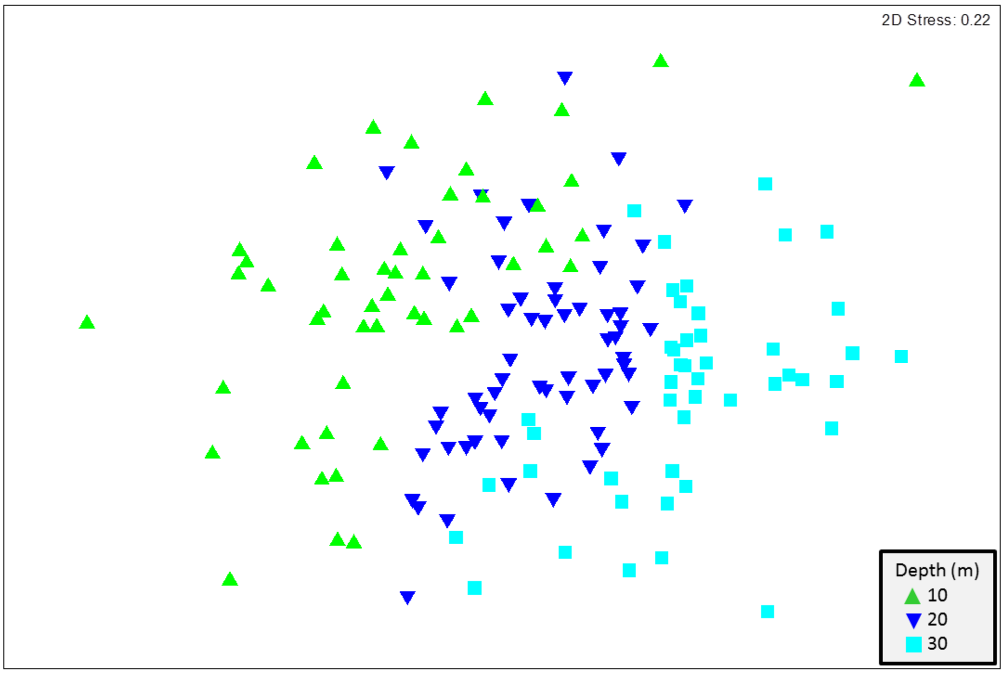


Figure 4. MDS ordinations for abundance of all replicates at each sampling site.

The SIMPER analysis confirmed the species contribution more responsible of this distribution.

Table 4). Also I plotted how the species were distributed at 3 depths, alongside the coast, as percentage of contribution.

Table 4. Contribution and cumulative contribution of the species the most responsible for similarity in all depth from Spanish coast NW-Mediterranean Sea based on square root transformed species abundances according to the SIMPER analysis; Av. similarity: (10 m 10%, 20 m 15%, 30 m 14%).

Species	**Av. Abund. (ind-m-2)**	**Contribution %**	**Cumulative contribution %**	**Depth (m)**
				10
Lumbrineris impatiens	27	25.14	25.14	
Owenia fusiformis	102	12.38	37.52	
Galathowenia oculata	16	7.69	45.22	
Aponuphis bilineata	8	5.94	51.16	
Paradoneis armata	10	5.23	56.39	
Chone duneri	28	5.16	61.55	
Species	**Av. Abund. (ind-m-2)**	**Contribution %**	**Cumulative contribution %**	**20**
Ditrupa arietina	142	15.36	15.36	
Galathowenia oculata	49	11.93	27.29	
Notomastus latericeus	48	10.08	37.38	
Aponuphis bilineata	34	8.98	46.35	
Lumbrineris latreilli	28	7.09	53.44	
Monticellina heterochaeta	65	4.67	58.11	
Spiophanes bombyx	16	3.79	61.9	
Species	**Av. Abund. (ind-m-2)**	**Contribution %**	**Cumulative contribution %**	**30 m**
Lumbrineris gracilis	*77*	21.13	21.13	
Monticellina heterochaeta	*37*	8.51	28.75	
Aponuphis bilineata	*39*	5.08	33.84	
Sternaspis scutata	*17*	4.79	38.63	
Ditrupa arietina	*107*	4.59	43.22	
Notomastus profundus	*10*	3.91	47.13	
Notocirrus scoticus	*10*	3.83	50.95	
Eunereis longissima	*23*	3.61	54.75	
Lumbrineris latreilli	*21*	3.42	57.98	
Scoletoma emandibulata	*10*	3.05	61.04	

The species that more contributed with similarity at 10 m depth were *Lumbrineris impatiens*, which was widely distributed (82% of sampling station at 10 m depth), however it abundance was low, see

Table 4. The owenids group *Owenia fusiformis and Galathowenia oculata*, where *O. fusiformis* was found in 53% of sampling station, closed to river mouth (e.g. Ter, Bèsos, Lobregat and Mijares) even though the most rivers have low flow (Figure 5). By contrast *G. oculata* had a minor abundance in the zone, but was found in 71% of sampling sites. *Aponuphis bilineata* have a low abundances but it was present in 71% of sampling sites. *Paradoneis armata* only was present in 65% of sampling sites with low abundances, and *Chone duneri* were present in 71% of sampling sites but it abundance was lower than at 20 m depth (Figure 5).

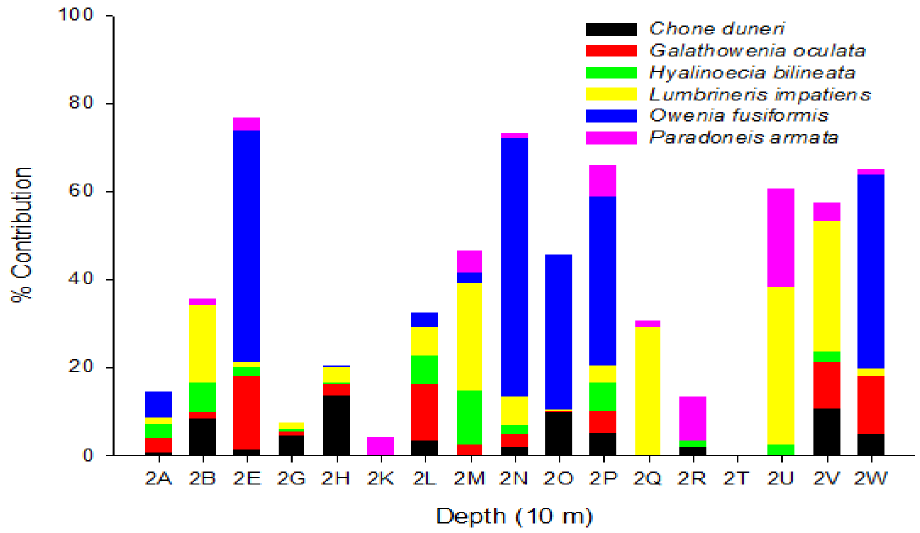


Figure 5. Distributional pattern of polychaetes most important at 10 m depth.

At 20 m depth *D. arietina* was found in 65% of the sampling sites (Figure 6) but it abundances was higher than 10 or 30 m depth and it was mainly found since Gulf of Roses until vicinity of Barcelona, and it again was present near to Ebro delta, but in minor densities. The other species *G. oculata* and *Notomastus latericeus* was represented in 95% of sampling station but with less density (Figure 6). *A. bilineata* was in 85% of sampling sites, but it abundance was higher is we compared with abundance found at 10 m depth but similar to found at 30 m depth, although at 30 m only was present in 64% of sampling site (Figure 6). *Lumbrineris latreilli* was found in 90% of sampling sites at 20 m depth, even though it abundance is similar at 20 and 30 m depth, in the later depth was ubiquity in the vicinity Barcelona to Ebro delta (Figure 7).

In the last depth (30 m) *Lumbrineris gracilis* was the mainly contributor although only was in 55% of sampling sites following by *Monticellina heterochaeta* which was the most widely distributed (82%) of sampling station but whose densities were moderated is we compared with density of it at 20 m depth.

Table 4, Figure 7).

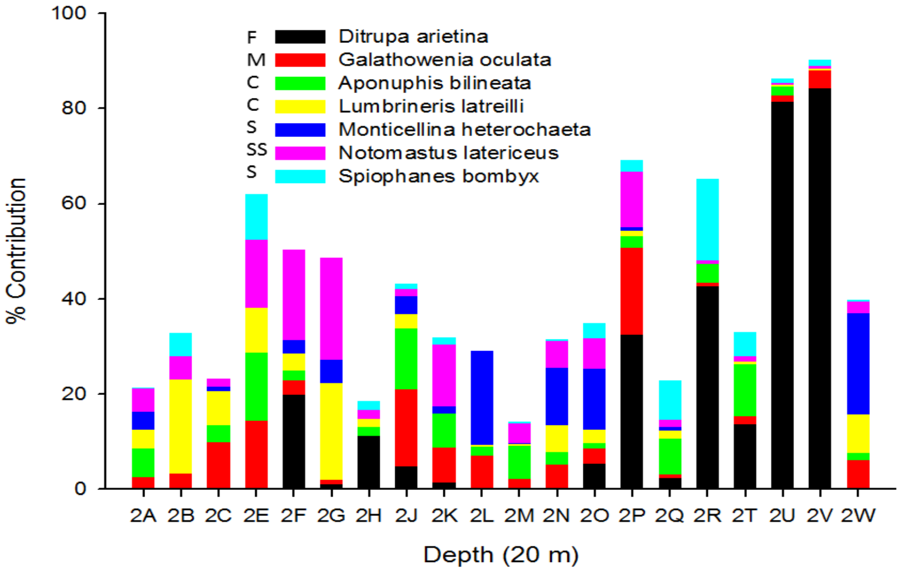


Figure 6. Distributional pattern of the most important polychaetes at 20 m depth

When I plot *D. arietina* average abundance pattern at all depth, it shows that *D. arietina* is the main contributor to differences among distribution in soft-bottom littoral zone. And it distribution in the infralittoral zone is most important in the north Spanish coast.

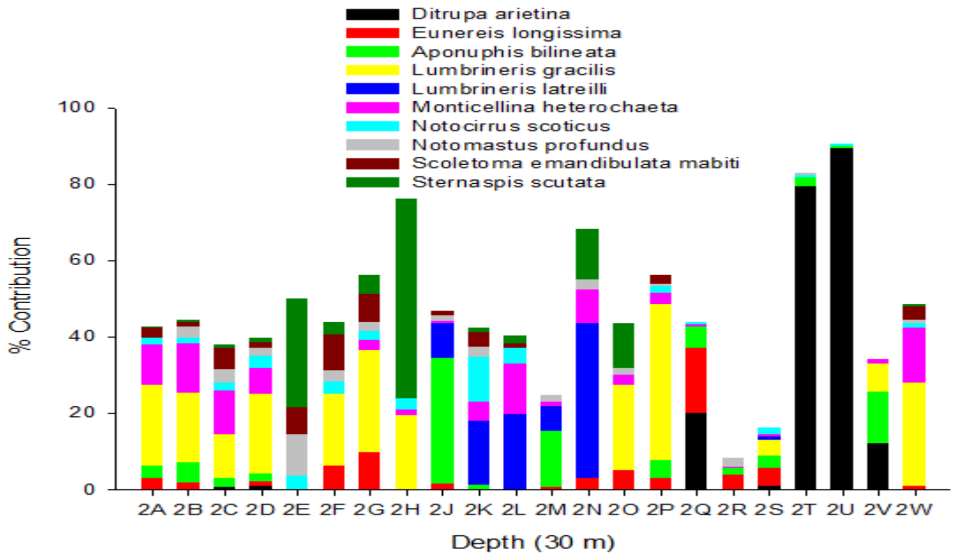


Figure 7. Distributional pattern of the most important polychaetes at 30 m depth.

In a view differences at all depth, shows some inconstancies, the cluster analysis shows that there are 5 assemblages in the zone at 24% of similarity, and (ANOVA R: 0.69 p< 0.001), reveals that there are significative differences among clusters. The cluster 1 was formed by 11 sampling station, all at 10 m depth with D50 (µm) 180.63 ± 117.57 and % silt-clay 4.15 ± 2.50 and it mainly contributors were *O. fusiformis*, *G. oculata*, *L. impatiens*, *C. duneri*, *P. armata* and *A. bilineata*; cluster 2 was shaped by 10 sampling stations northern Tordera river, D50 (µm) 171.55 ± 55.22 and % silt-clay 7.63 ± 8.82, exception was sampling station 2H20 (20 m depth) located near to the mouth of Ebro delta and it mainly contributor was *D. arietina* (81%) and Av. Abundance 402 ind. m^{-2} , which showed assemblages with those sampling stations located in gulf of Roses, and also near to Tordera river; the third cluster encircled 11 sampling station at 10 and 20 m depth southern Tarragona with D50 (µm) 100.68 ± 57.13 and % silt-clay 38.29 ± 25.72 which mainly contributors were *N. latericeus*, *L. latreilli*, *G. oculata*, *A. bilineata*, *C. arenicola* and *C. collaris*; the cluster 4 was the biggest of all cluster, it grouping 22 sampling stations between 20 and 30 m depth and D50 (µm) 184.00 ± 204.60, % silt-clay 37.33 ± 24.34, mainly before Gulf of Roses it mainly contributors were the lumbrinerids (*L. gracilis*, *L. nonatoi*, and *L. latreilli*), *M. dorsobranchialis*, *N. hombergii*, *A. bilineata and*; and the last cluster 5 only contained 5 sampling stations 30 m depth, located southern Barcelona and D50 (μm) 17.52 ± 5.93 and % silt-clay 81.98 ± 9.30, it mainly contributors were *S. scutata* and *L. gracilis* see (Figure 9).

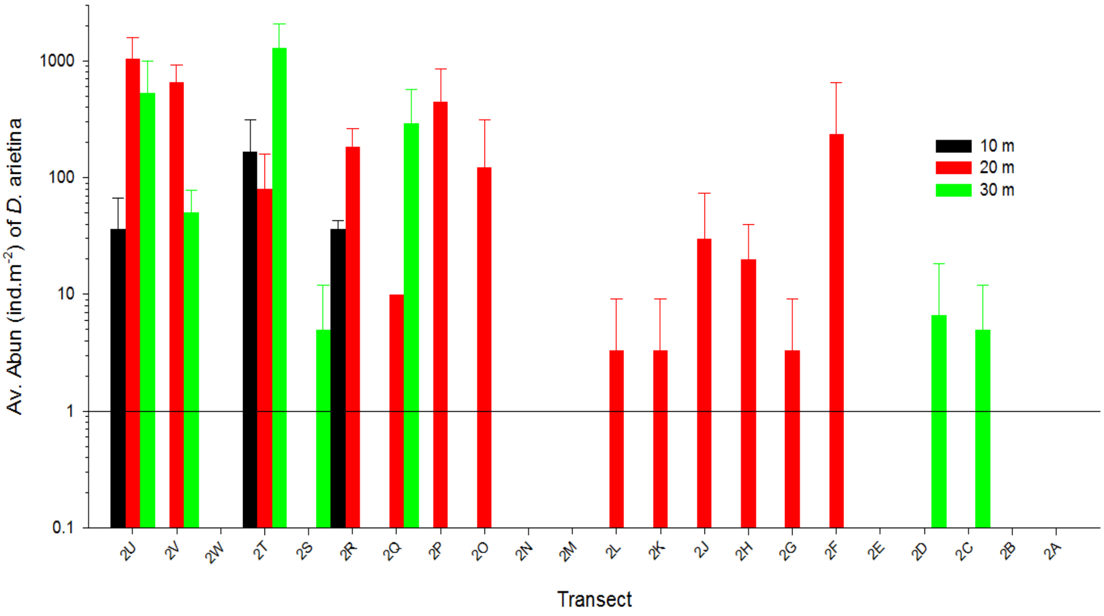


Figure 8. Presence and average abundance of *D. arietina* at all depth sampled (10, 20 and 30 m)

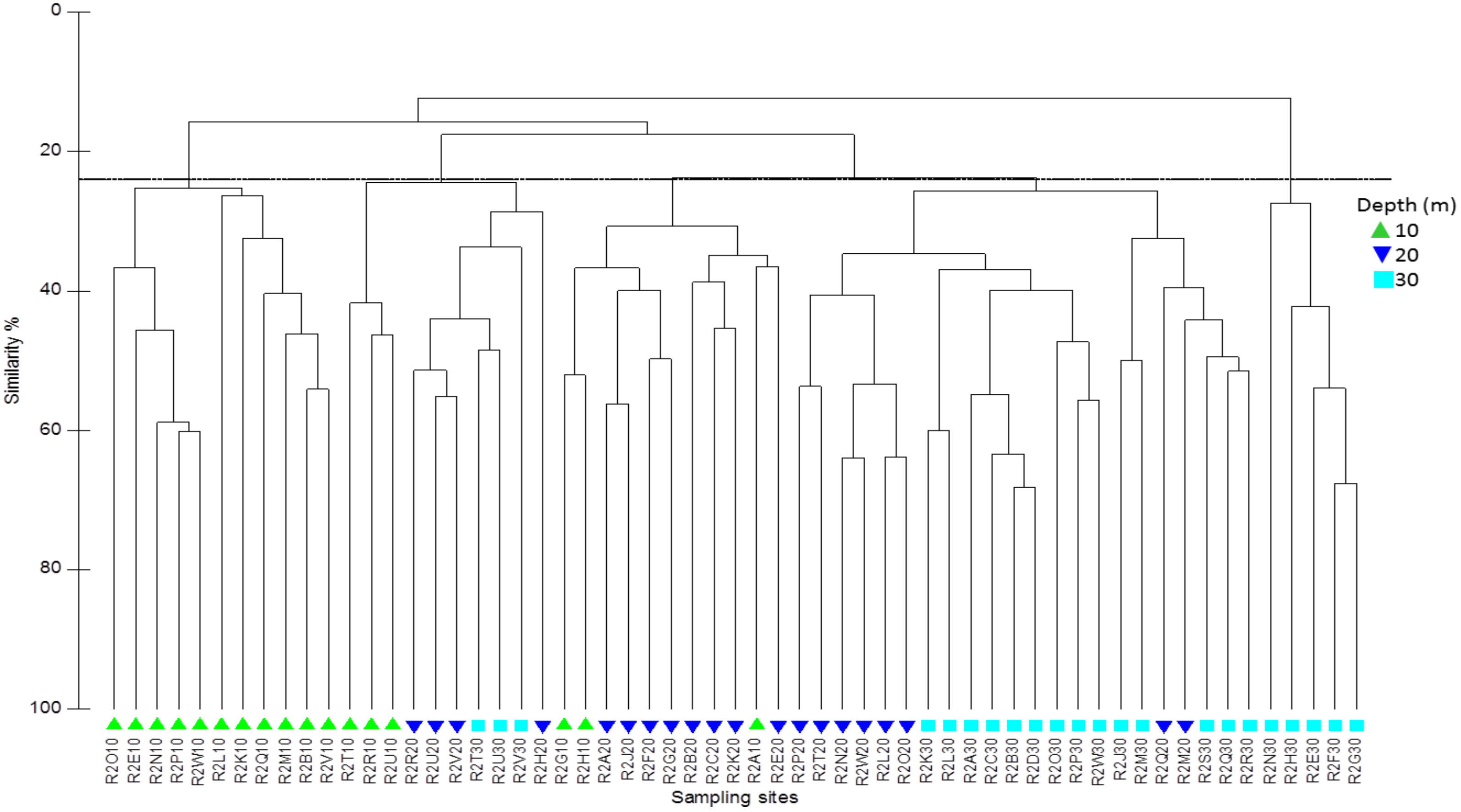


Figure 9. Dendrogram of cluster analysis alongside the coast.

