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Estrutura de comunidades bentónicas sob pressão de pesca de arrasto

Traits of benthic assemblages subjected to different trawling pressure

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palavras-chave impactos, pesca de arrasto, comunidades bentónicas, biodiversidade, estrutura trófica, espectro de tamanho, habitats de mar profundo

resumo

Ao longo do tempo, as artes de pesca têm vindo a evoluir como resposta às crescentes necessidades da população Humana. Ao mesmo tempo que a indústria pesqueira tem vindo a crescer têm-se vindo a observar importantes mudanças nos ecossistemas marinhos (ex. sobreexploração de recursos pesqueiros e perda ou degradação da biodiversidade). A sobre-pesca, pesca de espécies acessórias, rejeições e pesca fantasma são os impactos causados pelas pescas que geram maior preocupação, mas o efeito devastador de pesca de arrasto no fundo oceânico não deve ser subestimado, devido ao seu reconhecido impacto nas comunidades bentónicas.

Até aos dias de hoje o conhecimento acerca do impacto em comunidades bentónicas de mar profundo é escasso na Europa e ainda menor em fundos oceânicos Portugueses. Contudo, a avaliação dos impactos da indústria pesqueira em fundos marinhos e nos seus ecossistemas é essencial para obter uma gestão apropriada do setor e para um uso mais sustentável dos recursos biológicos. Neste contexto, este estudo tem como objectivo avaliar o impacto da contínua pressão das pescas de arrasto em comunidades de macrofauna bentónica em fundos lamosos de mar profundo nos habitats do crustáceo *Nephrops norvegicus* (Lagostim), através da comparação de fundos impactados com fundos não-impactados, considerando a análise da biodiversidade, densidade, biomassa, estrutura trófica, espectro de tamanhos e modos de vida.

Foram estudadas sete estações ao longo de um transeto, das quais, as primeiras duas estações (estações 1 e 2, área 1) correspondem a uma zona impactada, as seguintes três estações a uma zona não sujeita a pesca de arrasto (estações 3, 4 e 5, área 2,) e, por fim, duas estações (estações 6 e 7, área 3) novamente sujeitas a pressões de pesca de arrasto. A expedição oceanográfica foi realizada em Setembro de 2012 a bordo do navio RV Garcia del Cid (Consejo Superior de Investigaciones Cientificas) inserido no projecto IMPACT (Universidade do Algarve). De um modo geral, as zonas pescadas mostram uma menor heterogeneidade e embora os resultados da análise multivariada suportem uma diferença significante entre zonas pescadas e não-pescadas, as comparações de biodiversidade (número de familias, H’, EF(n)), densidade e biomassa) em zonas pescadas e não-pescadas são inconclusivas, inconsistentes e por vezes contraditórias quando comparadas com a literatura. Quando a estrutura trófica e o estilo de vida das comunidades são comparados, a pequena heterogeneidade nas zonas pescadas é confirmada, mas outros factores emergem, como a contribuição de animais de mobilidade livre, especialmente predadores de meiofauna e raspadores em zonas pescadas, em contraste com a alta contribuição de animais tubículos em zonas não-pescadas, a dominância de detritívoros que se alimentam de matéria orgânica associada ao sedimento sobre detritívoros que se alimentam de matéria orgânica particulada, em zonas pescadas e a presença de grandes suspensívoros em zonas não-pescadas. A

interpretação dos resultados taxonómicos e da estrutura trófica é complexa e deve ter em conta variações introduzidas por alterações não esperadas na estratégia de amostragem e diferenças de habitat das zonas estudadas.
No geral, este estudo contribui para o conhecimento do impacto de pescas de arrasto em comunidades de macrofauna bentónica de ambientes marinhos profundos. Nestas condições é dificil avaliar quais os efeitos de 60 anos de pressões de pesca de arrasto e futuros estudos são desejáveis. Surgiram alguns problemas metodológicos, o que pode servir como recomendações para futuros estudos de impactos de pesca de arrasto e monitorização da integridade dos fundos oceânicos: uma boa selecção de áreas controlo deve ser considerada; a seleção de tipos de amostradores deve ter em conta a selectividade de amostradores menores; o número de réplicas por estação deve ser suficiente para garantir representatividade da biodiversidade, abundância e biomassa, e a significância de testes comparativos; e por fim, estrutura trófica, espetro de tamanhos e modo de vida mostraram ser bons indicadores de diferenças entre as duas zonas, logo deveriam ser usados mais regularmente na avaliação de impactos de pesca de arrasto.

keywords

impact, trawling fisheries, benthic assemblages, biodiversity, trophic structure, body size spectrum, deep-sea habitats

abstract

Over time, fishing techniques improved as a response to the needs of Human populations. Alongside with the increase of fishing activities important changes in the marine ecosystems were also observed (e.g. overexploitation of stocks and habitat loss or degradation). Overfishing, by-catch, discards and ghost-fishing are some of the most discussed impacts of fishing activities, but the effect of bottom trawling should not be underestimated, since it has been proven to have a significant impact of benthic communities.

Up to now the knowledge about fisheries impact on deep-sea benthic macrofaunal assemblages is scarce in Europe and, for all we know, even more in Portuguese fishery grounds. However, assessing fisheries impacts on marine ecosystems and ensuring fisheries sustainability is essential to achieve proper management of the sector and for the conservation of marine resources. In this context, the present study was carried out aiming to investigate the impact of continued trawling on benthic macrofaunal assemblages from deep muddy grounds of the burrowing crustacean *Nephropsnorvegicus* (Norway lobster) by comparing towed and untowed stations regarding their biodiversity, density, biomass, trophic structure, life style and body size spectra.

Seven stations were studied along a transect of a highly Fished zone (Area 1, Stations 1 and 2), a Non-fished zone (Area 2, Stations 3, 4 and 5) and another Fished zone (Area 3, stations 6 and 7) during a cruise carried out in September 2012 onboard the RV Garcia del Cid (Consejo Superior de Investigaciones Cientificas) in the framework of the project IMPACT (Universidade do Algarve). In general Fished zones showed decreased heterogeneity and although the results of the multivariate analysis support a significant difference between Fished and Non-fished areas the comparisons of the biodiversity (number of families, H', EF(n)), density and biomass in Fished and Non-fished zones are inconclusive, inconsistent or even contradict most of the literature predictions. When the trophic structure and life style spectra of the assemblages are compared the decreased heterogeneity of the Fished zones is confirmed but other patterns emerge such as the higher relative contribution of free living organisms, especially meiofaunal predators, grazers and browsers in Fished zones in contrast with the higher relative contribution of tubiculous animals in Non-fished zones, the dominance of deposit feeders over detritus feeders in Fished areas and the presence of large suspension feeders in Non-fished zones. The interpretation of the observed taxonomic and trophic structure of the assemblages is complex and must take into account sources of variability introduced by unwanted alterations of the sampling strategy and habitat heterogeneities in the study area.

Overall this study constitutes a good asset for the knowledge of bottom trawling impact on macrofaunal assemblages from deep-sea habitats. It is at this point impossible to estimate the impact of 60 years of bottom trawling and regular monitoring studies are desirable. Some methodological issues arose which can be used as recommendations for future assessments of trawling impacts and monitoring of seafloor integrity: selection of adequate control area(s) must consider habitat heterogeneity, selection of the sampling gear must consider the possible selectivity of smaller samplers; the number of replicates per stations should be sufficiently large to ensure representativeness of biodiversity, abundance and biomass assessment and significance of the comparative tests; and finally, trophic structure, life style and body size spectra showed to be good indicators of change and therefore they should become a more common tool on the assessment of trawling impact.

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1 INTRODUCTION

The search for understanding and the curiosity of humans had led us to the most unknown places, and one of these places is the deep ocean floor. Home of a vast diversity of life the ocean covers approximately 70% of the Earth's surface; it is essential to human well-being as it is responsible to maintain the balance between hydrosphere, biosphere and atmosphere. The ocean has been serving the human needs in many ways. It is one of the most secret places on Earth that is yet to be explored, and we are now, more than ever, starting to disclose the magnificence of one of the richest ecosystems in terms of biodiversity. This search on the sea-floor coincides with a very worrying problem to our planet – habitat loss or degradation and consequent impoverishment of the biodiversity of the oceans.

The oceans have been serving human needs since the very beginning of mankind. For centuries the ship construction and navigation technology is being developed; ancient humans started building small boats to search for food and ships to colonize new lands, navigation and fishing techniques have been evolving since then to keep up with the progress of Human societies and to fulfill new needs. Exponential growth of human population required a large increase on the stock of food resources and fishery industries had to be prepared to respond to this demand. However, with the development of fisheries several issues emerged such as overfishing, pollution and habitat loss and degradation of marine ecosystems, problems that are very difficult to recover from. Overfishing can cause a cascade effect on the trophic web by endangering fisheries target species, and the large fishing fleets contribute to the pollution of the oceans (e.g. organic and chemical contamination, noise). The most destructive techniques have profound effects on the seafloor integrity owing to the mechanical destruction of the benthic habitats with subsequent alterations of the biodiversity and functioning of the marine ecosystems (Jackson *et al*. 2001).

During the 20th century the human population started to grow exponentially and the governments around the world started to increase their fishing fleets; things turn to worst with the increasing market competition. With the technology advances and improved new tactics, the initially artisanal fishing activities that had mostly a small-scale and local dimension, evolved rapidly into a well-concerted and efficient industry with a large-scale and global dimension. Throughout the 1950 and 1960 decades, the increase of global fishing effort led to an increase in catches, with a general belief that more ships would lead to higher catches (Pauly *et al*. 2002). In the 1960s, traditional fishing grounds of the North Atlantic and North Pacific became fully exploited and new fisheries were developed at lower latitudes (and in the Southern Hemisphere). During the 1970s, the case of the Peruvian anchoveta illustrated the first fishery collapse and it had global repercussions (Watson and Pauly 2001). At that time, the *El Nino* event was considered responsible for this collapse and industrial fisheries were allowed to continue. The pressure relief on deep fishing grounds lead to a slight decrease of the average depth of fish catches (Figure 1.1, A). The beginning of a decline in total catches from the North Atlantic during the mid-1970s and the deteriorating situation in the late 1980 and early 1990 decades, when most cod stocks off New England and eastern Canada collapsed, ended centuries of fishing traditions (Myers *et al*. 1997). Since the late 1980s, fisheries have been slowing declining at a rate of 0.36 million tons year^{-1} (Figure 1.1, B). According to the latest statistics, marine capture fisheries supplied the world with a value of 77.4 million tons of fish (FAO- United Nations Food and Agriculture Organization 2012).