DISCUSSION

Granulometry

The grain size fraction in the coastal zone were associated mainly with depth and river discard in the zone, in this survey the mainly river that affected granulometric fractions were Tordera, Llobregat and Ebro river. Even though some of these have freshwater discharges caused by episodic stormy rain flow (Cruzado *et al.* 2002). Also these process have been widely pointed out (Salen-Picard *et al.* 2002; Salen-Picard *et al.* 2003; Arnau *et al.* 2004; Darnaude *et al.* 2004; Hermand *et al.* 2008; Harmelin–Vivien *et al.* 2009). In the same way the variations in percentages of silt-clay which the highest values were associated mainly with the depth, Palanques *et al.* (2009) indicated that the maximum sediment resuspension near-bottom and sediment fluxes are associated with storm events and strong wind-induced currents, especially during storms in the Ebro delta river. Ulses *et al.* (2008) also reported these events in Gulf of Lions. Thus, the coastal area are strongly influenced by local meteorology, oceanography and submarine physiography, which determine coastal dynamics (Arnau *et al.* 2004), and it process determined the Littoral Fine Sands community (LFS), mostly by the predominant presence of fine to medium sediments in its infralittoral soft-bottom. (Labrune *et al.* 2007). In specific places where coarse sand sediments are dominant, near rocky shores as the Cap de Creus (Sardá *et al.* 2012) or highly dynamic deltas as the Tordera one (Sardá *et al.* 1999) and Ebro (Palanques and Drake 1990; Guillen and Palanques 1992), the LFS community is replace by the Littoral Coarse Sands community (LCS).

Species richness, abundances and heterogeneity diversity

The average H’ and J’ only shows significant differences between 10 and 30 m depth (ANOVA R: 0.23 $p<0.001$), these variations could be attributed to high number of rare species, uniques (restricted to a single site) and duplicates (restricted to only 2 sites) and the predominance of *D. arietina,* what is shows by low evenness. The highest densities of *D. arietina* and fast increased of it specie have been well documented in the Gulf of Lions by Grémare *et al.* (1998); Grémare *et al.* (1998); Medernach (2000) and recently by (Labrune *et al.* 2007) in Littoral Fine Sand community.

The species richness found in it survey 5 and 72 with H' values between 1.1 and 5.2 and J' between 0.3 and 0.9 are similar to registered by and Nicolaidou and Papadopoulou (1989) whose found between 2 and 64 species per site with H' values between 0.59 and 3.67 and J' between 0.37 and 0.90 in the Amvrakikos Bay. These variation were more alike than species richness registered by Cardell-Corral (1996) in the Maresme vicinity (13 and 37 with H' values between 1.2 and 4.5), Salen-Picard *et al.* (2003) (22 and 27 species) and by Labrune *et al.* (2006) 4 and 33 species per site and H' values between 0.39 and 4.42 and J' between 0.1 and 1.0.

Spatial distribution and faunal assemblages

The MDS analysis shows that the faunal polychaetes distribution changed across depth studies, and SIMPER analysis shows it distributions. In relationship to species distribution *L. impatiens* seem to be more frequently at 10 m depth and more homogeneity in abundance (27 ind. m^{-2}) than other species, this is in accordance to found by Cardell-Corral (1996), who reported densities between 32 to 41 ind. m^{-2} in altered communities in the vicinity to Barcelona wastewater discard and 60 ind. m^{-2} in detritic bottom and 6 to 25 ind. m^{-2} in Maresme zone and Serrano *et al.* (2011) found (19 ind. m^{-2}) in a sampling site benthic recovery after cessation of wastewater discharges near to Barcelona.

Even though *O. fusiformis* was the most abundant specie at 10 m depth, it presence was associated to the mouth of the river. Pinedo *et al.* (2000) found the highest percentages of densities of *O. fusiformis* in sited close 11% of silt-clay in Bay of Blanes (Spain), and by Dauvin and Gillet (1991); Dauvin (1992) in the Bay of Seine whose found patches of high densities associated with percentages of silt-clay >4%. In this survey the biggest densities of *O. fusiformis* occurred near to influence zone from river mouth of Lobregat and Bèsos. And also near to less important rivers like in the northern Muga River (in the Gulf o Roses) and southern Spain near to San Miguel River, although I found high densities at sampling sites with less percentages of silt-clay.

The owenid *G. oculata* also shows a pattern alike to *O. fusiformis* but it contribution was quite low, it could be explained because these two species (*O. fusiformis* and *G. oculata*) have similar feeding guild, e.g. a mix between filter-feeding and suspension-feeder (Fauchald and Jumars 1979).

The gradient depth distribution of species is clearer at 10 m depth than 20 and 30 m depth. It could linked with the highest percentages of silt-clay and the most important specie at this depth was the cirratulid *M. heterochaeta,* it could be because it polychaete is a an active deposit-feeder (Fauchald and Jumars 1979). About feeding guild (Gambi and Giangrande 1985) indicated the dominance of burrowers in deeper zone is related to the softness of sediment, it why high level of silt-clay favours penetration and ingestion of the substrate by burrowers.

D. arietina was the dominant specie in the cluster 2 located in the Gulf of Roses and closed to Tordera river, and agree with Labrune *et al.* (2007) found in the Littoral Fine Sand community. The highest densities of single polychaete species in soft-bottom environments are frequent in two basic conditions; in the response of assemblages to stressors such as organic enrichment e.g. *Capitella capitata* in the Barcelona region (Cardell *et al.* 1999), or in recruitment periods (Sardá *et al.* 1999). In the North-western Mediterranean, recruitment periods for soft-bottom polychaetes species take place in late winter-early spring while in the periods sampled during this study no recruits are seen in the bottoms. This could be an indication that such high numbers of it species occur as response of some type of pressure.

The capitellid *N. latericius* was the most important specie the cluster 3, and this specie is a burrower deposit-feeder non selective (Fauchald and Jumars 1979). It could be related to a high input of nutrient in the closed to Ebro. Where the Ebro River would add a surplus to primary production corresponds to nitrogen of which more than 104 tm

yr^{-1}. Thus, nitrogen regeneration took place in the lower river waters during fall and spring and nitrogen uptake prevailed in summer (Cruzado *et al.* 2002).

The cluster 4 was shaped mainly by *L. gracilis M. heterochaeta*, and *N. hombergii* although this cluster was biggest, it showed a more homogeneous distribution of the different groups. This cluster was resemblance to found by Gambi and Giangrande (1986), in the Tyrrhenian Sea, where they indicated species typical of sandy sediment together with species typical of mixed and muddy sediments. Most of polychaetes found here were burrowers, deposit-feeders and carnivorous/omnivorous. Deposit-feeders are influenced by the presence of detritus in the sediment (Gambi and Giangrande 1985). This cluster also was analogous to *N. hombergii* community (Guille 1971; Desbruyères *et al.* 1972-73), however in those community presented maximal abundance of 200 ind. m^{-2}, whereas in it study it abundance was low (30 ind. m^{-2}).

The last cluster 5, found in this study is more resemblance with Terrigenous Coastal Mud (TCM) (Labrune *et al.* 2007) and *Nucula sulcata* community (Guille 1971; Desbruyères *et al.* 1972-73). Where the mainly species were *S. scutata, L. gracilis S. costarum* are associated to muddy sediments (Gambi and Giangrande 1986). That fact agree with Picard (1965) and (Gambi and Giangrande 1986) mentioned over the existence of a general pattern of polychaetes distribution in Mediterranean Sea.

Even though the Sperman rank correlation no related to depth or median grain size with univariate measures of diversity, the clustering ordination reveals that assemblages found have significative differences, which agree with faunistic assemblages of polychaetes in others areas of the Mediterranean Sea, but some lightly variations. This fact could be related with other factors biotic. Regardless of the strength of a relationship, correlations (Ellingsen 2002) point out that it do not imply causality, and it is probable that factors other than those measured may have influenced the community structure. Biotic factors such as availability and abundance of benthic larvae/adults may be more important than sediment characteristics in determining benthic settlement (Wu and Shin 1997). On the other hand, the Mediterranean region has been inhabited for millennia and human settlements have been spreading continuously along its coastal areas (Margalef 1985). Thus, ecosystems have been altered in many ways due to the overexploitation of biological resources, direct habitat modification of sea and coastal areas, introduction of exotic species, pollution and climate change (Bianchi and Morri 2000), and the fishing activity as the first major human disturbance to coastal areas (Coll *et al.* 2006).

ACKNOWLEDGEMENTS

This research was supported by the project REDIT II, and by doctoral fellowship from IFARHU-SENACYT (Panama). Also I wish to thank to Gustavo Carreras for his help during weighing of samples and David March Morla for helping with the maps.

Chapter 4

Assessment of soft-bottom polychaete assemblages in Littoral Fine Sands (LFS) community based on a mesoscales survey:

From the mouth of the Rhone River (France) to the vicinity of Valencia (Spain)

CHAPTER 4

ASSESSMENT OF SOFT-BOTTOM POLYCHAETE ASSEMBLAGES IN LITTORAL FINE SANDS (LFS) COMMUNITY BASED ON A MESOSCALES SURVEY:

From the mouth of the Rhone River (France) to the vicinity of Valencia (Spain)

ABSTRACT

Forty-four inshore-offshore transects along the North-western Mediterranean portion of coast between the mouth of the Rhône River and the Valencia city were sampled during the REDIT-I campaign (September 1998, [R1]) and the REDIT-II campaign (December 1999, [R2]). The pool of polychaetes species and the distribution pattern of its assemblages on shallow littoral fine sands (10 and 20m stations) were analyzed at this regional scale. Biomass data from the obtained collection was assessed by species and trophic guilds, and here is provided together with estimates about its productivity.

INTRODUCTION

The assessment of biological diversity at different temporal and spatial scales is a prerequisite when criteria and methodological standards on Good Environmental Status (GEnS) of marine waters need to be evaluated following the Marine Strategy Framework Directive-MSFD (2008/56/EC). For these assessments, the natural characteristics of biodiversity (descriptor 1 of the MSFD), as well as the particular pressures requiring management responses, need to be understand because they change according to different biogeographic regions (Cochrane *et al.* 2010). Following the recommendations of the MSFD, a suitable set of European ecological assessment areas should be defined to analyze habitat/community distribution and condition. This knowledge is basic for cooperation in planning future coastal and marine conservation and uses, as well as for further implementation of the MSFD.

Although indicators of GEnS are obliged by the Directive at subnational economic exclusive zone regional scales, it is important to consider the utilization of indicators that give comparable information besides intrinsic variations due to spatial heterogeneity. Selected indicators can vary naturally according to different natural condition factors such as granulometrical configurations due to major currents and/or organic content in sediments due to river inflow or anthropic pressures. Here, we are providing data on a very extended community in the Mediterranean Sea, the Littoral Sand Community (Labrune et al., 2007), both at French and Spanish sublittoral waters to analyze its species composition, community variables, and differences due to geographical location.

During 1998 and 1999, French-Spanish cooperation was initiated to assess the biological diversity of shallow soft-bottom benthic macroinfauna in the region of the Gulf of Lions and the Northern Mediterranean Spanish coast. The coast portion between the mouths of the Rhône River to the vicinity of the Valencia city was assessed. The main aim of the present study was to describe the distribution pattern of the pool of species present in this particular region of the North-western Mediterranean Sea. This region comprises around 2000 km of coastal fringe and can be considered by its dimension, its social-ecological importance, and its scientific knowledge, a suitable area to be assessed in the implementation of the MSFD.

The Gulf of Lions has been the departure point for the pioneer biological description of soft-bottom communities in the Mediterranean (Picard 1965; Guille 1970, 1971; Massé 1972; Bellan and Bourcier 1984). Recently, the distribution, composition and ecological quality of the benthic macroinfauna in the Gulf of Lions was reassessed (Grémare *et al.* 1998; Grémare *et al.* 1998; Labrune *et al.* 2006; 2006; 2007; Labrune *et al.* 2008). In these papers, a new terminology for the soft-bottom assemblages observed in the Gulf of Lions: littoral fine sand community (LFS), littoral sandy mud community (LSM), and terrigenous coastal mud community (TCM) was introduced, and its correspondence with ancient community classification data (Picard 1965; Guille 1970) indicated. However, besides the additional information given for biodiversity and ecological quality of such environments, no biomass data was included. Despite its importance when functional analyses are taken into consideration, biomass estimates are often absent in macrofaunal studies, nevertheless, biomass data can be related with energy inputs of organic matter, biomass estimates can be used to compute crude measures of production, and biomass changes expressed as trophic guilds can be related with anthropogenic impacts on the marine environment.

From all the zoological taxa found in soft-bottom communities, polychaetes are one of the most characteristic groups (Knox 1977). It has been shown that in many cases polychaetes may constitute a good surrogate for describing the distribution of the entire communities (Mackie *et al.* 1997; Olsgard *et al.* 2003; Mackie *et al.* 2005). The predominance of polychaetes in soft-bottom communities confers to this group a significant importance in the understanding of the mechanisms that control the community dynamics, and calls for its inclusion as indicators for GEnS in benthic environments.

The main aim of the present study was to describe the pool of polychaete species throughout the observed region in their shallow Littoral Sands providing its basic community data. In addition, a second objective of the paper was to address the suitability of using particular indicators derived of this analysis for the Descriptor 1 of GEnS. In this context, the specific objectives of the present study were (1) to describe the distributional pattern of polychaetes for the region, (2) to identify the relationship between polychaetes assemblages and its main environmental parameters, (3) to include measurements of biomass that could give us indications on the productivity of the are, and (4) to select indicators for GEnS in the Littoral Sand Community.

MATERIAL AND METHODS

Sampling and laboratory procedures

Littoral sand benthic samples were obtained at 77 stations in forty-one inshore-offshore transects (10, 20 m depths) between the mouth of the Rhône river and the vicinity of the Valencia city in the area of the North-western Mediterranean coast (Figure 1). Transects were sampled during the course of the REDIT –I (September 1998, from the mouth of the Rhône river to the French-Spanish border on the N.O. Georges Petit) and the REDIT-II (December 1999, from the border to Valencia on the N.O. Tethys) campaigns (Table 1). Eight of the sample transects of the REDIT-I (R1) and REDIT-II (R2) campaigns could not be achieved at 10 m depth (R1O, R1P, R2C, R2D, R2F, R2I, R2J, and R2S) due to technical geo-morphological constraints, while transects R2D, R2I, and R2S were not sampled at 20 m depth for the same reason.

Table 1. Geographic coordinates location from sampling sites ordered north to south in both coast, granulometry expressed by D50 (μm) and % of silt-clay. The sample sites have 5 digits, the two first ones link campaign (e.g. R1_ Redite I (French coast campaign) or R2_ Redite II (Spanish coast campaign); the third digit corresponds to transects from long coast and are represented by a letter (A-W); and two last one are depth in meters (10 or 20).

French coast campaign							***Spanish coast campaign***						
S. Site	**Latitude**		**Longitude**		**D50 (μm)**	**% of silt-clay**	**S. Site**	**Latitude**		**Longitude**		**D50 (μm)**	**% of silt-clay**
R1U10	*43º19'55"*	*N*	*4º44'56"*	*E*	*111.5*	*12.7*	*R2U10*	*42º13'41"*	*N*	*3º07'49"*	*E*	*222.4*	*0.9*
R1U20	*43º19'01"*	*N*	*4º44'56"*	*E*	*79.9*	*36.1*	*R2U20*	*42º13'17"*	*N*	*3º08'01"*	*E*	*170.7*	*3.8*
R1T10	*43º20'06"*	*N*	*4º36'22"*	*E*	*182.8*	*1.4*	*R2V10*	*42º07'24"*	*N*	*3º08'39"*	*E*	*150.9*	*5.8*
R1T20	*43º19'26"*	*N*	*4º36'11"*	*E*	*55.0*	*52.2*	*R2V20*	*42º07'60"*	*N*	*3º09'59"*	*E*	*156.4*	*3.8*
R1S10	*43º26'24"*	*N*	*4º29'01"*	*E*	*47.2*	*61.4*	*R2W10*	*42º01'13"*	*N*	*3º12'22"*	*E*	*162.3*	*4.8*
R1S20	*43º22'55"*	*N*	*4º28'11"*	*E*	*45.6*	*61.8*	*R2W20*	*42º01'12"*	*N*	*3º12'47"*	*E*	*62.2*	*50.6*
R1R10	*43º26'16"*	*N*	*4º19'26"*	*E*	*124.7*	*3.7*	*R2T10*	*41º50'22"*	*N*	*3º06'06"*	*E*	*263.4*	*0.0*
R1R20	*43º24'57"*	*N*	*4º18'56"*	*E*	*49.8*	*53.5*	*R2T20*	*41º50'11"*	*N*	*3º06'14"*	*E*	*215.8*	*4.9*
R1Q10	*43º27'32"*	*N*	*4º09'26"*	*E*	*145.6*	*1.5*	*R2R10*	*41º40'18"*	*N*	*2º47'50"*	*E*	*174.7*	*1.6*
R1Q20	*43º26'45"*	*N*	*4º09'32"*	*E*	*108.0*	*23.0*	*R2R20*	*41º40'14"*	*N*	*2º48'03"*	*E*	*243.3*	*0.0*
R1P20	*43º21'14"*	*N*	*3º59'54"*	*E*	*32.1*	*77.4*	*R2Q10*	*41º34'34"*	*N*	*2º34'35"*	*E*	*529.2*	*1.3*
R1O20	*43º25'12"*	*N*	*3º49'41"*	*E*	*223.3*	*1.7*	*R2Q20*	*41º34'23"*	*N*	*2º34'38"*	*E*	*597.8*	*0.4*
R1N10	*43º22'55"*	*N*	*3º41'26"*	*E*	*131.2*	*6.8*	*R2P10*	*41º28'06"*	*N*	*2º18'50"*	*E*	*181.5*	*3.4*
R1N20	*43º22'22"*	*N*	*3º41'44"*	*E*	*104.0*	*22.8*	*R2P20*	*41º27'58"*	*N*	*2º18'37"*	*E*	*127.4*	*16.9*
R1M10	*43º16'40"*	*N*	*3º31'58"*	*E*	*192.8*	*0.0*	*R2O10*	*41º17'11"*	*N*	*2º07'56"*	*E*	*132.8*	*8.4*
R1M20	*43º16'19"*	*N*	*3º32'24"*	*E*	*132.9*	*14.6*	*R2O20*	*41º17'03"*	*N*	*2º08'01"*	*E*	*98.1*	*32.2*
R1L10	*43º15'39"*	*N*	*3º21'49"*	*E*	*133.7*	*1.9*	*R2N10*	*41º14'55"*	*N*	*1º54'23"*	*E*	*156.0*	*1.5*
R1L20	*43º13'55"*	*N*	*3º23'11"*	*E*	*100.2*	*20.9*	*R2N20*	*41º14'19"*	*N*	*1º54'42"*	*E*	*44.8*	*65.0*

French coast campaign							***Spanish coast campaign***						
S. Site	**Latitude**		**Longitude**		**D50 (µm)**	**% of silt-clay**	**S. Site**	**Latitude**		**Longitude**		**D50 (µm)**	**% of silt-clay**
R1K10	*43º11'9''*	*N*	*3º13'26''*	*E*	*158.0*	*0.0*	*R2M10*	*41º12'17''*	*N*	*1º46'02''*	*E*	*108.3*	*6.2*
R1K20	*43º10'33''*	*N*	*3º13'56''*	*E*	*78.9*	*37.0*	*R2M20*	*41º10'50''*	*N*	*1º46'01''*	*E*	*456.9*	*11.7*
R1J10	*43º07'08''*	*N*	*3º09'10''*	*E*	*167.7*	*0.0*	*R2L10*	*41º10'40''*	*N*	*1º33'05''*	*E*	*133.6*	*5.8*
R1J20	*43º06'57''*	*N*	*3º09'26''*	*E*	*125.9*	*15.1*	*R2L20*	*41º10'12''*	*N*	*1º33'38''*	*E*	*67.2*	*45.6*
R1I10	*43º00'03''*	*N*	*3º04'28''*	*E*	*161.8*	*1.7*	*R2K10*	*41º06'39''*	*N*	*1º15'52''*	*E*	*171.7*	*0.0*
R1I20	*43º00'03''*	*N*	*3º04'55''*	*E*	*77.5*	*42.1*	*R2K20*	*41º06'29''*	*N*	*1º16'07''*	*E*	*159.9*	*6.7*
R1H10	*42º55'55''*	*N*	*3º03'40''*	*E*	*157.9*	*6.0*	*R2J20*	*40º52'44''*	*N*	*0º48'44''*	*E*	*196.0*	*25.1*
R1H20	*42º55'55''*	*N*	*3º04'30''*	*E*	*125.3*	*9.5*	*R2H10*	*40º36'02''*	*N*	*0º49'06''*	*E*	*80.7*	*38.4*
R1G10	*42º50'56''*	*N*	*3º03'26''*	*E*	*189.3*	*2.6*	*R2H20*	*40º35'01''*	*N*	*0º50'49''*	*E*	*103.0*	*24.8*
R1G20	*42º50'56''*	*N*	*3º03'54''*	*E*	*97.4*	*23.8*	*R2G10*	*40º30'44''*	*N*	*0º34'50''*	*E*	*27.4*	*80.6*
R1F10	*42º46'44''*	*N*	*3º02'54''*	*E*	*217.2*	*2.4*	*R2G20*	*40º29'22''*	*N*	*0º37'15''*	*E*	*28.2*	*82.3*
R1F20	*42º46'44''*	*N*	*3º03'21''*	*E*	*147.8*	*10.8*	*R2F20*	*40º20'04''*	*N*	*0º26'15''*	*E*	*62.7*	*50.2*
R1E10	*42º43'22''*	*N*	*3º02'50''*	*E*	*211.7*	*3.2*	*R2E10*	*40º09'30''*	*N*	*0º12'47''*	*E*	*127.9*	*5.2*
R1E20	*42º43'26''*	*N*	*3º03'12''*	*E*	*200.3*	*4.4*	*R2E20*	*40º09'06''*	*N*	*0º13'51''*	*E*	*92.6*	*33.8*
R1D10	*42º41'27''*	*N*	*3º02'50''*	*E*	*182.6*	*4.2*	*R2C20*	*39º48'02''*	*N*	*0º03'44''*	*W*	*94.2*	*22.0*
R1D20	*42º41'27''*	*N*	*3º03'14''*	*E*	*163.4*	*8.8*	*R2B10*	*39º39'54''*	*N*	*0º11'42''*	*W*	*132.7*	*3.3*
R1C10	*42º39'03''*	*N*	*3º02'42''*	*E*	*177.4*	*1.6*	*R2B20*	*39º39'25''*	*N*	*0º10'38''*	*W*	*99.6*	*15.2*
R1C20	*42º39'03''*	*N*	*3º03'14''*	*E*	*153.5*	*6.8*	*R2A10*	*39º28'23''*	*N*	*0º18'30''*	*W*	*n.a.*	*n.a.*
R1B10	*42º35'20''*	*N*	*3º03'04''*	*E*	*160.7*	*4.6*	*R2A20*	*39º27'50''*	*N*	*0º16'45''*	*W*	*165.5*	*28.6*
R1B20	*42º35'20''*	*N*	*3º03'41''*	*E*	*91.1*	*25.4*							
R1A10	*42º33'25''*	*N*	*3º03'13''*	*E*	*148.1*	*7.2*							
R1A20	*42º33'25''*	*N*	*3º04'08''*	*E*	*278.2*	*3.4*							

(n.a.) data no aviable

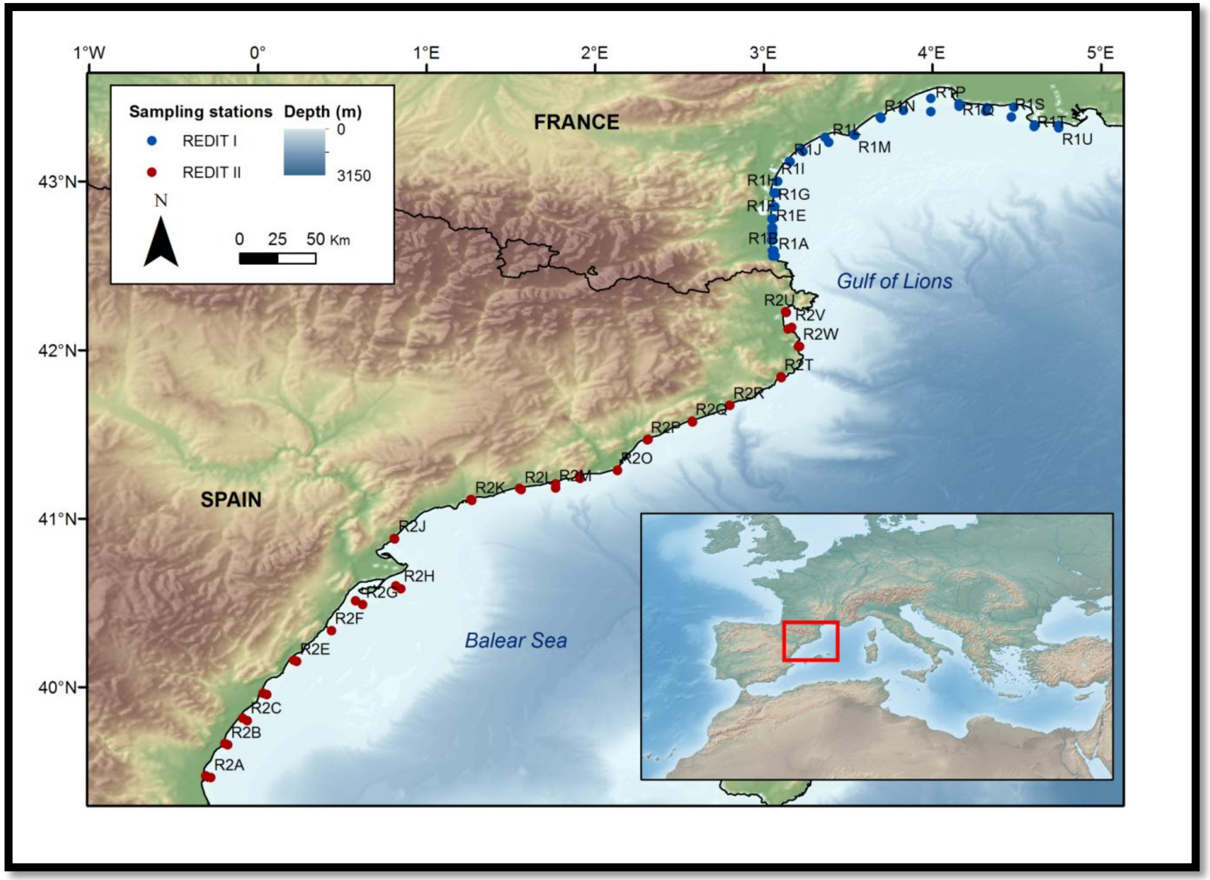


Figure 1. Map of the zone study. The blue circle belongs to sampling stations from Gulf of Lions and red circles from Spain coast.

Sediment samples were collected using a 0.1 m² van Veen grab. At each sampled site, 3 grabs were taken for the analysis of benthic macrofauna, and 1 for granulometric and organic content analyses. Macrofauna samples were immediately sieved on a 1 mm mesh and the fauna retained were fixed in 5% formaldehyde. At the laboratory, samples were sorted and polychaetes were separated from the remaining fauna. Polychaete species were later identified to the lowest practical taxonomic level and counted. Unidentified species were only taken into account when they could not be mistaken for other identified species. Data analyses were carried out on data pooled over the three replicated sampling units (Ellingsen 2001). Individual polychaete species biomass was determined as wet weight to avoid destruction of the collected material except for two nominal species *Ditrupa arietina* and *Owenia fusiformis*. For these two species I used regressions of width vs. dry weight to convert it width measurements to biomass following Sardá *et al.* (1999). Then for *D. arietina* the regression used is:

$$\mathrm{DW}_{Da} = 0.4522\ (d_{Da})^{3.992}$$

where DW_{Da} is dry weight of *D. arietina* in mg and (d_{Da}) is diameter aperture of it tube in mm.

For *Owenia fusiformis* the regression is:

$$\mathrm{DW}_{Of} = 0.8434\ (wt_{Of})^{2.177}$$

where DW_{Of} is dry weight of *O. fusiformis* in mg and (wt_{Of}) is the maximum width of the tube in mm.

A binocular microscope equipped with a camera lucida and digitizing tablet was used for all measurements. For comparative purposes data given in this paper are expressed in dry weight using the conversion factor of dry weight = 17,6% of wet weight calculated for polychaetes (Rumohr *et al.* 1987). Each species was attributed to a feeding guild: (F) filter feeders; (M) mixed (filter and surface-deposit feeders); (S) surface-deposit feeders; (SS) subsurface-deposit feeders; and (C) carnivores/omnivores, using information in (Fauchald and Jumars 1979; Dauvin and Ibanez 1986).

To examine possible physical habitat characteristics that might be correlated with macrofaunal assemblages, several variables were analyzed for each sampling station. Water depth was recorded from the ship echosounder log at the time of sampling. Granulometric analysis was conducted on fresh sediment using a Malvern® Mastersizer 2000 laser microgranulometer.

Data analysis

Analysis of biological data for the classification of polychaetes assemblages was performed on previously reduced sets of species in order to limit the noise introduced by the not so common species (i.e. those presented at least in 8 of 77 sample sites). The elimination of these later species from the analysis was based on general presences on samples sites lower than 10%. Polychaetes assemblages were then elucidated by cluster analysis based on the faunal composition (Bray Curtis similarity, average link grouping). Abundances were square-root transformed to limit the influence of the most dominant taxa. The taxa most responsible for similarities within each cluster of stations on one hand, and for dissimilarities between clusters of stations on the other hand were identified using the SIMPER procedure. All these analyses were carried out using the Primer© 6 software package (version 6.1.13) (Warwick 1986). The relationships between polychaetes distribution and environmental parameters were first assessed by testing for significant correlation between the similarity matrices of polychaetes abundance and (1) depth, (2) silt-clay content using Mantel tests.

Production estimates were obtained based on is biomass data. In order to rank the most important polychaetes contributors to the productivity of the region, we estimated its secondary production using the allometric equation developed by (Brey 1990; Warwick *et al.* 2010):

$$\boldsymbol{P = (B/A)^{0.73} * A}$$

where ***A*** is abundance, ***B*** is biomass, ***B/A*** is mean body size and ***0.73*** is the average exponent of the regression of annual production on body size for macrobenthic invertebrates. The ***P/B*** ratio was also calculated because it could reflect the metabolism and life cycle of species in a particular assemblage. This indirect method is based on the use of empirical relationships allow us yields the secondary production of all species within a community.

Ecological indicators based on diversity were measured through the use of different univariate indices: Species richness, Shannon-Wiener index (*H'),* Margalef index *(d*), and Simpson index (1-λ') were computed using the Primer$^{©}$ 6 software package (version 6.1.13) (Warwick 1986).

RESULTS

Assemblage classification

The species found within the sampled stations included 257 species of polychaetes (Appendix A). On the whole taxa, we found 70 species constant, accessories or accidentals (29%). That means the rest of taxa were considered rare (71%) because there were less than 10% in the study area. The species with the highest frequency of occurrence, were *O. fusiformis* (present in 75% of the samples); *Galathowenia oculata* and *H. bilineata* (73%); *L. latreilli* (69%); *Nephtys hombergii* (68%); *Glycera unicornis* (64%); *D. arietina* (61%); *C. duneri* (60%); *Spiophanes bombyx* (58%); *Nephtys cirrosa* (52%).

Our multivariate classification technique divided the zone into two large groups (clusters) with two clear sub-clusters in the first one (Figure 2). Species composition within these clusters was similar but the three groups were separated based on the density of two most abundant species and its granulometrical composition. These three clusters and sub-clusters structured within three different assemblages of the Littoral Fine Sands Community (LFS) following Labrune et al., (2007).

Sedimentology

The entire group of sampled stations consisted predominantly in fine-medium sands (Wentworth 1922), with a mean D50 µm (150.91 ± 65.67) and a mean value of fraction < 63 µm in percentage was 17.96 ± 21.56. Cluster I showed a mean of D50 µm of 142.90 ± 89.70 with a mean value of the fraction < 63 µm in percentage of 20.40 ± 22.40. The ANOSIM analyses show us differences between two *subclusters (1-A* and *1-B)* (Goblal R: 0.19, $p < 0.001$).The variation in *sublcluster (1-A* and *1-B)* was over the fraction < 63 µm because the percentage was the double in *sublcluster1-B* (32.0 ± 24.6) than *sublcluster 1-A* (15.2 ± 19.7). On the other hand, in Cluster II the D50 µm was calculated to be 219.20 ± 134.60, and the mean value of fraction < 63 µm in percentage was in this case much lower 2.40 ± 2.50, and no subclusters were identified. The ANOSIM analysis show us also differences between the deep on the overall analyzed zone (Goblal R: 0.11, $p < 0.001$) because at 10 m deep the mean of D50 µm was (159.93 ± 81.88) and the mean value of fraction < 63 µm in percentage was 8.06 ± 19.94, while at 20 m deep it was (139.33 ± 107.95) and the mean value of fraction < 63 µm in percentage was 26.21 ± 21.69.

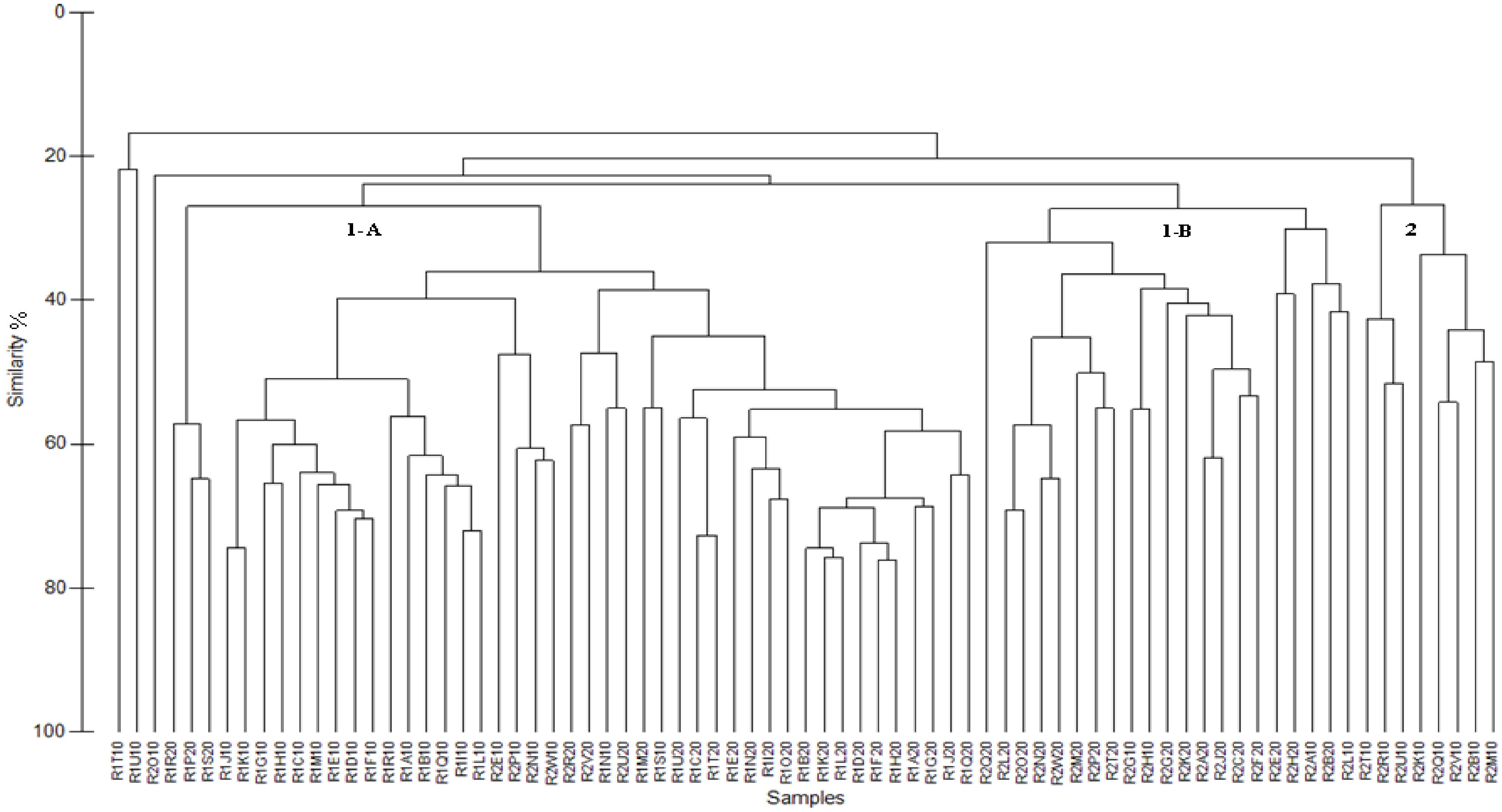


Figure 2. Dendrogram for hierarchical clustering of the all 77 sampling sites in the area.