Owing to the increasing pressure of the coastal fisheries, new technological developments and decreasing costs of technologies that allow ever-greater access, deep-sea habitats were subjected to increasing amounts of fishing (Dayton *et al*. 1995), as the tendency for an increasing depth range of the fisheries continued over the years (Figure 1.1). Despite the scarce knowledge of deep-sea habitats, their associated biological assemblages are thought to be characterized by life-history adaptations such as slow growth, extreme longevity, delayed age maturation and low natural mortality (Dayton *et al*. 1995) which likely lead to low tolerance to disturbance and little capacity of recovery.

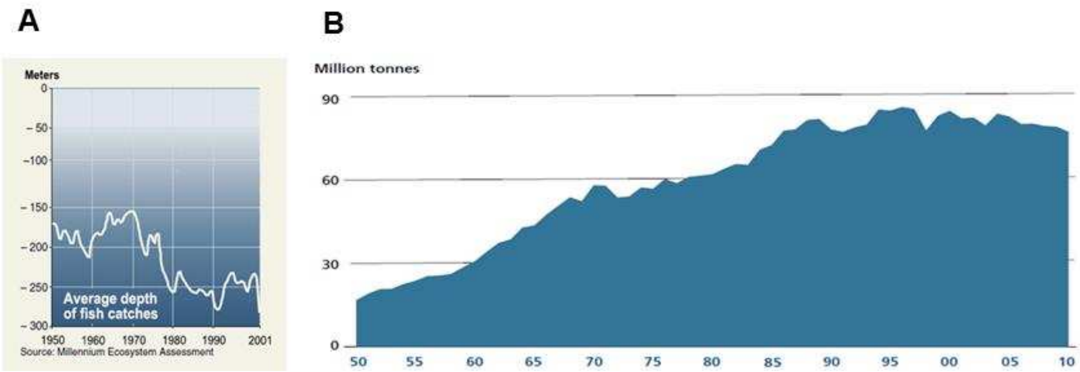

Figure 1.1. A: Average depth of fish catches; B: World marine catches fisheries production (million tons) between 1950 and 2010 (Source: FAO- United Nations Food and Agriculture Organization2012)

1.1 FISHING TECHNIQUES

Over time, fishing techniques improved to satisfy the needs of Human populations. Hook and line fishing were replaced by intensive beam trawl during the 18th century (Jackson *et al*. 2001) and the fishing process became industrialized in the early 19th century when English fishermen started operating steam trawlers, soon rendered more effective by power winches. After the First World War the introduction of diesel engines and later, after the Second World War, new improvements such as freezer trawlers, radars and acoustic fishing finders contributed to the dramatic development of the fisheries accompanying the increasing numbers of human populations (Cushing 1988, Pauly *et al*. 2002).

Fishing techniques can be separated in two categories, passive and active (Jennings and Kaiser 1998). Passive fishing techniques are based on cages, baskets and nets settled in strategic locations that remain there until they are gathered sometime after. These traps are placed normally on the seafloor and target animals are caught seeking for refuge or food. These techniques use different equipment for different target species. Examples of passive fishing techniques are gillnetting, long-line fishing and the use of traps, cages and boxes.

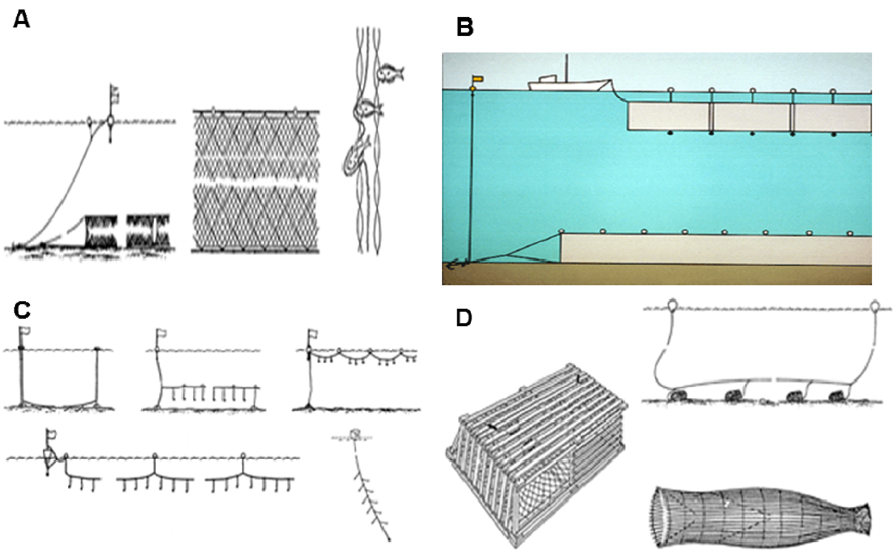

Figure 1.2. Examples of passive fishing techniques. A, B: Entangling and gillnetting nets can be settled on the pelagic zone or on the bottom; C: Long-lines installation; D: Cages and traps.(Source: Nédélec and Prado 1990)

Entangling and gillnetting: involve strings of single, double or triple netting walls, vertical, near by the surface, in mid-water or at the bottom, in which fish will gill, entangle or enmesh (Prado *et al*. 1990), they have floats on the upper line and weights on the grounding line, and they can be anchored to the bottom or left drifting free or connected to the vessel (Figure 1.2.A and B).

Long-line fishing (or long-lining): consist in settle lines adrift from vessels for a period of several hours and a distance of 1 up to 100 km, using hooks and bait; this technique can be used in the pelagic zone or on the seafloor (Figure 1.2.C).

Cages and traps: Used with or without bait, depending on the target species, traps are settled on the seafloor, with dimensions ranging from around half a meter to two meters, they have one or more openings and they are usually set in a row (Figure 1.2.D).