Community structure

There was a mean density in overall zone of 814 ± 798 ind. m^{-2} of polychaetes belonging 257 taxa with a total mean biomass 1.02 ± 1.73 g dry wt. m^{-2} (Figure 5-c). The most abundant species were *Ditrupa arietina* (266 ± 663 ind. m^{-2} and 0.37 ± 1.44 g dry wt. m^{-2}) and *Owenia fusiformis* (141 ± 308 ind. m^{-2} and 0.35 ± 1.04 g dry wt. m^{-2}), whose densities were 50% (33% and 17% respectively) and biomass were 69% (35% and 34% respectively) of whole polychaetes fauna. These taxa were followed by *Hyalinoecia bilineata* (29 ± 40 ind. m^{-2} and 0.02 ± 0.04 g dry wt. m^{-2}) 4% of density and 2% of biomass, *Lumbrineris latreilli* (22 ± 36 ind. m^{-2} and 0.02 ± 0.06 g dry wt. m^{-2}) and *Chone duneri* (22 ± 40 ind. m^{-2} and 0.01 ± 0.02 g dry wt. m^{-2}) both of them with 3% of density and 2 and 1% of biomass respectively. The rest of polychaetes had less than 2% of abundance left (Appendix A).The diversity of polychaete species assemblages in our study was larger in the REDIT-2 regional area than in the REDIT-1 one. If we plotted the accumulative curves of the number of individuals vs number of species for both REDIT campaigns (Figure 3a) we can see how abundances were larger in the REDIT-1 campaign; however this is just due to the important presence of the two more abundant species (*D. arietina* and *O. fusiformis*), if we take out of the analysis these two species (Figure 3b), then the number of individuals is smaller in REDIT-1 than REDIT-2.

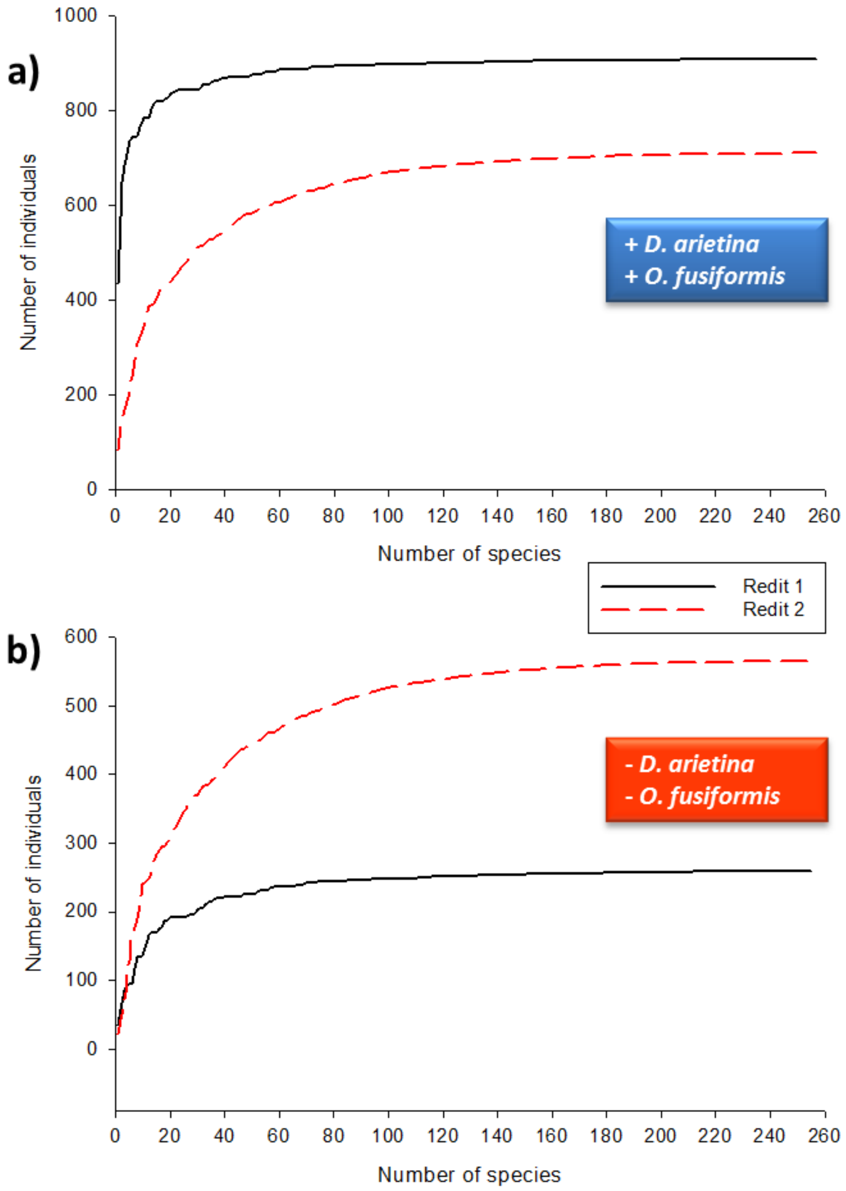


Figure 3. Cumulative curves of the number of individual vs number of species in both coast (France and Spain). a) Plot with all species founded. b) Plot without *D. arietina* and *O. fusiformis*

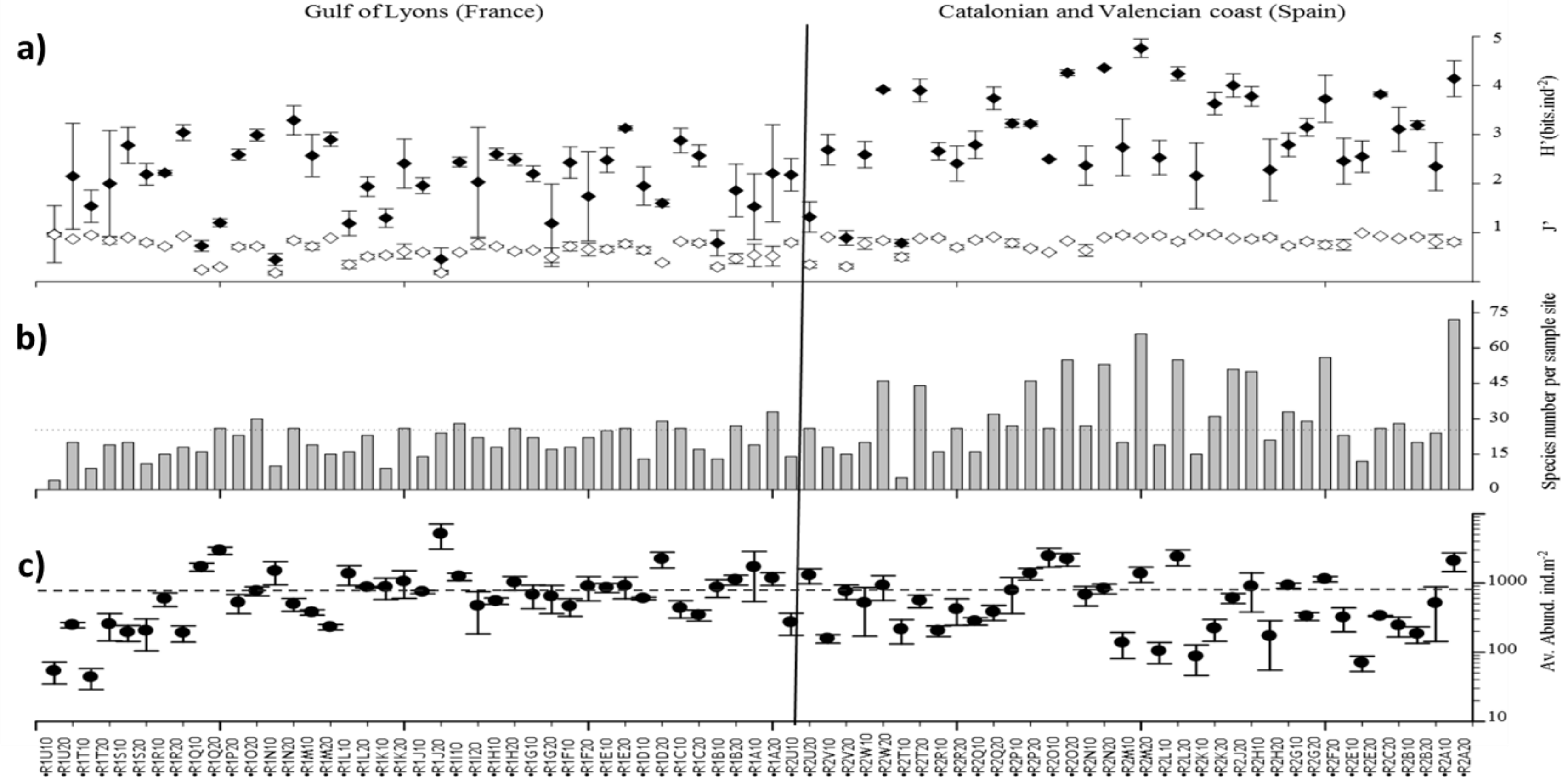


Figure 4. Range of distribution of all species found in the zone. a) Av. Abundance (ind. m^{-2}). b) Species richnees per sampling site. c) Shannon diversity H' (bit. ind^{-1}).

The sampling station the highest richness was R2A20 (72 ssp.) located near Valencia port in Spain and the lowest was R1U10 (4 ssp.) located near the Rhone river (Figure 4-b). The most abundant sampling station was R1J20 (5103 ± 3451 ind. m^{-2}) which the most contributor was *D. arietina* (4770 ± 3163 ind. m^{-2}) and the lowest R1T10 (43 ind. m^{-2}) (Figure 4-c). The highest *D. arietina* biomass was found in R1Q20 (11.88 ± 7.46 g dry wt. m^{-2}) (Figure 5-b) and the highest *O. fusiformis* biomass (6.37 ± 3.53 g dry wt. m^{-2}) was found in R1L10 (Figure 5-a).

The biggest cluster observed in the analysis grouped 66 stations and it has two sub-clusters that we named *1-A* and *1-B.* The sub-cluster *1-A* has 45 stations, principally located to the Gulf of Lions and out of these 6 were north zone Spain coast, exception R2E10 which was located southern in Torre Nostra (Valencia). The sub-cluster *1-B* has 21 stations; most of these principally located at 20 m deep from Spain coast a few of them at 10 m deep (R2G10, R2H10, R2L10 AND R2A10). This cluster 1 contained 69 species that were considered constant, accessories or accidentals. Average mean sand grain size composition for both clusters is 170 and 155 µm respectively for sub-cluster *1-A* and *1-B* respectively. The main difference between both subclusters is the large densities observed for the two most abundant species (*Ditrupa arietina* and *Owenia fusiformis*) in subcluster *1-A* when compared with subcluster *1-B*. This caused that the averages abundances of all species in these two subclusters totaled 911 ind. m^{-2} and 835 ind. m^{-2}, respectively. The species composition for the most abundant species can be seen in Table 4.

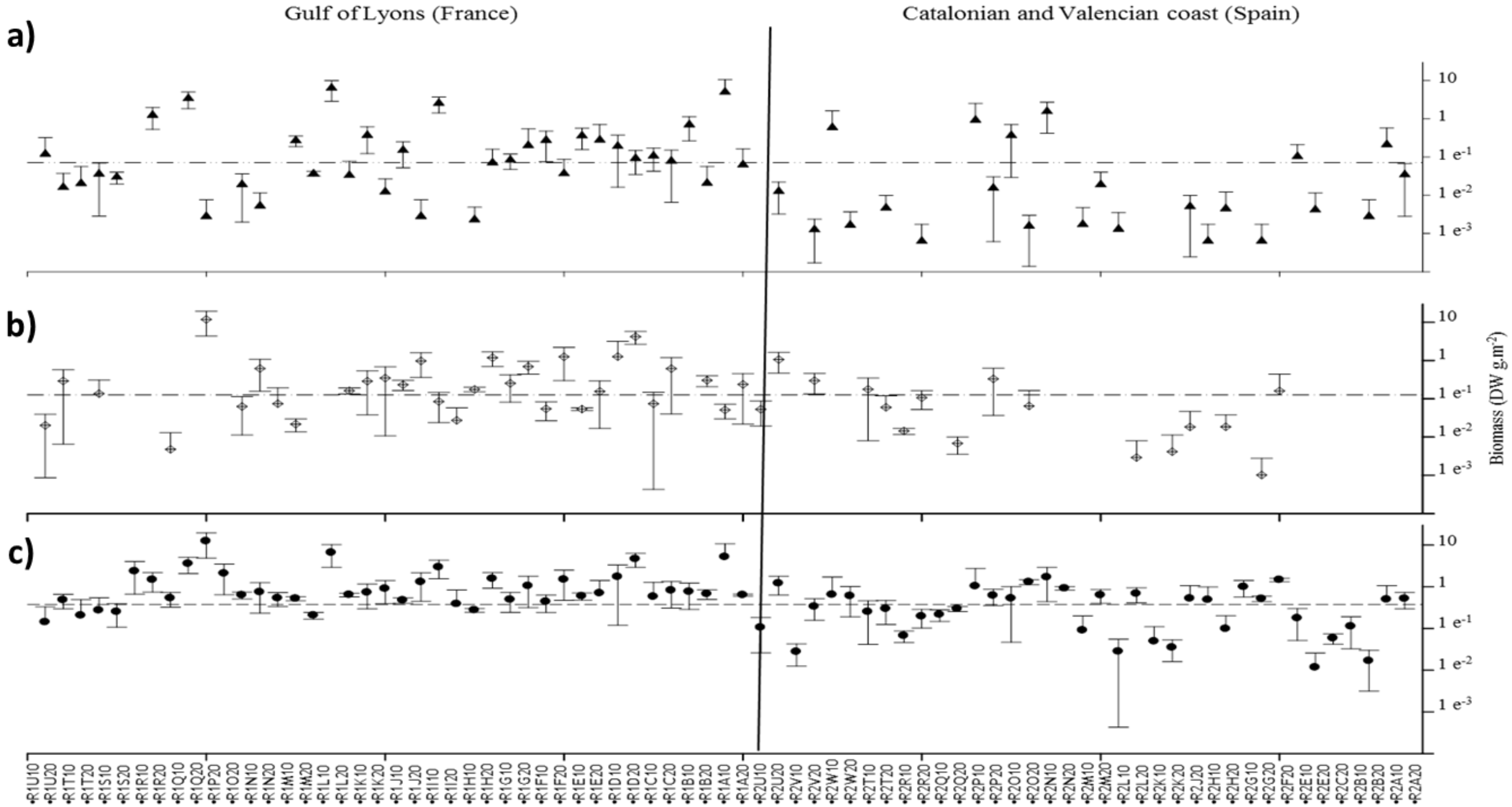


Figure 5. Biomass plot in dry weight gm^2. a) *O. fusiformis* biomass. b). *D. arietina* biomass c) Biomass of all species found.

The second cluster (2) has eight stations all of these from the Spanish coast (R2B10, R2K10, R2M10, R2Q10, R2R10, R2T10, R2U10 and R2V10). Only there were 3 stations left from these clusters, R1T10 and R1U10 which had very low taxa (Labrune *et al.* 2007) in the Gulf of Lions, and another one (R2O10) was located near Llobregat mouth river in Spain coast. In this case, this cluster contained only 33 species that were considered constant, accessories or accidentals. These samples contain a significant larger amount of grain size in its sediment composition averaging 226 µm. The species composition for the most abundant species can be seen in Table 3.

The diversity in general was moderately to low, it ranked between *H'* 0.45 to 4.76 bits.ind^{-2}, in addition *J'* indicated that species were unbalanced distributed. Exceptions were some sampling station, where the highest diversity was obtained from 20 m deep in Spain coast within sub-cluster *1-B*. On the other hand almost the lowest from Gulf of Lions (France coast) (Figure 4-a). Average values and standard deviations of the different computed univariate indices [average abundance, Shannon-Wiener index (*H'),* Margalef index *(d*), and Simpson index (1-λ')] of diversity within each cluster and subcluster are shown in Table 2.

Table 2. Data of diversity and dominance in the zone.

	Av. Abund. (ind.m^{-2})	**d**	**H'(log2)**	**1-λ'**
Cluster 1	887 ± 796	4 ± 2	3 ± 1	1 ± 0
Sub-cluster 1-A	911 ± 843	3 ± 1	2.4 ± 1	0.6 ± 0.2
Sub-cluster 1-B	835 ± 700	6 ± 2	4.2 ± 0.6	1 ± 0.1
Cluster 2	199 ± 68	3 ± 1	3 ± 1	1 ± 0

Table 3. Contribution and cumulative contribution of the species the most responsible for similarity in the Principal Cluster from Mediterranean coast based on square root transformed species abundances according to the SIMPER analysis; Av. similarity: (*Cluster 1: 20 %; Cluster 2: 22 %*).

Species	**Av. Abund.**	**Av. Biom.**	**Contribution %**	**Cumulative contribution %**	**Cluster 1**
	(ind-m-2)	(dry wt m2)			
Ditrupa arietina	306	0.425	31	31	
Owenia fusiformis	151	0.398	19	50	
Hyalinoecia bilineata	33	0.025	8	58	
Lumbrineris latreilli	25	0.024	6	64	
Nephtys hombergii	18	0.030	5	68	
Galathowenia oculata	23	0.003	5	73	
Chone duneri	21	0.012	4	77	
Glycera unicornis	12	0.020	3	81	
Lumbrineris impatiens	15	0.006	2	83	
Spiophanes bombyx	8	0.004	2	84	
Notomastus latericeus	20	0.035	2	86	
Nephtys cirrosa	5	0.005	1	87	
Monticellina heterochaeta	21	0.003	1	88	
Glycinde nordmanni	3	0.003	1	89	
Anobothrus gracilis	5	0.003	1	89	
Eunice vittata	5	0.005	1	90	
Melinna palmata	5	0.004	1	91	

Species	**Av. Abund.**	**Av. Biom.**	**Contribution %**	**Cumulative contribution %**	**Cluster 2**
	(ind-m-2)	(dry wt m2)			
Lumbrineris impatiens	38	0.015	33	33	
Paradoneis armata	13	0.001	9	42	
Nephtys cirrosa	8	0.007	8	52	
Ditrupa arietina	30	0.031	8	59	
Magelona mirabilis	9	0.004	7	66	
Sigalion mathildae	4	0.001	5	72	
Hyalinoecia bilineata	6	0.01	4	76	
Glycera alba	7	0	4	80	
Scoloplos (Scoloplos) armiger	2	0	3	83	
Clymenura clypeata	5	0	3	86	
Chone duneri	5	0	2	88	
Chaetozone setosa	1	0	1	89	
Prionospio fallax	2	0	1	91	

Table 4. Contribution and cumulative contribution of the species the most responsible for similarity in *sub-cluster 1-A* and *sub-cluster 1-B* from Mediterranean Sea based on square root transformed species abundances according to the SIMPER analysis; Av. similarity: (*sub-cluster1- A: 28 %; sub-cluster 1-B: 18 %*).