These techniques are not too destructive compared to active fishing, because normally they use equipment that stay immobile in the pelagic zone or at the seafloor and the impact is almost none. The most concerning impact referent to passive fishing techniques happens when the gear is lost, left behind or forgotten and it settles on the seafloor or drifts at the surface of the ocean leading to ghost-fishing or causing damage to other vessels.

In case of active fishing techniques vessels dislocate to catch target species. These techniques use mostly nets, and examples of these strategies are seine fishing (including the xávega technique), surrounding nets, trolling lines, dredges and trawlers (Prado *et al*. 1990).

Seine fishing: consists in a very long net, with or without a bag in the center (Prado *et al*. 1990), which can be set either from the shore or from a boat that surround a certain area and is operated with two ropes attached to the ends of the net. It is divided into two categories: beach seines and boat seines. The targets are mainly demersal species in shallow areas. One example of beach seine fishing is xávega technique, typical from Portugal, where the nets are released and after pulled from shore, formerly by hand or with the help of animals, nowadays using mechanical power (Fiamozi *et al*. 1992) (Figure 1.3.A and B).

Surrounding nets: large netting walls set for surrounding fish both from the sides and from underneath thus preventing them from escaping by diving downwards (Nédélec and Prado1990, Fiamozi *et al*. 1992, Cochrane *et al*. 2005) (Figure 1.3.C).

Dredges: there are two main type of dredges: heavy dredges towed by ships (boat dredges), and lighter ones operated by hand usually in shallow waters (hand dredges); they are used to catch shellfish and molluscs on the seafloor (Figure 1.3.D).

Trawling: it can be classified in several types such as bottom otter trawls, beam trawls, bottom pair trawling, otter twin trawls and mid-water otter trawls. Otter twin trawls and mid-water otter trawls are cone-shaped nets which are towed in mid-water not touching the seafloor. Bottom trawling consists in a cone-shaped net that is towed (by one or two ships) on the seafloor. It is a net that has a body ending in a cod-end, which retains the catch. Normally the net has two lateral wings extending forward from the opening. Usually the net is kept open with floats on the upper head and weights on the groundrope. It is designed and rigged to catch species living on or near the seafloor. Bottom trawl can be divided in three categories that are distinguished based on how their horizontal opening is maintained: beam trawls, bottom otter trawls, and bottom pair trawls. In a beam trawl the horizontal opening of the net is provided by a beam, made of wood or metal, which is up to 12 m long and the vertically opening is provided by two hoop-like trawl made from steel. Bottom otter trawl is kept open horizontally by two otter boards, there are many models of otter boards, they may be relatively heavy, made of wood, aluminum and steel or a combination of these, rectangular or oval shaped and equipped with a steel sole designed for good contact with the ground. Bottom pair trawling consists in a trawl towed by two vessels that maintain a distance apart that will provide the mouth opening and headline height found most effective for the gear and species being fished (Figure 1.3.E - I).