Species	**Av. Abund. (ind-m-2)**	**Av. Biom. (dry wt m2)**	**Contribution %**	**Cumulative contribution %**	**Sub-cluster 1-A**
Ditrupa arietina	428	0.608	38	38	
Owenia fusiformis	217	0.576	26	65	
Hyalinoecia bilineata	33	0.024	5	70	
Chone duneri	27	0.017	5	75	
Nephtys hombergii	17	0.034	5	80	
Glycera unicornis	15	0.016	4	83	
Lumbrineris latreilli	22	0.029	3	86	
Lumbrineris impatiens	21	0.007	3	89	
Galathowenia oculata	12	0.001	2	91	

Species	**Av. Abund. (ind-m-2)**	**Av. Biom. (dry wt m2)**	**Contribution %**	**Cumulative contribution %**	**Sub-cluster 1-B**
Notomastus latericeus	62	0.060	15	15	
Galathowenia oculata	47	0.007	12	26	
Lumbrineris latreilli	31	0.010	11	37	
Hyalinoecia bilineata	32	0.031	9	46	
Monticellina heterochaeta	63	0.007	5	51	
Mediomastus fragilis	42	0.004	4	54	
Ditrupa arietina	46	0.032	3	57	
Spiophanes bombyx	11	0.005	3	60	
Chone collaris	8	0.000	2	62	
Owenia fusiformis	9	0.015	2	65	
Nephtys hombergii	21	0.020	2	67	
Eunice vittata	8	0.006	2	69	
Melinna palmata	9	0.004	1	70	
Pseudopolydora paucibranchiata	17	0.000	1	72	
Spiochaetopterus costarum	9	0.005	1	73	
Clymenura clypeata	8	0.003	1	74	

Lumbrineris nonatoi	14	0.005	1	75
Phyllodoce lineata	4	0.006	1	76
Scoloplos (Scoloplos) armiger	6	0.000	1	77
Glycera unicornis	7	0.003	1	78
Exogone (Exogone) verugera	7	0.000	1	79
Pista cristata	4	0.005	1	80
Lumbrineris gracilis	14	0.006	1	81
Euchone	4	0.000	1	82
Chone duneri	10	0.000	1	82
Aricidea (Aricidea) pseudoarticulata	19	0.009	1	83
Chone arenicola	4	0.001	1	84
Praxillella affinis	7	0.003	1	84
Euclymene robusta	8	0.001	1	85
Glycera alba	7	0.004	1	86
Eunereis longissima	7	0.017	1	86
Magelona minuta	12	0.000	1	87
Euclymene oerstedi	10	0.004	1	87
Spio filicornis	4	0.000	1	88
Chone acustica	10	0.001	1	89
Scoletoma emandibulata mabiti	6	0.006	1	89
Paranaitis kosteriensis	3	0.001	1	90

Trophic composition and estimates of productivity

Based on species feeding guild, the trophic group distribution for the polychaetes species found can be observed in the graphic bars of (Figure 6-a.b). The proportions of (F) filter feeders, (S) surface-deposit feeders and (SS) subsurface-deposit feeders was more or less comparable in both clusters if we see the presence of *O. fusiformis* (M) and *D. arietina* (F) separately, then we can see these later two species are clearly responsible when all data is totaled. Regarding cluster 1 Figure 6-a), the filter-feeder group was the most important one, it was richer in abundance (35%) and biomass (36%) and its most important contributor was *D. arietina* (65% of the entire F group). This group was followed by the mixed group (M), in this case the percentage of presence also was also lower (6%) than others group, and abundance (23%) and biomass (35%), its main contributor was *O. fusiformis (*82% of the entire M group). Conversely, the cluster *2* (Figure 6-b) had the same pattern corresponding to species number of carnivores/omnivores (C) group; but the mainly difference was linking with abundance (48%) and biomass (54%) because them were in agreement to species number. However, the (M) group had poor species number (9%), abundance (5%) and biomass (2%). The mainly different were in the proportions about (C) and (M) group i.e., even though in both of cluster carnivores/omnivores (C) group look alike in presence (38% in cluster 1, 40% in cluster 2) it abundance and biomass was less important in cluster 1 (20 and 18% respectively) than cluster 2 (48 and 54% respectively), while (M) group had a presence (6% in cluster 1, 9% in cluster 2) it abundance and biomass was more important in cluster 1 (23 and 35% respectively) than cluster 2 (5 and 2% respectively).

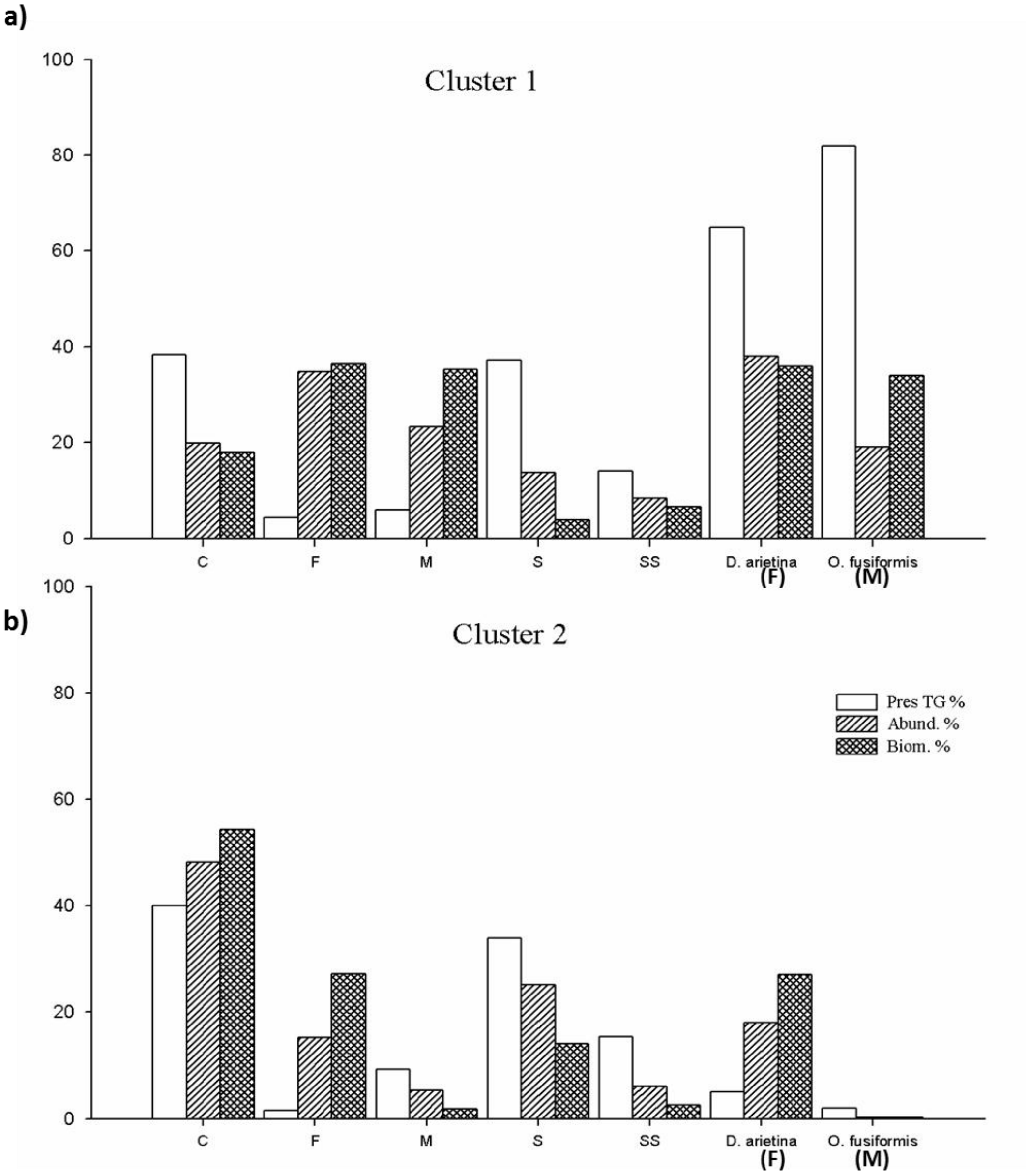


Figure 6. Trophic guild distribution in both clusters. a) Cluster 1. b) Cluster 2.

The mean secondary production in the whole zone was computed as (5.73 g dry wt. $m^{-2}y^{-1}$). It was clearly highest in Cluster *1* (6.59 g dry wt. $m^{-2}y^{-1}$) than in Cluster *2* (0.10 g dry wt. $m^{-2}y^{-1}$). By trophic group in overall zone the (F) group was the most productive (4.24 g dry wt. $m^{-2}y^{-1}$), it was following by (M) group (3.71 g dry wt. $m^{-2}y^{-1}$), (C) group (2.03 g dry wt. $m^{-2}y^{-1}$), the other two group were SS (0.75 g dry wt. $m^{-2}y^{-1}$) and S group (0.65 g dry wt. $m^{-2}y^{-1}$).

DISCUSSION

Along the littoral sands analyzed from the mouth of the Rhône River to the vicinity of Valencia City, three natural species assemblages were distinguished related to grain size and the increased presence of two polychete species (*D. arietina* and *O. fusiformis*). The three assemblages found in this study, belong to the Littoral Fine Sands community (LFS) according to Labrune *et al.* (2007). Littoral sands of the North-western Mediterranean are mostly occupied by the LFS community due to the predominant presence of fine to medium sediments in its soft-bottom infralittoral (Wentworth 1922). In specific places where coarse sand sediments are dominant, near rocky shores as the Cap de Creus (Sardá *et al.* 2012) or highly dynamic deltas as the Tordera one (Sardá *et al.* 1999), the LFS community is replace by the Littoral Coarse Sands community (LCS). LFS and LCS are the two basic communities that can be described.

Even though Mediterranean has been considered an oligotrophic Sea (Margalef 1985) due to negative balance with Atlantic sea, Atlantic sea obtains nutrient inputs from deep water of Mediterranean while it lasted receives poor nutrient surfaces water from Atlantic sea (Lloret *et al.* 2001; Salat *et al.* 2011). For this reason, local events such as wind-driven mixing and river discharges can have an important role on its local fertilization (Estrada 1996; Estrada *et al.* 1999). In the North-western Mediterranean, there are only small freshwater discharges caused by episodic stormy rain flow through otherwise dry rivers. However, long stretches of coastline are fertilized only by the discharge of mostly treated but nutrient-rich urban and industrial effluents. Exceptions to this rule are estuarine areas receiving the discharges of the large rivers, Rhone and Ebro collecting the runoff from snow-covered mountain ranges (Alps, Pyrenees) and wastewater from large cities and intensive agricultural and industrial activities (Cruzado *et al.* 2002). The linkage between river runoff (Salen-Picard and Arlhac 2002; Salen-Picard *et al.* 2003; Darnaude *et al.* 2004; Hermand *et al.* 2008) or wastewater discharges

(Cardell *et al.* 1999; Serrano *et al.* 2011) on macroinfaunal assemblages and coastal fishery yields trough trophic webs has also been well recorded.

Those processes also could help to maintain mostly well sorted fine sand bottom like found by (Guille 1970; Desbruyères *et al.* 1972-73; Labrune *et al.* 2007) and found in this study alongside the Mediterranean French and the Northern Mediterranean Spanish coast, because almost sampling sites had mainly fine sand. Palanques Palanques *et al.* (2009) point out that the maximum near-bottom sediment fluxes are associated with storm events and strong wind-induced currents, as well as sediment resuspension is mainly produced on the inner shelf by the action of waves, especially during storms in the Ebro delta river as well as Ulses *et al.* (2008) reported in Gulf of Lions. Even though Arnau *et al.* (2004), shows us that flood events lead to the formation of sediment plumes off river mouths which play a major role in the overall water and sediment discharge and, consequently, in the development of prodeltaic bodies and their fine-grained extensions alongshore, towards the continental shelf, and beyond.

The three assemblages found for the LFS community in this work can be distinguished by the disproportionate presence of two polychaete species and its average grain size. A small proportion of stations were isolated by a higher grain size due to shallower depths in open environments. Most of the other stations (10 and 20 m) were located in fine sands sediments but, in this case, some of them, were highly influenced by the large presence of individuals of two species (*D. arietina* and *O. fusiformis*). Large densities of single polychaete species in soft-bottom environments are frequent in two basic conditions; in the response of assemblages to stressors such as organic enrichment (e.g. *Capitella capitata* in the Barcelona region, Cardell et al., 1999), or in recruitment periods (Sardá et al., 1999). In the North-western Mediterranean, recruitment periods for soft-bottom polychaetes species take place in late winter-early spring while in the periods sampled during this study no recruits are seen in the bottoms. This could be an indication that such high numbers of these two species are as a response of some type of pressure. The presence in high numbers of these two species reduced deeply the diversity of the assemblage in which this occurs.

Peres and Picard (1957) pointed out *D. arietina* was associated to instable soft sediment and Desbruyères *et al.* (1972-73) considered it as accompanist specie of *N. hombergii* community after the tenth rank. However, Grémare *et al.* (1998); Grémare *et al.* (1998); Labrune *et al.* (2007) found an augment of *D. arietina* population, they attributed the highest densities as response as environmental factors. Sarda *et al.* (2000) also reported increase sharply after dredging activities in Catalonian coast as density as biomass on both of two species (i.e. *D. arietina* and *O. fusiformis*). In this study *D. arietina* was a third part of whole density, that means this specie was an important population within faunal polychaetes community structure mainly 20 m deep, this fact was similar to found by Medernach *et al.* (2000), they indicated *D. arietina* maximal density was associated to 20-25 m deep. It also was comparable in sense of this specie was more frequent in French coast than Spanish coast.

O. fusiformis seem to be a population more steady and frequent historically, in this sense Guille (1970); Desbruyères *et al.* (1972-73) reported it in the most stratus in Northwestern Mediterranean (e.g. since well sorted fine sand 5 m deep until detritus sediment 163 m deep). This specie also has considered a common species in the littoral and infralittoral muddy sand communities from the northeastern European seas (Gentil *et al.* 1990; Ménard *et al.* 1990). As I pointed out above, this specie is the second more important specie in Levantine-balear coast, even though *D. arietina* density is a double than *O. fusiformis*, in biomass both of them gathered over two of third whole faunal biomass. This could be for the reason that *O. fusiformis* has a longer cycle life 3-4 yrs (Ménard *et al.* 1989; Gentil *et al.* 1990) than *D. arietina* 1-2 yrs (Medernach 2000). Desbruyères *et al.* (1972-73) also pointed out maximal densities and biomass of *O. fusiformis* at 10 m deep on fine sand populations as 3916 ind. m^{-2} and biomass 2.028 g dry wt. m^{-2}. Although in our work *O. fusiformis* was found over 75% from sample sites, the average density was 141 ± 308 ind. m^{-2} and average biomass was 0.35 ± 1.04 g dry wt. m^{-2} that situation could be lower than reported by these authors due to in Northwestern Mediterranean this specie is more stable.

The highest richness found near to Valencia port could be due to there is an important transport of nutrient from coastal zone produced from river runoff outwards western. In this sense Arnau *et al.* (2004) point out once the water carried by the river flood enters the sea and the suspensate plume starts to form, its spreading and dispersal are dependent on the oceanic circulation linking features such as gyres, meanders, filaments, and fronts from tens to a few hundred kilometers in size and from days to months in duration. Estrada (1996) reported that Western Mediterranean also presents a series of mesoscale structures as the shelf-slope fronts along the continental and insular coasts and the central divergence zones of the Liguro-Provençal and Catalano-Balearic Seas which seem to be parts of a continuum.

The principal cluster shows that the French coast (10 and 20 m deep) and the samples sites in the Spanish coast (20 m deep) were more resemblance than sampling sites of Spanish coast 10 m deep. It could be linked to reported by (Cruzado *et al.* 2002) about of the wide shelf coastal areas, internal nutrient fluxes are often controlled by biological regeneration, mostly in surface sediments. Conversely, in the narrow-shelf coastal environments the relatively strong longshore currents and density fronts control the internal nutrient fluxes mainly by interaction of currents with bottom topography. Estrada *et al.* (1999) also indicated that smaller scale physical processes like winds storms or mesoscale eddies also may induce local nutrient enrichment, even though this enrichment are difficult to detect, but may generate important changes in the phytoplankton community structure and productivity. Then the similarities found in our study could be associated to these processes.

Following the rules of MSFD, here I tried to elucidate the composition of manly assemblages in the northwestern Mediterranean Sea. However it necessary more studies in dynamical of specie *D. arietina*, because it recently arise of *D. arietina* could be associated to other factors no considered in this survey.

ACKNOWLEDGEMENTS

This research was supported by the project REDIT II, and by doctoral fellowship from IFARHU-SENACYT (Panama). Also I wish to thank to Gustavo Carreras for his help during weighing of samples.

References

REFERENCES

Afonso-Carrillo, J., S. Pinedo and Y. Elejabeitia (1992). Notes on the benthic marine algae of the Canary islands. Cryptogamie, Algol. 13: 281-290.

Amengual, P., G. Borrás, A. Julía and R. Navarro (1988). Proyecto integrado para el estudio del depósito submarino de lodos de la zona del río Besós sobre la zona costera de Barcelona. Technical report: 4-5.

Arnau, P., C. Liquete and M. Canals (2004). River mouth plume events and their dispersal in the Northwestern Mediterranean Sea. Oceanography-Washington DC-Oceanography Society 17: 22-31.

Arvanitidis, C., G. Bellan, P. Drakopoulos, V. Valavanis, C. Dounas, A. Koukouras and A. Eleftheriou (2002). Seascape biodiversity patterns along the Mediterranean and the Black Sea: lessons from the biogeography of benthic polychaetes. Marine Ecology Progress Series 244: 139-152.

Astraldi, M., S. Balopoulos, J. Candela, J. Font, M. Gacic, G. P. Gasparini, B. Manca, A. Theocharis and J. Tintoré (1999). The role of straits and channels in understanding the characteristics of Mediterranean circulation. Progress In Oceanography 44(1–3): 65-108.

Audouin, J. V. and H. Milne-Edwards (1834). Recherches pour servir a l'histoire naturelle du littoral de la France, ou, Recueil de mémoires sur l'anatomie, la physiologie, la classification et les moeurs des animaux des nos côtes : ouvrage accompagné de planches faites d'après nature / par MM. Audouin et Milne Edwards. Paris :, Crochard, libraire, 1832-1834.

Beesley, P. L., G. J. B. Ross and C. J. Glasby (2000). Polychaetes & allies: the southern synthesis, Csiro.

Bellan, G. and M. Bourcier (1984). Bilan ecologique du detournement permanent d'un petit fleuve côtier dans l'émissaire d'eaux usées d'une grande ville. Marine Environmental Research 12(2): 83-111.

Benke, A. C. (1979). A modification of the Hynes method for estimating secondary production with particular significance for multivoltine populations. Limnology and Oceanography 24(1): 168-171.

Bianchi, C. N. and C. Morri (2000). Marine Biodiversity of the Mediterranean Sea: Situation, Problems and Prospects for Future Research. Marine Pollution Bulletin 40(5): 367-376.

Blake, J. A. and B. Hilbig (1990). Polychaeta from the vicinity of deep-sea hydrothermal vents in the eastern Pacific. II. New species and records from the Juan de Fuca and Explorer Ridge systems.

Borja, A., J. Franco and V. Pérez (2000). A Marine Biotic Index to Establish the Ecological Quality of Soft-Bottom Benthos Within European Estuarine and Coastal Environments. Marine Pollution Bulletin 40(12): 1100-1114.

Borja, A. and J. Mader (2008). Instructions for the use of the AMBI index software (version 4.1). AZTI-Tecnalia: 13 pp.

Borja, A. and I. Muxika (2005). Guidelines for the use of AMBI (AZTI's Marine Biotic Index) in the assessment of the benthic ecological quality. Marine Pollution Bulletin 50(7): 787-789.

Borja, A., I. Muxika and J. Franco (2003). The application of a Marine Biotic Index to different impact sources affecting soft-bottom benthic communities along European coasts. Marine Pollution Bulletin 46(7): 835-845.

Brey, T. (1990). Estimating productivity of macrobenthic invertebrates from biomass and mean individual weight. Archive of fishery and marine research 32: 329-343.

Capaccioni-Azzati, R. (1987). Anélidos Poliquetos de la ensenada de los Alfaques (Delta del Ebro, Mediterráneo Occidental) Doctoral, Universidad de Valencia (Ser. Publ., Num. Ser. 045-5).

Cardell-Corral, M. J. (1996). Estructura y dinámica de la macrofauna bentónica en sedimentos marinos sometidos a vertidos domésticos e industriales : efecto de las aguas y lodos residuales de la planta depuradora de Sant Adrià de Besòs (Barcelonès). PhD Tesis doctoral, Universidad de Barcelona.

Cardell, M. J., R. Sardà and J. Romero (1999). Spatial changes in sublittoral soft-bottom polychaete assemblages due to river inputs and sewage discharges. Acta Oecologica 20(4): 343-351.

Cinar, M. E., T. Katagan, F. Kocak, B. Ozturk, Z. Ergen, A. Kocatas, M. Onen, F. Kirkim, K. Bakir, G. Kurt, E. Dagli, S. Acik, A. r. Dogan and T. Ozcan (2008). Faunal assemblages of the mussel *Mytilus galloprovincialis* in and around Alsancak Harbour (Izmir Bay, eastern Mediterranean) with special emphasis on alien species. Journal of Marine Systems 71(1-2): 1-17.

Clarke, K. R. and R. N. Gorley (2006). PRIMER v6: user manual/tutorial (Plymouth routines in multivariate ecological research). Plymouth, Primer-E Ltd.

Cochrane, S. K. J., D. W. Connor, P. Nilsson, I. Mitchell, J. Reker, J. Franco, V. Valavanis, S. Moncheva, J. Ekebom and K. Nygaard (2010). Marine Strategy Framework Directive.

Colwell, R. K. and J. A. Coddington (1994). Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences 345(1311): 101-118.

Coll, M., I. Palomera, S. Tudela and F. Sard (2006). Trophic flows, ecosystem structure and fishing impacts in the South Catalan Sea, Northwestern Mediterranean. Journal of Marine Systems 59(1-2): 63-96.

Coll, M., C. Piroddi, J. Steenbeek, K. Kaschner, F. B. R. Lasram, J. Aguzzi, E. Ballesteros, C. N. Bianchi, J. Corbera and T. Dailianis (2010). The biodiversity of the Mediterranean Sea: Estimates, patterns, and threats. PLoS One 5(8): e11842.

Cosson-Sarradin, N., M. Sibuet, G. L. J. Paterson and A. Vangriesheim (1998). Polychaete diversity in tropical Atlantic deep-sea sites: environmental effects. Marine Ecology Progress Series 165: 173-185.

Costello, M. J., P. Bouchet, C. S. Emblow and A. Legakis (2006). European marine biodiversity inventory and taxonomic resources: state of the art and gaps in knowledge. Marine Ecology Progress Series 316: 257-268.

Cruzado, A., Z. Velásquez, M. a. d. C. Pérez, N. Bahamón, N. S. Grimaldo and F. Ridolfi (2002). Nutrient fluxes from the Ebro River and subsequent across-shelf dispersion. Continental Shelf Research 22(2): 349-360.

Cuvier, G., W. H. Dall, G. B. Goode, P. A. Latreille, C. L. Laurillard, G. P. Louvet, J. A. Pierron, W. Schaus, W. W. Wood and Library of Congress (1817). Le règne animal distribué d'après son organisation : pour servir de base a l'histoire naturelle des animaux et d'introduction a l'anatomie comparée / par M. le cher. Cuvier ; avec figures, dessinées d'après nature. A Paris :, Chez Déterville :.

Dahlgren, T. G., A. G. Glover, A. Baco and C. R. Smith (2004). Fauna of whale falls: systematics and ecology of a new polychaete (Annelida: Chrysopetalidae) from the deep Pacific Ocean. Deep Sea Research Part I: Oceanographic Research Papers 51(12): 1873-1887.

Dales, R. P. (1977). The polychaete stomodeum and phylogeny. Essays on Polychaetous Annelids in Memory of Dr. Olga Hartman. D. J. Reish and K. Fauchald. Los Angeles, The Allan Hancock Foundation, University of Southern California: 525-546.

Darnaude, A., C. Salen-Picard, N. C. Polunin and M. Harmelin-Vivien (2004). Trophodynamic linkage between river runoff and coastal fishery yield elucidated by stable isotope data in the Gulf of Lions (NW Mediterranean). Oecologia 138(3): 325-332.

Dauvin, J.-C. and F. Ibanez (1986). Variations à long-terme (1977–1985) du peuplement des sables fins de la Pierre Noire (baie de Morlaix, Manche occidentale): analyse statistique de l'évolution structurale. Hydrobiologia 142(1): 171-186.

Dauvin, J. C. (1992). Cinétique du recrutement et croissance des juvéniles d'Owenia fusiformis Delle Chiaje en baie de Seine (Manche orientale). Oceanologica Acta 15(2): 187-196.

Dauvin, J. C. and P. Gillet (1991). Spatio-temporal variability in population structure of Owenia fusiformis Delle Chiaje (Annelida: Polychaeta) from the bay of Seine (eastern English Channel). Journal of Experimental Marine Biology and Ecology 152: 105-122.

Day, J. H. (1967). A monograph on the Polychaetes of Southern Africa. Part 1. Errantia. Trustees of the British Museum (Natural History) 656: 1-656.

Day, J. H. and D. P. Wilson (1934). On the relation of the substratum to the metamorphosis of Scolecolepis fuliginosa (Claparede). Journal of the Marine Biological Association of the United Kingdom 19(2): 655-662.

Desbruyères, D., A. Guille and J. M. Ramos (1972-73). Bionomie benthique du plateau continental de la côte catalane espagnole. Vie Milieu 23(2): 335-363.

Dexter, D. M. (1969). Structure of an intertidal sandy-beach community in North Carolina. Chesapeake Science 10(2): 93-98.

Dexter, D. M. (1992). Sandy Beach Community Structure: The Role of Exposure and Latitude. Journal of Biogeography 19(1): 59-66.

Díaz, R. J. and L. C. Schaffner (1990). The functional role of estuarine benthos. Perspectives on the chesapeake bay. Advances in estuarine sciences. Shesapeake Research consortium, Golucester Pt. K. M. Haire, E. C. Virginia: 25-56.

DIRECTIVE_2008/56/EC (2008). DIRECTIVE 2008/56/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 June 2008. Oficial Journal of the European Union.

Ellingsen, K. E. (2001). Biodiversity of a continental shelf soft-sediment macrobenthos community. Marine Ecology Progress Series.

Ellingsen, K. E. (2002). Soft-sediment benthic biodiversity on the continental shelf in relation to environmental variability. Marine Ecology Progress Series.

Estrada, M. (1996). Primary production in the northwestern Mediterranean. Producción primaria en el Mediterráneo noroccidental.

Estrada, M., R. Varela, J. Salat, A. Cruzado and E. Arias (1999). Spatio-temporal variability of the winter phytoplankton distribution across the Catalan and North Balearic fronts (NW Mediterranean). Journal of Plankton Research 21(1): 1-20.

Fauchald, K. (1977). The polychaete worms. Definitions and keys to the orders, families and genera. Natural History Museum of Los Angeles County. Science Series 28: 1-188.

Fauchald, K. and P. A. Jumars (1979). The diet of worms: A study of polychaete feeding guilds. Oceanography and Marine Biology: An Annual Review 17: 193-284.

Fauchald, K. and G. W. Rouse (1997). Polychaete systematics: Past and present. Zoologica Scripta 26(2): 71-138.

Fauvel, P. (1923). Faune de France. Polychètes Errantes. Faune de France 5: 1-488.

Fauvel, P. (1927). Faune de France. Polychètes Sedentaires. Faune de France 16: 1-475.

Fiege, D., I. Krönche and R. Barnich (2000). High abundance of *Myriochele fragilis* Nilsen & Holthe,1985 (Polychaeta: Oweniidae) in the deep sea of the Eastern Mediterranean. Hydrobiologia 426: 97-103.

Foster, N. (1972). Freshwater polychaetes (Annelida) of North America. Oceanography, Limnology, Program United, States.

Gambi, M. C., A. Castelli, A. Giangrande, D. Prevedelli and R. Zunarelli-Vandini (1994). Polychaetes of commercial and applied interest in Italy: an overview. Mémoires du Muséum National d'Histoire Naturelle, Paris 162: 593-602.

Gambi, M. C. and A. Giangrande (1985). Distribution of feeding guilds of the soft-bottom polychaetes in the gulf of salerno (Tyrrhenian Sea). Rapports de la Commission Internationale pour l'Exploration de la Mer Méditerranéene 29: 237-240.

Gambi, M. C. and A. Giangrande (1986). Distribution of soft-bottom polychaetes in two coastal areas of the Tyrrhenian Sea (Italy): Structural analysis. Estuarine, Coastal and Shelf Science 23(6): 847-862.

Gentil, F., J. C. Dauvin and F. Ménard (1990). Reproductive biology of the Polychaete Owenia fusiformis Delle Chiaje in the Bay of Seine (eastern English Channel). Journal of Experimental Marine Biology and Ecology 142: 13-23.

Gili, J. M., J. D. Ros and F. Pagès (1987). Types of bottoms and benthica cnidaria from the trawling grounds (littoral and bathyal) off Catalonia (ne Spain). Vie et Milieu 37: 85-98.

Glasby, C. and T. Timm (2008). Global diversity of polychaetes (Polychaeta; Annelida) in freshwater. Hydrobiologia 595(1): 107-115.

Glover, A. G., B. Källström, C. R. Smith and T. G. Dahlgren (2005). World-wide whale worms? A new species of *Osedax* from the shallow north Atlantic. Proceedings of the Royal Society B: Biological Sciences 272(1581): 2587-2592.

Grassle, J. F. and N. J. Maciolek (1992). Deep-sea species richness: regional and local diversity estimates from quantitative bottom samples. American Naturalist 139: 313-341.

Gray, J. S. (2000). The measurement of marine species diversity, with an application to the benthic fauna of the Norwegian continental shelf. Journal of Experimental Marine Biology and Ecology 250(1-2): 23-49.

Grémare, A., J.-M. Amouroux, F. Charles, L. Medernach, E. Jordana, C. Nozais, G. Vetion and J.-C. Colomines (1998). Temporal changes in the biochemical composition of particulate organic matter sedimentation in the Bay of Banyuls-sur-Mer. Oceanologica Acta 21(6): 783-792.

Grémare, A., J. M. Amouroux and G. Vétion (1998). Long-term comparison of macrobenthos within the soft bottoms of the Bay of Banyuls-sur-mer (northwestern Mediterranean Sea). Journal of Sea Research 40(3-4): 281-302.

Grémare, A., R. Sardá, L. Medernach, E. Jordana, S. Pinedo, J. M. Amouroux, D. Martin, C. Nozais and F. Charles (1998). On the Dramatic Increase of Ditrupa arietina O.F. Müller (Annelida: Polychaeta) Along Both the French and the Spanish Catalan Coasts. Estuarine, Coastal and Shelf Science 47(4): 447-457.

Guille, A. (1970). Bionomie benthique du plateau continental de la côte catalane française. II. Les communautés de la macrofaune. Vie Milieu 21(1B): 149-280.

Guille, A. (1971). Bionomie benthique du plateau continental de la côte catalane française. IV. Densités, biomasses et variations saisonnières de la macrofaune. Vie Milieu 22(1B): 93-158.

Guille, A. (1971). Bionomie benthique du plateau continental de la côte catalane française.VI. Donnees autecologiques (Macrofaune). Vie et Milieu XXII: 469-527.

Guillen, J. and A. Palanques (1992). Sediment dynamics and hydrodynamics in the lower course of a river highly regulated by dams: the Ebro river. Sedimentology 39: 567-579.

Hamilton, A. L. and H. B. N. Hynes (1969). On Estimating Annual Production. Limnology and Oceanography 14(5): 771-782.

Harmelin–Vivien, M., D. Banaru, J. Dierking, R. Hermand, Y. Letourneur and C. Salen-Picard (2009). Linking benthic biodiversity to the functioning of coastal ecosystems subjected to river runoff (NW Mediterranean). Animal biodiversity and conservation 32(2): 135-145.

Hartman, O. (1959). Capitellidae and Nereidae (Marine Annelids) from the Gulf Side of Florida, with a Review of Freshwater Nereidae. Bulletin of marine science 9: 153-168.

Hermand, R., C. Salen-Picard, E. Alliot and C. Degiovanni (2008). Macrofaunal density, biomass and composition of estuarine sediments and their relationship to the river plume of the Rhone River (NW Mediterranean). Estuarine, Coastal and Shelf Science 79(3): 367-376.

Hutchings, P. A. (1998). Biodiversity and functioning of polychaetes in benthic sediments. Biodiversity and Conservation 7: 1133-1145.

Hynes, H. B. N. and M. J. Coleman (1968). A simple method of assessing the annual production of stream benthos. Limnology and Oceanography 13(4): 569-573.

INE (2008). Anuario Estadístico de España.

Knox, G. (1977). The role of polychaetes in benthic soft-bottom communities. Essays on Polychaetous Annelids in Memory of Dr. Olga Hartman. Allan Hancock Foundation, Los Angeles: 547-604.

Knox, G. A., D. J. Reish and K. Fauchald (1977). The role of polychaetes in benthic soft-bottom communities. Essays on Polychaetous Annelids in Memory of Dr. Olga Hartman. Los Angeles: 547-604.

Labrune, C., J.-M. Amouroux, R. Sarda, E. Dutrieux, S. Thorin, R. Rosenberg and A. Grémare (2006). Characterization of the ecological quality of the coastal Gulf of Lions (NW Mediterranean). A comparative approach based on three biotic indices. Marine Pollution Bulletin 52(1): 34-47.

Labrune, C., A. Grémare, J.-M. Amouroux, R. Sardá, J. Gil and S. Taboada (2007). Assessment of soft-bottom polychaete assemblages in the Gulf of Lions (NW Mediterranean) based on a mesoscale survey. Estuarine, Coastal and Shelf Science 71(1-2): 133-147.

Labrune, C., A. Grémare, J.-M. Amouroux, R. Sardá, J. Gil and S. Taboada (2007). Structure and diversity of shallow soft-bottom benthic macrofauna in the Gulf of Lions (NW Mediterranean). Helgol. Mar. Res.

Labrune, C., A. Grémare, J.-M. Amouroux, R. Sardá, J. Gil and S. Taboada (2008). Structure and diversity of shallow soft-bottom benthic macrofauna in the Gulf of Lions (NW Mediterranean). Helgoland Marine Research 62(3): 201-214.

Labrune, C., A. Gremare, J. M. Amouroux, R. Sarda, J. Gil and S. Taboada (2006). Diversity of polychaete fauna in the Gulf of Lions (NW Mediterranean). Vie et Milieu 56(4): 315-326.

Lamarck, J. B. M. (1818). Histoire naturelle des animaux sans vertebres, presentant les caracteres generaus et particuliers de ces animaux, leur distribution, leurs classes, leurs families, leurs genres, etla citation des principales especes qui s'y rapportent; precedes d'une Introduction offrant la determination des caracteres essentiels de l'Animal, sa distinction du vegetal et desautres coprs naturels, enfin, l'Exposition des Principes fondamentaux de la Zoologie. Paris, Deterville.

López-Sánchez, J. F., R. Rubio, C. Samitier and G. Rauret (1996). Trace metal partitioning in marine sediments and sludges deposited off the coast of Barcelona (Spain). Water Research 30(1): 153-159.

Lloret, J., J. Lleonart, I. Solé and J.-M. Fromentin (2001). Fluctuations of landings and environmental conditions in the north-western Mediterranean Sea. Fisheries Oceanography 10(1): 33-50.

Mackie, A. S. Y., P. G. Oliver, T. Darbyshire and K. Mortimer (2005). Shallow marine benthic invertebrates of the Seychelles Plateau: high diversity in a tropical oligotrophic environment. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 363(1826): 203-228.

Mackie, A. S. Y., C. Parmiter and L. K. Y. Tong (1997). Distribution and Diversity of Polychaeta in the Southern Irish Sea. Bulletin of marine science 60: 467-481.

Magurran, A. E. (2004). Measuring biological diversity.

Malanotte-Rizzoli, P. (2001). Currents Systems In The Mediterranean Sea. Encyclopedia of Ocean Sciences. J. H. Steele. Oxford, Academic Press**:** 605-612.

Margalef, R. (1985). Introduction to the Mediterranean. Key environments: Western Mediterranean. R. Margalef. London, Pergamon Press**:** 1-16.

Martin, D., C. Alós and R. Sardá (1990). *Miscellania dentata* gen. et sp. nov. (Polychaeta, Syllydae) from the Spanish Mediterranean coast. Zoologica Scripta 19: 169-172.

Martin, D. and T. A. Britayev (1998). Symbiotic polychaetes: Review of known species. Oceanography and Marine Biology - an Annual Review 36: 217-340.