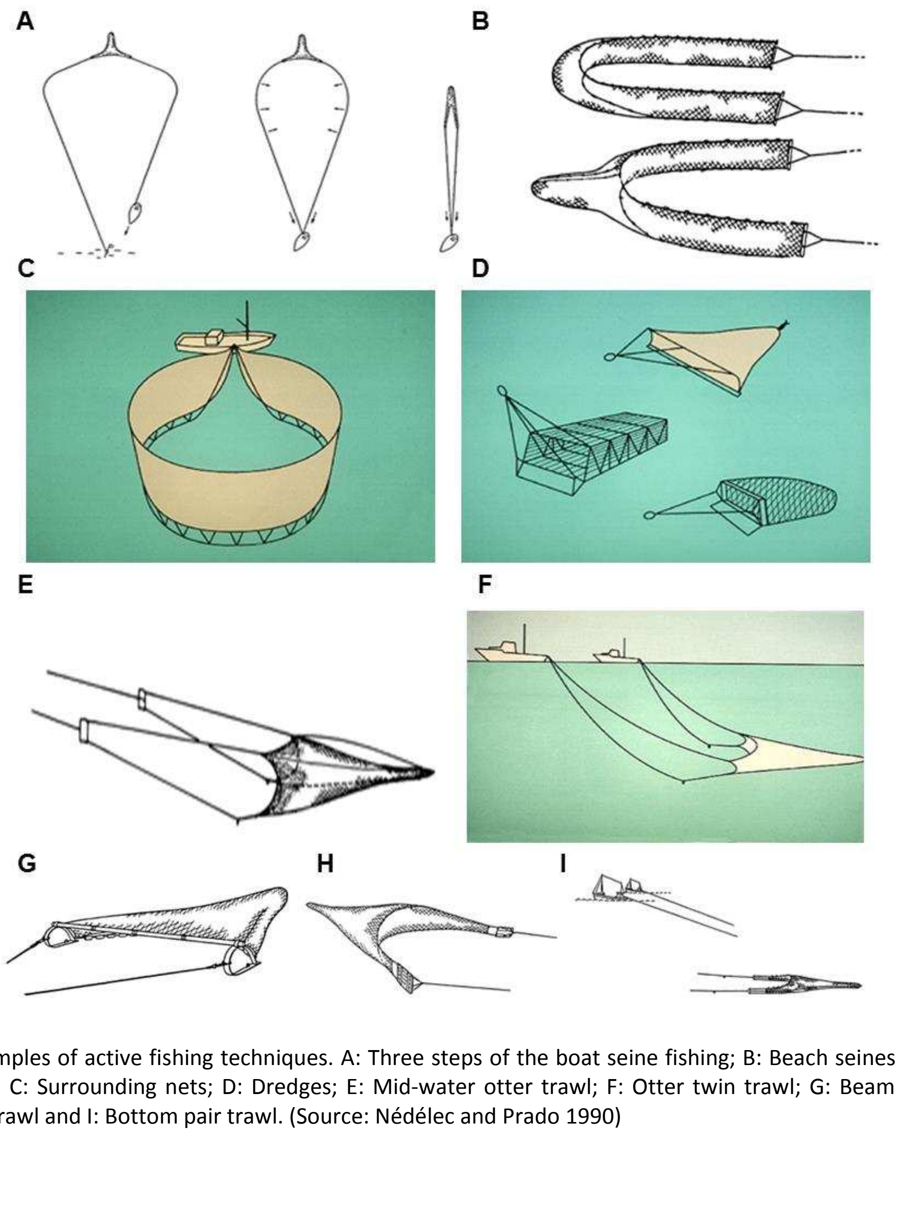

Figure 1.3.Examples of active fishing techniques. A: Three steps of the boat seine fishing; B: Beach seines with and without a bag; C: Surrounding nets; D: Dredges; E: Mid-water otter trawl; F: Otter twin trawl; G: Beam trawl; H: Bottom otter trawl and I: Bottom pair trawl. (Source: Nédélec and Prado 1990)

1.2 FISHERIES IMPACTS

All the fishing techniques have a direct or indirect impact on the marine ecosystems, with active fishing techniques having a more devastating impact than passive fishing. Direct effects include fishing mortality used on target populations (overfishing), fishing mortality affecting non-target species (by-catch) and physical impacts caused by towed gears on benthic organisms and on the seabed (bottom trawling). Indirect effects include impacts mediated by biological interactions, the environmental effects of dumping discards and organic detritus, and the mortality caused by lost fishing gear (Goni 1998).

1.2.1 EFFECTS ON TARGET AND NON-TARGET SPECIES (BY-CATCH)

The main direct impact of fishing is the reduction of the abundance of target species. Most fishing methods have low selectivity, resulting in the accidental capture of non-target species or undersized or damaged individuals of target species (by-catch). By definition by-catch can be considered as “catch that it is unused or unmanaged” (Davies 2009). This problem is inherent to all kind of fishing techniques and affects not only the pelagic marine fishes, but also marine mammals (e.g. cetaceans and pennipeds) and benthic assemblages.

In developed countries there is a high market demand and the price paid for swordfishes, tunas, sharks, and other top predators is remarkably high and leads to a high pressure on these fishes. The fishing gear targeting these species will cause by-catches of other large and frequently long-lived species (e.g. marine mammals, sea turtles and sea birds) and will affect the invertebrate community (Hall *et al*. 2000).

By-catch species with a low economic value, with a protection status, non-target species, small, damaged, incompatible with the rest of the catch (from the point of view of storage) and poisonous species are often thrown overboard as discards (Figure 1.4). Other reasons for discard are lack of space on board and prohibited fishing season, ground or gear (Clucas 1997).

In fact, discards can affect the benthic layer and associated biodiversity. Besides leading to resource depletion, discards can cause changes in the food webs, contribute to the increase of scavenging species and promote decomposition processes, causing anoxia, transferring biomass between water layers or causing accumulations of biomass that affect the usual nutrient flow and organic matter (Dayton *et al*. 1995, Goni 1998, Cabral *et al*.2002).

The total amount of fish discarded annually by marine fisheries throughout the world was estimated eight years ago by FAO as 7.3 million tons (Kelleher 2005). Recentstudies revealed a reduction of the amount of discards over the past few years, attributed to the use of more selective fishing gears and fishing practices, to the decline of some particularly wasteful fisheries, higher retention and enforcement of regulatory measures (Valdemarsen 2005). In addition to the more selective fishing, another solution to the discard problem is to use the unwanted catch in other industries (e.g. preserved fish food) (Caddy and Cochrane 2001).

Figure 1.4. Examples of discards of non usable catch.(Source: Walker 2011)

1.2.2 EFFECTS CAUSED BY LOST GEAR (GHOST-FISHING)

Fishing activity produces waste disposal (e.g. lines, nets, cages, anchors, traps, pots and ropes) through the accidental loss of gear of by dumping or abandoning the gear, which continue to fish and capture individuals for some time after being discarded or lost. This incident is known as ghost-fishing and has been confirmed to occur for traps, gill and trammel nets and small seine nets (Matsuoka *et al*. 2005). This litter deposited on the seafloor and/or in the water column can damage other vessels (entangling in the boat propeller) but more seriously, it causes mortality in the marine fauna. In addition to the possible water pollution, these residues affect not only small fishes but also sea turtles, sea birds, cetaceans and large predator fishes that approach the nets to feed on entrapped animals and may end up getting caught. These residues can also be positively used by the fauna (e.g. filter feeding anemones can settle on fishing lines or cages and traps (Mordecai *et al*. 2011)).Data on the quantity of fishing gears lost, or knowledge on how long such gears continue to fish is scarce, and thus the scale of the impacts of ghost-fishing is poorly known (Pawson 2003).