Martin, D., C. Le Nourichel, M. J. Uriz, M. Bhaud and C. Duchêne (2000). Ontogenic shifts in chemical defences in the NW Mediterranean *Eupolymnia nebulosa* (Polychaeta, Terebellidae). In: Proceedings of the VI International Polychaete Conference. Bulletin of marine science 67(1): 287-298.

Massé, H. (1972). Quantitative investigations of sand-bottom macrofauna along the Mediterranean north-west coast. Marine Biology 15(3): 209-220.

Mazouni, N., J. Gaertner and J. M. Deslous-Paoli (2001). Composition of biofouling communities on suspended oyster cultures: an in situ study of their interactions with the water column. Marine Ecology Progress Series 214: 93-102.

McHugh, D. (2000). Molecular phylogeny of the Annelida. Canadian Journal of Zoology 78(11): 1873-1884.

Medernach, L., E. Jordana, A. Grémane, C. Nozais, F. Charles & J. M. Amoroux (2000). Population dynamcis, secondary production and calcification in a Mediterranean population of *Ditrupa arietina* (Annelida: Polychaeta). Marine Ecology Progress Series 199: 171-184.

Medernach, L., E. Jordana, A. Grémare, C. Nozais, F. Charles and J. M. Amouroux (2000). Ditrupa arietina (Annelida: Polychaeta). Marine Ecology Progress Series 199: 171-184.

Ménard, F., F. Gentil and J.-C. Dauvin (1990). Population dynamics and secondary production of Owenia fusiformis Delle Chiaje (Polychaeta) from the Bay of Seine (eastern English Channel). Journal of Experimental Marine Biology and Ecology 133(3): 151-167.

Ménard, F., F. Gentil and J. C. Dauvin (1989). Population dynamics and secondary production of Owenia fusiformis Delle Chiaje (Polychaeta) from the Bay of Seine (eastern English Channel). Journal of Experimental Marine Biology and Ecology 133: 151-167.

Méndez, N., J. Romero and J. Flos (1997). Population dynamics and production of the polychaete Capitella capitata in the littoral zone of Barcelona (Spain, NW Mediterranean). Journal of Experimental Marine Biology and Ecology 218(2): 263-284.

Méndez, N. C.-C., M. J. (1996). Littoral annelid polychaetes inhabiting soft bottoms of the Barcelonès (Catalonia, NE Spain). Miscel·lània Zoològica [en línia] 19(1): 119-147.

Menzie, C. A. (1980). A Note on the Hynes Method of Estimating Secondary Production. Limnology and Oceanography 25(4): 770-773.

Millot, C. (1989). La circulation générale en Méditerranée occidentale : Aperçu de nos connaissances et projets d'études. Annales de Géographie: 497-515.

Millot, C. (1999). Circulation in the Western Mediterranean Sea. Journal of Marine Systems 20(1-4): 423-442.

Nicolaidou, A. and K. N. Papadopoulou (1989). Factors affecting the distribution and diversity of polychaetes in Ambrakikos Bay, Greece. P.S.Z.N. I: Marine Ecology 10(3): 193-204.

Núñez, J., R. Riera, M. C. Brito and M. Pascual (2001). Anélidos Poliquetos intersticiales recolectados en las Islas Salvajes. Vieraea. Santa Cruz de Tenerife 29: 29-46.

Olive, P. J. W. (1994). Polychaeta as a world resource: a review of exploitation as a sea angling baits, and the potential for aquaculture based production. Mémoires du Muséum National d'Histoire Naturelle, Paris 162: 603-610.

Olsgard, F., T. Brattegard and T. Holthe (2003). Polychaetes as surrogates for marine biodiversity: lower taxonomic resolution and indicator groups. Biodiversity and Conservation 12(5): 1033-1049.

Pagliosa, P. R. (2005). Another diet of worms: the applicability of polychaete feeding guilds as a useful conceptual framework and biological variable. P.S.Z.N. I: Marine Ecology 26: 246–254.

Palanques, A. and D. E. Drake (1990). Distribution and dispersal of suspended particulate matter on the Ebro continental shelf, northwestern Mediterranean Sea. Marine Geology 95(3-4): 193-206.

Palanques, A., P. Puig, M. Latasa and R. Scharek (2009). Deep sediment transport induced by storms and dense shelf-water cascading in the northwestern Mediterranean basin. Deep Sea Research Part I: Oceanographic Research Papers 56(3): 425-434.

Peres, J. and J. Picard (1957). Note préliminaire sur une communauté benthique récemment mise en évidence: la biocoenose à Dentalium rubescens et Lucina (Miltha) borealis. Rec. Trav. Stat. Mar. Endoume 21: 12.

Pérès, J. M. and J. Picard (1964). Nouveau manuel de bionomie benthique de la mer Méditerranée. Recueil des Travaux de la Station marine d'Endoume 31(47): 5–137.

Pettibone, M. H. (1963). Marine polychaete worms of the New England region. Part 1. Families Aphroditidae through Trochochaetidae. Bulletin of the United States National Museum 227: 1-356.

Pettibone, M. H. (1982). Annelida Synopsis and Classification of Living Organisms. 2: 1-43.

Picard, J. (1965). Recherches qualitatives sur les biocénoses marines des substrats meubles dragables de la région marseillaise (France). Bulletin des recherches et travaux de la station marine d’Endoume, Marseille: 160.

Pinedo, S., R. Sardá, C. Rey and M. Bhaud (2000). Effect of sediment particle size on recruitment of Owenia fusiformis in the Bay of Blanes (NW Mediterranean Sea): an experimental approach to explain field distribution. Marine Ecology Progress Series 203: 205-213.

Quatrefages, A. (1865). Histoire naturelle des annelés marins et d'eau douce. Annélides et géphyriens, Librairie Encyclopédique de Roret.

Robinson, A. R., W. G. Leslie, A. Theocharis and A. Lascaratos (2001). Mediterranean Sea circulation. Ocean Currents: A Derivative of the Encyclopedia of Ocean Sciences: 283.

Ros, J. D., M. J. Cardell, G. Colombo, I. Ferrari, V. U. Ceccherelli and R. Rossi (1992). Seasonal distribution pattern of polychaetes from a heavily polluted coastal area (Barcelona, NE Spain, NW Mediterranean). Marine Eutrophication and Population Dynamics, Olsen & Olsen: 101-110.

Rosenberg, R., S. Agrenius, B. Hellman, H. C. Nilsson and K. Norling (2002). Recovery of marine benthic habitats and fauna in a Swedish fjord following improved oxygen conditions. Marine Ecology Progress Series 234: 43-53.

Rouse, G. C. and F. Pleijel (2001). Polychaetes. New York, Oxford University Press Inc.

Rouse, G. W. and K. Fauchald (1995). The articulation of annelids. Zoologica Scripta 24(4): 269-301.

Rouse, G. W. and K. Fauchald (1997). Cladistics and polychaetes. Zoologica Scripta 26(2): 139-204.

Rousset, V., F. Pleijel, G. W. Rouse, C. Erséus and M. E. Siddall (2007). A molecular phylogeny of annelids. Cladistics 23(1): 41-63.

Rumohr, H., T. Brey and S. Ankar (1987). A compilation of biometric conversion factors for benthic invertebrates of the Baltic Sea. Baltic Mar. Biol. Publ 9: 1-56.

Salat, J., I. Palomar, J. Lloret and I. Solé (2011). Impacto de los aportes fluviales sobre la productividad de la población de anchoa del sur de Cataluña. VII Congreso Ibérico sobre Gestión y Planificación del agua "Ríos Ibéricos + 10. Mirando al futuro tras 10 años de DMA". Talavera de la Reina.

Salen-Picard, C. and D. Arlhac (2002). Long-term changes in a Mediterranean benthic community: Relationships between the polychaete assemblages and hydrological variations of the Rhône River. Estuaries and Coasts 25(6): 1121-1130.

Salen-Picard, C., D. Arlhac and E. Alliot (2003). Responses of a Mediterranean soft bottom community to short-term (1993-1996) hydrological changes in the Rhone river. Marine Environmental Research 55(5): 409-427.

Salen-Picard, C., A. Darnaude, D. Arlhac and M. Harmelin-Vivien (2002). Fluctuations of macrobenthic populations: a link between climate-driven river run-off and sole fishery yields in the Gulf of Lions. Oecologia 133(3): 380-388.

Sardá, R. (2001). Shoreline development on the Spanish Coast: problem identification and solutions. Science and Integrated Coastal Management. Dhalem University Press, Berlin: 149-163.

Sarda, R., C. Avila and J. Mora (2005). A methodological approach to be used in integrated coastal zone management processes: the case of the Catalan Coast (Catalonia, Spain). Estuarine, Coastal and Shelf Science 62(3): 427-439.

Sardá, R., D. Martin, S. Pinedo, A. Dueso, M. J. Cardell and A. Nicolaidou (1995). Seasonal dynamics of shallow-water benthic communities in the Western Mediterranean. The biology and ecology of shallow coastal waters. Fredensborg, Olssen & Olssen: 191-198.

Sarda, R., S. Pinedo, A. Gremare and S. Taboada (2000). Changes in the dynamics of shallow sandy-bottom assemblages due to sand extraction in the Catalan Western Mediterranean Sea. ICES J. Mar. Sci. 57(5): 1446-1453.

Sardá, R., S. Pinedo and D. Martin (1999). Seasonal dynamics of macroinfaunal key species inhabiting shallow bottoms in the Bay of Blanes (NW Mediterranean). Acta Oecologica 20(4): 315-326.

Sardá, R., S. Pinedo and D. Martin (1999). Seasonal dynamics of macroinfaunal key species inhabiting shallow soft-bottoms in the Bay of Blanes (NW Mediterranean). Acta Oecologica 20(4): 315-326.

Sardá, R., S. Rossi, X. Martí and J. M. Gili (2012). Marine benthic cartography of the Cap de Creus (NE Catalan Coast, Mediterranean Sea). Scientia marina 76(1).

Serrano, L. G., M. J. Cardell, J. P. Lozoya and R. Sardá (2011). A polychaete-dominated community in the NW Mediterranean Sea, 20 years after cessation of sewage discharges. Italian Journal of Zoology: 1-14.

Smith, C. R. and A. R. Baco (2003). Ecology of whale falls at the deep-sea floor. Oceanography and Marine Biology 41: 311-354.

Thorpe, J. P., A. M. Solé-Cava and P. C. Watts (2000). Exploited marine invertebrates: genetics and fisheries. Hydrobiologia 420(1): 165-184.

Tolosa, I., J. W. Readman, S. W. Fowler, J. P. Villeneuve, J. Dachs, J. M. Bayona and J. Albaiges (1997). PCBs in the western Mediterranean. Temporal trends and mass balance assessment. Deep Sea Research Part II: Topical Studies in Oceanography 44(3-4): 907-928.

Tsutsumi, H. (1990). Population persistence of Capitella sp. (Polychaeta; Capitellidae) on a mud flat subject to environmental disturbance by organic enrichment. Marine Ecology Progress Series 63: 147-156.

Tsutsumi, H., S. Fukunaga, N. Fujita and M. Sumida (1990). Relationship between growth of Capitella sp. and organic enrichment of the sediment. Marine ecology progress series. Oldendorf 63(2): 157-162.

Ulses, C., C. Estournel, X. Durrieu de Madron and A. Palanques (2008). Suspended sediment transport in the Gulf of Lions (NW Mediterranean): Impact of extreme storms and floods. Continental Shelf Research 28(15): 2048-2070.

Viéitez, J. M., C. Alós, J. Parapar, C. Besteiro, J. Moreira, J. Núñez, A. J. Laborda and G. San Martín (2004). Annelida Polychaeta I. Fauna Iberica., vol. 25. M. A. Ramos, J. Alba, X. Bellés, J. Gosálbez, A. Guerra, E. Macpherson, J. Serrano and J. Templado. Madrid, CSIC. 25: 530.

Warwick, R. M. (1986). A new method for detecting pollution effects on marine macrobenthic communities. Marine Biology 92(4): 557-562.

Warwick, R. M., K. Robert Clarke and P. J. Somerfield (2010). Exploring the marine biotic index (AMBI): variations on a theme by Ángel Borja. Marine Pollution Bulletin 60(4): 554-559.

Watson, G. J., P. Farrell, S. Stanton and L. C. Skidmore (2007). Effects of bait collection on Nereis virens populations and macrofaunal communities in the Solent, UK. Journal of the Marine Biological Association of the United Kingdom 87(3): 703-716.

Wentworth, C. K. (1922). A Scale of Grade and Class Terms for Clastic Sediments. The Journal of Geology 30(5): 377-392.

Westheide, W., D. McHugh, G. Purschke and G. W. Rouse (1999). Systematization of the Annelida: different approaches. Hydrobiologia 402: 291-307.

Williams, D. D. (2004). Review of the Polychaete Genus Namanereis (Nereididae) in the Caribbean Region, with a Record of N. hummelincki from Deep Freshwater Wells on Barbados. Caribbean Journal of Science 40: 401-408.

Wu, R. and P. Shin (1997). Sediment characteristics and colonization of soft-bottom benthos: a field manipulation experiment. Marine Biology 128(3): 475-487.

Yepes, V. and J. Medina (2005). Land use tourism models in Spanish coastal areas. A case study of the Valencia Region. Journal of Coastal Research: 83-88.

Appendix

Monticellina sp.

Appendix A.

Species list from this study with its abundances and biomass in both of campaing Redit I (French coast campaign) and Redit II (Spanish coast campaign). The species list was ordered according to the highest abundances found it.

	French coast campaign		Spanish coast campaign	
Polychaetes Species	**Av. Abun (ind.m^{-2})**	**Biomass (g dry wt m^{-2})**	**Av. Abun (ind.m^{-2})**	**Biomass (g dry wt m^{-2})**
Ditrupa arietina	(435 ± 869)	(0.648 ± 1.959)	(83 ±212)	(0.064 ± 0.186)
Owenia fusiformis	(215 ± 383)	(0.56 ± 1.378)	(62 ±169)	(0.122 ± 0.354)
Hyalinoecia bilineata	(34 ± 46)	(0.026 ± 0.043)	(22 ±32)	(0.018 ± 0.036)
Lumbrineris latreilli	(24 ± 44)	(0.032 ± 0.08)	(21 ±26)	(0.009 ± 0.013)
Chone duneri	(28 ± 33)	(0.019 ± 0.025)	(16 ±46)	(0.002 ± 0.005)
Galathowenia oculata	(8 ± 10)	(0.001 ± 0.003)	(34 ±52)	(0.005 ± 0.009)
Monticellina heterochaeta	(1 ± 3)	(0.001 ± 0.001)	(36 ±100)	(0.004 ± 0.01)
Notomastus latericeus	(1 ± 4)	(0.024 ± 0.154)	(35 ±65)	(0.036 ± 0.068)
Lumbrineris impatiens	(21 ± 34)	(0.007 ± 0.012)	(12 ±24)	(0.006 ± 0.015)
Nephtys hombergii	(18 ± 19)	(0.04 ± 0.041)	(13 ±31)	(0.016 ± 0.033)
Spiochaetopterus costarum	-	-	(26 ±121)	(0.006 ± 0.015)
Mediomastus fragilis	(2 ± 10)	(0.001 ± 0.004)	(24 ±60)	(0.003 ± 0.009)
Glycera unicornis	(16 ± 14)	(0.018 ± 0.024)	(4 ±9)	(0.016 ± 0.038)
Magelona mirabilis	(12 ± 24)	(0.006 ± 0.013)	(2 ±6)	(0.001 ± 0.002)
Spiophanes bombyx	(4 ± 5)	(0.002 ± 0.004)	(11 ±19)	(0.004 ± 0.009)
Pseudopolydora paucibranchiata	-	-	(14 ±34)	(0.001 ± 0.003)
Aricidea (Aricidea) pseudoarticulata	-	-	(11 ±39)	(0.005 ± 0.021)
Nephtys cirrosa	(5 ± 8)	(0.007 ± 0.013)	(5 ±9)	(0.003 ± 0.009)
Melinna palmata	(4 ± 7)	(0.004 ± 0.007)	(5 ±15)	(0.003 ± 0.008)
Anobothrus gracilis	(9 ± 12)	(0.005 ± 0.006)	-	-
Euclymene oerstedi	(2 ± 4)	(0.003 ± 0.009)	(7 ±18)	(0.003 ± 0.01)
Eunice vittata	(3 ± 9)	(0.005 ± 0.009)	(5 ±9)	(0.004 ± 0.009)
Paradoneis armata	(0 ± 1)	(0 ± 0)	(8 ±15)	(0.001 ± 0.001)
Glycera alba	-	-	(8 ±12)	(0.005 ± 0.008)
Lumbrineris nonatoi	(0 ± 2)	(0 ± 0.002)	(8 ±20)	(0.003 ± 0.011)
Trypanosyllis (Trypanosyllis) coeliaca	-	-	(8 ±48)	(0 ± 0)
Lumbrineris gracilis	-	-	(8 ±24)	(0.003 ± 0.011)
Magelona minuta	(0 ± 1)	(0 ± 0)	(7 ±25)	(0 ± 0.001)
Clymenura clypeata	(2 ± 9)	(0.003 ± 0.012)	(6 ±11)	(0.002 ± 0.004)
Hesiospina similis	-	-	(7 ±41)	(0 ± 0.001)
Scoloplos (Scoloplos) armiger	(3 ± 5)	(0.001 ± 0.001)	(4 ±12)	(0 ± 0.001)
Prionospio caspersi	(6 ± 13)	(0.002 ± 0.004)	(0 ±1)	(0 ± 0)
Prionospio fallax	(1 ± 1)	(0 ± 0.001)	(6 ±15)	(0 ± 0.001)
Peresiella clymenoides	-	-	(7 ±34)	(0 ± 0.002)
Laonice bahusiensis	(5 ± 8)	(0.005 ± 0.009)	(1 ±4)	(0 ± 0.001)
Pherusa eruca	(4 ± 7)	(0.004 ± 0.008)	(2 ±4)	(0.002 ± 0.007)
Euclymene santandarensis	-	-	(6 ±30)	(0.003 ± 0.016)