1.2.3 PHYSICAL DISTURBANCE AND HABITAT LOSS

Bottom trawling is perhaps the most destructive fishing technique, affecting directly and indirectly the marine ecosystem (Gage *et al*. 2005). In fact, towed gears can cause more impact than any other form of activity on the seafloor such as oil exploration, pipelines, sub aquatic communication cables, waste disposal, military activities or marine scientific research (Benn *et al*. 2010). The physical contact of fishing gear with the substratum can lead to reduction of topographic complexity, re-suspension of the upper layers and fragmentation of rock and biogenic substrata, with implications on eutrophication processes and biogeochemical cycling (Dayton *et al*. 1995, Jennings and Kaiser 1998, Duplisea *et al*. 2001, Kaiser *et al*.2002, Puig *et al*.2012).

Towed gears can have direct effects in organisms, such as mortality, and indirect due to modifications in their habitats, changes in sedimentation patterns, benthic algal production or nutrient cycling. Alterations of the benthic biological assemblages may impact indirectly on species with potential commercial value. These impacts depend on factors such as the duration and frequency of exposure to the disturbance and the magnitude of the impacted zone by fishing trawlers (Tyler-Walters *et al*. 2009). The magnitude of these effects has proven difficult to evaluate, since the intensity of disturbance and its magnitude depends on the characteristics of the gear, sediment type and water depth among other factors (Trush *et al*. 1998, Kaiser *et al*. 2002).

1.2.4 EFFECTS MEDIATED BY BIOLOGICAL INTERACTIONS

Fishing activities can lead to changes in the structure of marine habitats affecting the diversity, composition, biomass and productivity of the associated fauna (in- or epifauna), (Jennings and Kaiser 1998). These effects can cascade along the entire food chain through competition and predation links (Goni 1998). In addition the constant disturbance will make difficult the recovery of the community (Bergman and Hup 1992, Jennings *et al*. 1999).

As fisheries tend to remove large, slow growing long-lived predatory fish, there will be a shift to smaller species with faster turnover (Jennings and Kaiser 1998). In the last decades, due to selective catches, the mean trophic level (TL) of landed species declined from slightly more than 3.3 in the early 1950s to less than 3.1 in 1994. A gradual transition in landings from long-living, high TL, piscivorous fish toward short-lived, low TL invertebrates and planktivorous pelagic fish has occurred reflecting changes in marine food webs, a process documented globally and known as "fishing down marine food webs" (Pauly *et al*. 1998). Nevertheless indices based on the TL of catches alone are insufficient to identify structural changes in trophic networks and to detect possible consequences of these changes on network function. The estimates of catch TL do not adequately correlate with ecosystem TL and thus this index does not properly measure the magnitude of fishing effects or the rate at which ecosystems are being altered by fishing (Branch *et al*. 2010). Since fisheries simultaneously harvest species at different trophic levels (multispecific fisheries), changes in the TL become masked and the index remains more or less stable with time, potentially giving the impression of a sustainable fishery through time (Pérez-España *et al*. 2006).

1.3 PORTUGUESE FISHERIES

Portugal is the main consumer of fish per capita in Europe, with over 60 kg per capita (FAO 2012), well above the average (Failler 2007). With an Exclusive Economic Zone (EEZ) 18 times larger than its mainland territory, Portugal has one of the largest EEZ's in Europe (including not only the EEZ associated with the Mainland but also with the two Autonomous Regions of Azores and Madeira). After the adhesion to the European Union in 1986, the national fisheries sector has lost importance at different levels, including in the national economy. Fleet dimension, number of fishermen and catches has decreased since then: the number of vessels decreased to approximately half of the number in the 1980s and currently the sector employs less than 0.35% of the active population, contrasting with the 1.44% in 1950 (Baeta 2009).

Portuguese fisheries are highly diverse in their characteristics and present peculiarities in relation to other areas and within our country. In mainland Portuguese fisheries focus on a high diversity of resources in fishing grounds located a short distance from shore, whereas in the autonomous regions pelagic species are the most exploited (Baeta 2009).

Few studies have analyzed impacts on marine ecosystems of Portuguese fishing activities. Until now all the studies have been carried out in the southern coast of Portugal, where they focused on: a) the influence of fishing gear on the benthic habitats (Chicharo *et al*. 2002, Falcão *et al*. 2003); b) impacts of dredge fishing (Gaspar *et al*. 2001, 2002, 2003); and c) impacts of trawl fishing (Morais *et al*. 2007).

The European parliament established a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive): "The aim of the European Union's ambitious Marine Strategy Framework Directive (adopted in June 2008) is to protect more effectively the marine environment across Europe. It aims to achieve good environmental status of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend."(http://ec.europa.eu/environment/index_en.htm). Each Member State has the obligation to develop a Marine Strategy according to concerted approaches and standardized methodologies. For determining the good environmental status (GES) member states should use 11 standard descriptors among which Descriptor 6 – Seafloor integrity, is particularly relevant to human induced pressures related to trawling fisheries. Sea-floor integrity must be "at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected" (Box 1.1).

Box 1.1. Text extracted from the Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters – Descriptor 6 (Source: European Commission 2010).

Descriptor 6: Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

The objective is that human pressures on the seabed do not hinder the ecosystem components to retain their natural diversity, productivity and dynamic ecological processes, having regard to ecosystem resilience. The scale of assessment for this descriptor may be particularly challenging because of the patchy nature of the features of some benthic ecosystems and of several human pressures. Assessment and monitoring needs to be carried out further to an initial screening of impacts and threats to biodiversity features and human pressures, as well as an integration of assessment results from smaller to broader scales, covering where appropriate a subdivision, sub-region or region ([19]).

6.1. Physical damage, having regard to substrate characteristics

The main concern for management purposes is the magnitude of impacts of human activities on seafloor substrates structuring the benthic habitats. Among the substrate types, biogenic substrates, which are the most sensitive to physical disturbance, provide a range of functions that support benthic habitats and communities.

— Type, abundance, biomass and areal extent of relevant biogenic substrate (6.1.1)

— Extent of the seabed significantly affected by human activities for the different substrate types (6.1.2).

6.2. Condition of benthic community

The characteristics of the benthic community such as species composition, size composition and functional traits provide an important indication of the potential of the ecosystem to function well. Information on the structure and dynamics of communities is obtained, as appropriate, by measuring species diversity, productivity (abundance or biomass), tolerant or sensitive taxa and taxocene dominance and size composition of a community, reflected by the proportion of small and large individuals.

— Presence of particularly sensitive and/or tolerant species (6.2.1)

— Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species (6.2.2)

— Proportion of biomass or number of individuals in the macrobenthos above some specified length/size (6.2.3)

— Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community (6.2.4).

The initial characterization made by the Portuguese government - Direcção Geral dos Recursos Naturais, Segurança e Serviços Marítimos (DGRM 2013) highlights trawling fisheries as one of the most pervasive activities along the Portuguese margin (Figure 1.5), affecting between 50 to 100% of the areas covered by different substrate types and covering extensive areas between the 6nautical miles line and down to 800-1000m depths. In the same document the definition of GES concerning the integrity of the seafloor implies that "the diversity and productivity of the ecosystems are maintained and that human activities are not causing adverse impacts (both spatially and temporally) on the natural structure and functioning of the ecosystem. Pressure associated to human use should be balanced, allowing the sustainable use of the ecosystems (i.e. allowing the maintenance of the diversity, productivity and other dynamic ecological processes). Disturbance caused by human use should be limited to an amount that allows rapid and safe recovery" (DGRM 2013). In Portugal most studies dealing with the impacts of trawling were carried out at depths shallower than 100 m. The DGRM report (2013) clearly states the insufficiency of the available data to determine the condition of the benthic assemblages in the extensive areas affected by trawling fisheries.

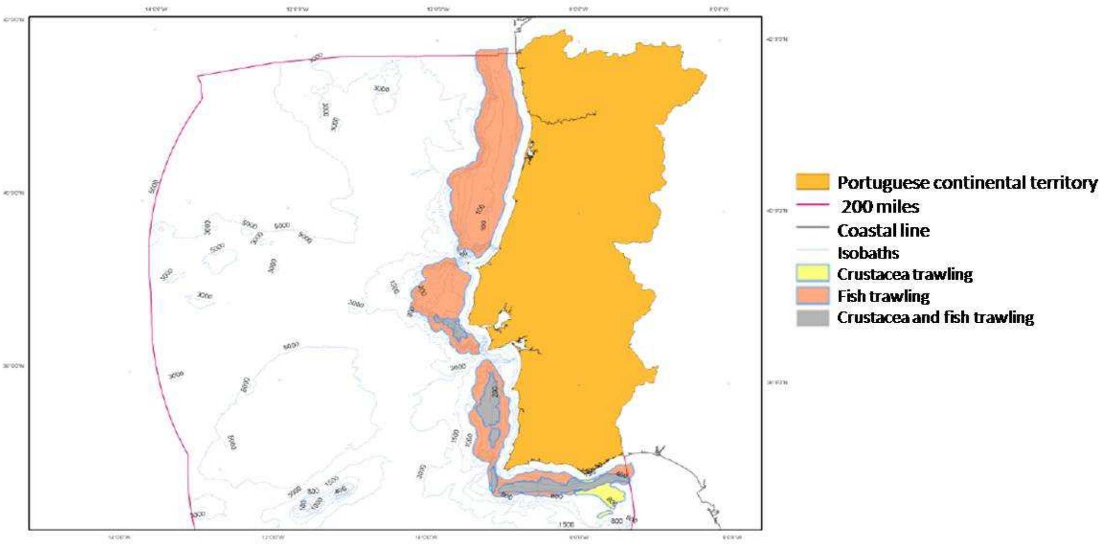

Figure 1.5 Map representative of trawling activity in Portugal. (Source: DGRM 2013)

1.4 Objectives

The present study aims to contribute to the knowledge on the impact of trawling fisheries on benthic macrofaunal assemblages. The study focus on a deep muddy area (ca. 500 m depth) within the fishery grounds of the burrowing crustacean Norway lobster (*Nephrops norvegicus*) off the Algarve coast (Portugal). Towed and untowed stations are compared regarding the diversity, density, biomass, trophic structure, mobility and body size structure of the benthic macroinvertebrate fauna.

2 MATERIAL AND METHODS

The traditional methodological approach to study trawling effects consists of “before and after studies” - an area where little or no trawling occurred is studied before and after experimental trawling is conducted. Owing to the vast extension of the impacted areas along the Portuguese margin and for various practical reasons the approach used in the present study focused on the comparison of impact and no-impact areas. This study was performed under the framework of the project IMPACT (lead by Universidade de Algarve, with participation of Universidade de Aveiro, Instituto Português do Mar e da Atmosfera e Consejo Superior de Investigaciones Cientificas) and benefited from EuroFleets funding to conduct a cruise off the Algarve coast.