Glycinde nordmanni	(4 ± 5)	(0.003 ± 0.004)	(2 ±4)	(0.001 ± 0.003)
Phyllodoce lineata	(2 ± 3)	(0.003 ± 0.006)	(3 ±5)	(0.004 ± 0.013)
Chone acustica	-	-	(5 ±15)	(0.001 ± 0.003)
Spiophanes kroyeri	(0 ± 1)	(0 ± 0)	(5 ±24)	(0 ± 0.001)
Spio filicornis	(2 ± 3)	(0.001 ± 0.001)	(3 ±8)	(0.001 ± 0.002)
Exogone (Exogone) verugera	-	-	(5 ±9)	(0 ± 0)
Chone collaris	-	-	(5 ±10)	(0 ± 0.001)
Euclymene robusta	(0 ± 1)	(0.001 ± 0.005)	(4 ±14)	(0.008 ± 0.032)
Praxillella affinis	(0 ± 1)	(0 ± 0.002)	(4 ±10)	(0.002 ± 0.005)
Goniada maculata	-	-	(4 ±11)	(0.001 ± 0.004)
Eunereis longissima	-	-	(4 ±11)	(0.01 ± 0.043)
Thelepus setosus	(3 ± 9)	(0.003 ± 0.008)	-	-
Pista cristata	(1 ± 2)	(0 ± 0.001)	(3 ±5)	(0.003 ± 0.007)
Lumbrineris	(0 ± 1)	(0 ± 0.002)	(3 ±11)	(0.001 ± 0.003)
Chone arenicola	-	-	(3 ±7)	(0.001 ± 0.002)
Scoletoma emandibulata mabiti	(0 ± 1)	(0 ± 0)	(3 ±9)	(0.004 ± 0.01)
Sigalion squamosus	(2 ± 4)	(0.004 ± 0.01)	(1 ±3)	(0.001 ± 0.003)
Eumida sanguinea	(3 ± 5)	(0.001 ± 0.002)	(0 ±1)	(0 ± 0)
Chone	-	-	(3 ±12)	(0 ± 0.001)
Minuspio multibranchiata	-	-	(3 ±15)	(0 ± 0.002)
Prionospio cirrifera	-	-	(3 ±12)	(0 ± 0)
Lagis koreni	(2 ± 4)	(0.007 ± 0.013)	(1 ±2)	(0.004 ± 0.014)
Notomastus	(3 ± 5)	(0.007 ± 0.029)	-	-
Levinsenia kantaurensis	-	-	(3 ±10)	(0 ± 0)
Sphaerosyllis taylori	(0 ± 1)	(0 ± 0)	(3 ±14)	(0 ± 0)
Aricidea suecica meridionalis	-	-	(3 ±12)	(0.001 ± 0.002)
Capitella capitata	-	-	(3 ±6)	(0 ± 0)
Polydora ciliata	-	-	(3 ±9)	(0 ± 0.001)
Clymenura tricirrata	-	-	(3 ±10)	(0.001 ± 0.002)
Eumida punctifera	-	-	(2 ±9)	(0 ± 0.001)
Maldanidae	(1 ± 3)	(0.001 ± 0.003)	(1 ±2)	(0 ± 0.002)
Goniada emerita	-	-	(2 ±4)	(0.001 ± 0.003)
Levinsenia gracilis	-	-	(2 ±7)	(0 ± 0.001)
Terebellidae	(2 ± 6)	(0.002 ± 0.008)	(0 ±1)	(0 ± 0)
Mysta picta	(1 ± 3)	(0.003 ± 0.012)	(1 ±2)	(0 ± 0.002)
Euchone	-	-	(2 ±6)	(0 ± 0)
Prionospio banyulensis	-	-	(2 ±10)	(0 ± 0)
Protodorvillea kefersteini	(0 ± 1)	(0 ± 0)	(2 ±8)	(0 ± 0)
Cirriformia filigera	(2 ± 4)	(0.003 ± 0.011)	(0 ±1)	(0 ± 0)
Glycera oxycephala	-	-	(2 ±11)	(0.001 ± 0.006)
Nephtys assimilis	-	-	(2 ±5)	(0.004 ± 0.011)
Paranaitis kosteriensis	-	-	(2 ±4)	(0 ± 0.002)
Sthenelais boa	(1 ± 2)	(0.002 ± 0.006)	(1 ±2)	(0.001 ± 0.002)
Notocirrus scoticus	-	-	(2 ±4)	(0.002 ± 0.005)
Micronephthys stammeri	-	-	(2 ±5)	(0 ± 0)
Amphitrite affinis	-	-	(2 ±6)	(0.001 ± 0.002)

Harmothoe spinifera	-	-	(2 ±6)	(0.001 ± 0.003)
Sigalion mathildae	(0 ± 1)	(0.001 ± 0.004)	(1 ±3)	(0.002 ± 0.004)
Sigambra parva	-	-	(2 ±3)	(0 ± 0)
Euclymene	(0 ± 2)	(0 ± 0.001)	(1 ±5)	(0 ± 0.001)
Chaetozone setosa	(0 ± 1)	(0 ± 0.001)	(1 ±3)	(0 ± 0.001)
Aricidea capensis bansei	-	-	(1 ±6)	(0 ± 0)
Dipolydora coeca	(1 ± 2)	(0.001 ± 0.006)	(1 ±2)	(0 ± 0.001)
Drilonereis filum	-	-	(1 ±3)	(0.005 ± 0.015)
Nematonereis hebes	-	-	(1 ±7)	(0.001 ± 0.005)
Schistomeringos neglecta	-	-	(1 ±6)	(0 ± 0.002)
Nereiphylla rubiginosa	(0 ± 1)	(0 ± 0)	(1 ±5)	(0 ± 0)
Poecilochaetus serpens	(1 ± 2)	(0 ± 0.001)	(1 ±2)	(0 ± 0)
Aricidea	(0 ± 1)	(0 ± 0)	(1 ±5)	(0 ± 0.001)
Onuphis eremita	-	-	(1 ±8)	(0 ± 0.001)
Scolelepis fuliginosa	-	-	(1 ±4)	(0.002 ± 0.011)
Maldane glebifex	-	-	(1 ±6)	(0.004 ± 0.022)
Aonides paucibranchiata	-	-	(1 ±4)	(0 ± 0.001)
Pseudomastus deltaicus	-	-	(1 ±6)	(0 ± 0.002)
Sternaspis scutata	(0 ± 3)	(0.002 ± 0.014)	(1 ±2)	(0.003 ± 0.01)
Pholoe inornata	-	-	(1 ±5)	(0 ± 0)
Pilargis verrucosa	-	-	(1 ±2)	(0 ± 0.001)
Spirobranchus triqueter	(1 ± 5)	(0.001 ± 0.004)	-	-
Polychaeta	-	-	(1 ±3)	(0 ± 0.002)
Nephtys kersivalensis	-	-	(1 ±4)	(0.001 ± 0.003)
Cossura	-	-	(1 ±4)	(0 ± 0)
Pseudomalacoceros tridentata	(0 ± 1)	(0 ± 0)	(1 ±2)	(0 ± 0.002)
Ampharete grubei	-	-	(1 ±2)	(0.001 ± 0.002)
Capitellidae	(0 ± 1)	(0 ± 0)	(1 ±3)	(0.002 ± 0.011)
Capitomastus minima	-	-	(1 ±3)	(0 ± 0)
Hydroides	(1 ± 2)	(0.001 ± 0.003)	(0 ±1)	(0 ± 0)
Ampharetidae	(1 ± 2)	(0 ± 0.001)	(0 ±1)	(0 ± 0)
Chaetozone gibber	-	-	(1 ±2)	(0 ± 0.001)
Paradoneis lyra	(0 ± 1)	(0 ± 0)	(1 ±2)	(0 ± 0)
Polydora	(0 ± 2)	(0 ± 0.001)	(0 ±3)	(0 ± 0)
Marphysa bellii	(0 ± 1)	(0.001 ± 0.005)	(1 ±2)	(0.002 ± 0.011)
Sabellides octocirrata	-	-	(1 ±2)	(0 ± 0)
Syllis garciai	(0 ± 1)	(0 ± 0)	(1 ±3)	(0 ± 0)
Paralacydonia paradoxa	(0 ± 0)	(0 ± 0)	(1 ±2)	(0 ± 0.001)
Pista unibranchia	(1 ± 3)	(0.001 ± 0.003)	(0 ±1)	(0 ± 0.001)
Aricidea suecica	(0 ± 1)	(0 ± 0)	(0 ±2)	(0 ± 0)
Diopatra neapolitana	-	-	(1 ±2)	(0.001 ± 0.002)
Euclymene collaris	-	-	(1 ±3)	(0.002 ± 0.013)
Magelona filiformis	-	-	(1 ±2)	(0 ± 0)
Nephtys incisa	-	-	(1 ±3)	(0.003 ± 0.019)
Scalibregma inflatum	(0 ± 2)	(0.002 ± 0.007)	(0 ±1)	(0 ± 0.002)
Schistomeringos rudolphii	-	-	(1 ±3)	(0 ± 0)

Terebellides stroemi	(0 ± 1)	(0.002 ± 0.007)	(0 ±1)	(0.001 ± 0.004)
Cirratulidae	(0 ± 1)	(0 ± 0)	(0 ±1)	(0 ± 0.002)
Macrochaeta clavicornis	-	-	(1 ±2)	(0 ± 0)
Magelona alleni	-	-	(1 ±3)	(0 ± 0.001)
Nereis	-	-	(1 ±2)	(0 ± 0.002)
Ophiodromus flexuosus	(0 ± 2)	(0 ± 0.001)	(0 ±1)	(0 ± 0)
Parapionosyllis brevicirra	-	-	(1 ±2)	(0 ± 0)
Pectinaria (Amphictene) auricoma	-	-	(1 ±2)	(0.001 ± 0.003)
Polyophthalmus pictus	-	-	(1 ±1)	(0 ± 0)
Prosphaerosyllis campoyi	-	-	(1 ±2)	(0 ± 0)
Gyptis rosea	(0 ± 1)	(0 ± 0)	-	-
Nerinides cantabra	-	-	(0 ±2)	(0 ± 0.001)
Chone longiseta	-	-	(0 ±2)	(0 ± 0)
Cirrophorus	-	-	(0 ±3)	(0 ± 0)
Cirrophorus branchiatus	-	-	(0 ±1)	(0 ± 0)
Euclymene palermitana	-	-	(0 ±2)	(0 ± 0.001)
Harmothoe	(0 ± 1)	(0.001 ± 0.002)	-	-
Mastobranchus	-	-	(0 ±1)	(0 ± 0.001)
Nephtys	(0 ± 1)	(0 ± 0)	(0 ±2)	(0 ± 0)
Nicomache (Loxochona) trispinata	-	-	(0 ±3)	(0 ± 0.002)
Parapionosyllis labronica	(0 ± 0)	(0 ± 0)	(0 ±2)	(0 ± 0)
Pherusa flabellata	(0 ± 1)	(0.001 ± 0.004)	-	-
Phyllodoce laminosa	(0 ± 1)	(0 ± 0.001)	(0 ±1)	(0 ± 0)
Polynoidae	(0 ± 1)	(0 ± 0.001)	-	-
Prionospio malmgreni	-	-	(0 ±3)	(0 ± 0)
Sabellidae	(0 ± 1)	(0 ± 0.001)	-	-
Serpula vermicularis	-	-	(0 ±2)	(0.001 ± 0.005)
Syllis	(0 ± 1)	(0 ± 0)	(0 ±2)	(0 ± 0)
Ancistrosyllis groenlandica	-	-	(0 ±1)	(0 ± 0)
Aonides oxycephala	(0 ± 1)	(0 ± 0)	(0 ±1)	(0 ± 0.001)
Aphelochaeta filiformis	(0 ± 1)	(0 ± 0.002)	(0 ±2)	(0 ± 0.002)
Aricidea cerruti	-	-	(0 ±2)	(0 ± 0)
Chaetozone jubata	-	-	(0 ±1)	(0 ± 0.001)
Glycera gigantea	-	-	(0 ±2)	(0 ± 0.001)
Laeonereis glauca	(0 ± 1)	(0.036 ± 0.23)	(0 ±1)	(0 ± 0)
Magelona	(0 ± 1)	(0 ± 0)	-	-
Pontogenia chrysocoma	-	-	(0 ±2)	(0 ± 0)
Cirratulus cirratus	-	-	(0 ±1)	(0 ± 0.001)
Amphicteis gunneri	-	-	(0 ±1)	(0 ± 0)
Caulleriella alata	-	-	(0 ±1)	(0 ± 0)
Chrysopetalum debile	-	-	(0 ±2)	(0 ± 0)
Euchone pseudolimnicola	-	-	(0 ±1)	(0 ± 0)
Exogone (Parexogone) gambiae	-	-	(0 ±2)	(0 ± 0)
Exogone (Parexogone) hebes	-	-	(0 ±1)	(0 ± 0)
Glycera lapidum	-	-	(0 ±2)	(0.001 ± 0.006)
Lumbrineridae	(0 ± 1)	(0 ± 0.001)	-	-

Lumbrineriopsis paradoxa	(0 ± 0)	(0 ± 0)	(0 ±1)	(0 ± 0)
Nicomache lumbricalis	-	-	(0 ±2)	(0 ± 0)
Ophryotrocha	-	-	(0 ±1)	(0 ± 0)
Phyllodocidae	(0 ± 1)	(0 ± 0)	(0 ±1)	(0 ± 0)
Polycirrus aurantiacus	-	-	(0 ±1)	(0 ± 0.001)
Pseudomystides limbata	(0 ± 2)	(0 ± 0)	-	-
Serpula lobiancoi	-	-	(0 ±1)	(0.001 ± 0.007)
Spio multioculata	-	-	(0 ±2)	(0 ± 0)
Spionidae	(0 ± 1)	(0 ± 0)	(0 ±1)	(0 ± 0)
Sthenelais limicola	-	-	(0 ±1)	(0.001 ± 0.002)
Streblosoma bairdi	(0 ± 1)	(0 ± 0.001)	-	-
Aricidea claudiae	(0 ± 1)	(0 ± 0)	(0 ±1)	(0 ± 0)
Diplocirrus glaucus	-	-	(0 ±1)	(0 ± 0.002)
Euchone rosea	(0 ± 1)	(0 ± 0.001)	-	-
Hesiospina aurantiaca	-	-	(0 ±1)	(0 ± 0)
Heteromastus filiformis	-	-	(0 ±1)	(0 ± 0)
Lipobranchius jeffreysii	-	-	(0 ±1)	(0 ± 0)
Lumbrineris fragilis	-	-	(0 ±1)	(0 ± 0)
Lysidice ninetta	-	-	(0 ±1)	(0 ± 0.001)
Myrianida brachycephala	-	-	(0 ±1)	(0 ± 0)
Myriochele heeri	-	-	(0 ±1)	(0 ± 0)
Nereididae	(0 ± 1)	(0.002 ± 0.011)	-	-
Orbinia latreillii	-	-	(0 ±1)	(0.001 ± 0.005)
Paraonis	(0 ± 1)	(0 ± 0)	-	-
Petaloproctus terricolus	-	-	(0 ±1)	(0.002 ± 0.011)
Phyllodoce	(0 ± 1)	(0 ± 0)	(0 ±1)	(0 ± 0)
Pisione remota	-	-	(0 ±1)	(0 ± 0)
Praxillella gracilis	-	-	(0 ±1)	(0 ± 0)
Praxillella lophoseta	(0 ± 1)	(0 ± 0.001)	(0 ±1)	(0 ± 0)
Prionospio	-	-	(0 ±1)	(0 ± 0)
Prosphaerosyllis	-	-	(0 ±1)	(0 ± 0)
Protula	(0 ± 1)	(0.002 ± 0.015)	-	-
Sabella	(0 ± 1)	(0.001 ± 0.003)	-	-
Sabella discifera	-	-	(0 ±1)	(0 ± 0.002)
Syllis pontxioi	-	-	(0 ±1)	(0 ± 0)
Syllis torquata	-	-	(0 ±1)	(0 ± 0)
Pseudopolydora	(0 ± 1)	(0 ± 0)	-	-
Aglaophamus	(0 ± 1)	(0 ± 0)	-	-
Amage adspersa	(0 ± 1)	(0 ± 0)	-	-
Amphitrite	-	-	(0 ±1)	(0 ± 0)
Amphitrite cirrata	-	-	(0 ±1)	(0 ± 0.002)
Aphelochaeta	-	-	(0 ±1)	(0 ± 0.001)
Aricidea (Acmira) assimilis	-	-	(0 ±1)	(0 ± 0)
Cirriformia	-	-	(0 ±1)	(0 ± 0)
Dorvillea rubrovittata	(0 ± 1)	(0 ± 0)	-	-
Dorvilleidae	-	-	(0 ±1)	(0 ± 0)

Euphrosine foliosa	(0 ± 1)	(0 ± 0)	-	-
Euratella salmacidis	(0 ± 1)	(0 ± 0.002)	-	-
Euthalenessa oculata	-	-	(0 ±1)	(0 ± 0)
Glycera	(0 ± 1)	(0 ± 0)	-	-
Glycera convoluta	-	-	(0 ±1)	(0 ± 0)
Glycera tesselata	-	-	(0 ±1)	(0 ± 0)
Glyceridae	(0 ± 1)	(0.006 ± 0.035)	-	-
Haplosyllis spongicola	-	-	(0 ±1)	(0 ± 0.001)
Hesionidae	(0 ± 1)	(0 ± 0)	-	-
Jasmineira elegans	-	-	(0 ±1)	(0 ± 0.001)
Johnstonia clymenoides	-	-	(0 ±1)	(0 ± 0.001)
Kefersteinia cirrata	(0 ± 1)	(0 ± 0)	-	-
Laetmonice hystrix	-	-	(0 ±1)	(0.009 ± 0.053)
Lumbrinerides acuta	-	-	(0 ±1)	(0 ± 0.001)
Lysilla	-	-	(0 ±1)	(0 ± 0.001)
Malacoceros fuliginosus	(0 ± 1)	(0 ± 0)	-	-
Myrianida longoprimicirrata	-	-	(0 ±1)	(0 ± 0)
Neanthes irrorata	-	-	(0 ±1)	(0 ± 0)
Nereiphylla	(0 ± 1)	(0 ± 0)	-	-
Nereis rava	(0 ± 1)	(0 ± 0)	-	-
Odontosyllis fulgurans	-	-	(0 ±1)	(0 ± 0)
Orbiniidae	-	-	(0 ±1)	(0 ± 0.001)
Paramphitrite tetrabranchia	-	-	(0 ±1)	(0 ± 0.003)
Parapionosyllis minuta	-	-	(0 ±1)	(0 ± 0)
Parathelepus	-	-	(0 ±1)	(0 ± 0)
Pherusa plumosa	-	-	(0 ±1)	(0 ± 0.001)
Phylo foetida	-	-	(0 ±1)	(0.004 ± 0.025)
Polycirrus	-	-	(0 ±1)	(0 ± 0.001)
Polycirrus plumosus	-	-	(0 ±1)	(0 ± 0.001)
Polymnia	-	-	(0 ±1)	(0 ± 0.001)
Prionospio dubia	-	-	(0 ±1)	(0 ± 0)
Pygospio elegans	-	-	(0 ±1)	(0 ± 0.001)
Sabellaria alcocki	-	-	(0 ±1)	(0 ± 0)
Serpulidae	(0 ± 1)	(0 ± 0)	-	-
Spiochaetopterus	(0 ± 1)	(0 ± 0)	-	-
Tharyx	-	-	(0 ±1)	(0 ± 0)