2.1 STUDY AREA

The study area is herein described according to the IMPACT cruise report (Castro *et al*. 2013). The study area is located in the slope of the Southwest and South coast of Portugal (from 200 to 800 m depth) where otter trawling, targeting the Norway lobster (*Nephrops norvegicus*), has occurred continuously over the past 60 years. Whilst at present trawling extends to depths above and below the *Nephrops* grounds (aiming several species of deep water shrimps), the enduring fishing, the absence of grounds with fixed gear and the trawling obstruction between the coast and 6 nautical miles from the shore (red line, Figure 2.1) contribute to define the *Nephrops* grounds as the target of this study. On the South coast of Portugal, the stocks are intensively fished due to good weather conditions year-round and the proximity of rich rose shrimp grounds potentially enhances the contrast between no-fishing versus intensively fished areas.

The study area was selected following a process to identify regions with no or little fishing pressure adjacent to areas of intense fishing. This process included crossing the information obtained from interviews to several experienced skippers with the VMS (Vessel Monitoring System) database available at Direção Geral das Pescas. The selected “No-fishing” area, sits along the Northern edge of the Álvares Cabral Trench (Southwestern coast of the Algarve) that presents steep slopes off limits to fishing. The “No-fishing” area is avoided by trawlers because of large boulders surfacing out of the sediment. Here, it was easier to find a transect starting in a heavily fishing zone (Area A1), continuing to a no-fishing zone (Area A2) and going again through heavily fished grounds (Area A3) at the northern edge of a marine canyon with depths around 500 meters.

The oceanic setting, tides, geomorphology of the bottom and the type of sediment contributed to the choice of the sampling sites. The sediment grain size composition varies across the study area(Castro *et al*. 2013). According to the geologic map, the sediment along the transect changes from sandy (beginning) to muddy sediment (end). This variability is likely to have some influence in the biota abundance and distribution but unfortunately could not be avoided. In the study area, both temperature and salinity decrease with depth. However, near-bottom oceanographic conditions are characterized by the presence of a westward flowing vein of warmer and saltier Mediterranean water. Although the main Mediterranean outflow reaches its equilibrium depth between 800 and 1200 m after descending abruptly from the strait of Gibraltar sill into the Gulf of Cadiz, a detached upper vein flows along the continental slope of the northern margin of the Gulf of Cadiz at depths as shallow as 400 m or less (Ambar 1983). This upper vein enters the Álvares Cabral trench beneath the colder and less saline North Atlantic Central water, influencing the erosion and sedimentation processes in the study area (Castro *et al*. 2013).

2.2 SAMPLING STRATEGY

Sampling sites were defined along a transect running eastwards from Olhos-de-Água to Tavira (08°07'W and 07°38'W) following when possible the 500 meters isobath, starting in a heavily fished area, going across an area of no fishing and continuing to a second zone of intense fishing. A detail map is presented in Figure 2.1. Along this transect, 7 stations were defined: 2 on the West portion (Fishing zone, Area A1), 3 in the centre (No fishing zone, green markers, Area A2) and 2 more at the East (fishing zone, Area A3), with a total of twenty six replicate samples taken (Castro et al. 2013).

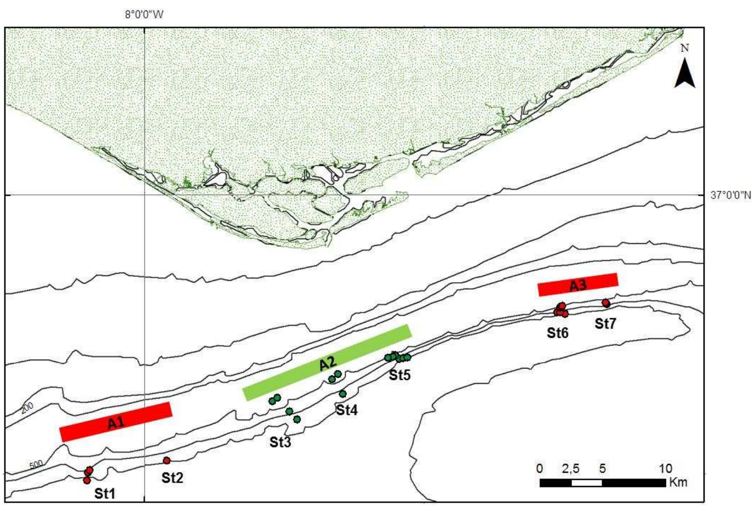

Figure 2.1. Location of the 3 studied areas (A1, A2 and A3) with the 7 stations (St1, St2, St3, St4, St5, St6 and St7) and respective replicate sampling sites. For station details see Table 2.1

2.2.1 SAMPLE COLLECTION AND PROCESSING

Samples were collected during the IMPACT cruise onboard the RV Garcia del Cid (Consejo Superior de Investigaciones Cientificas- CSIC, Spain) in September 2012 using a USNEL box-corer (L) (dimensions 50x50x50cm) and a smaller box-corer (S) (dimensions 10.5x17x35.5cm) (Figure 2.2). Due to technical problems the large box-corer (L) became inoperative during the sample collection, being replaced by the small box-corer (S) leading to two types of samples.

Samples were processed immediately after recovery. The overlying water was siphoned through a 0.25mm sieve in order to retrieve any small swimming fauna. When possible at least ¼ of the large box-corer(L) and all the small box-corer (S) were used for macrofaunal quantitative sampling, but non-quantitative samples with a variable volume of sediment were also collected (see details in Table 2.1). Quantitative samples were sliced into 5 five depth layers (0-1, 1-3, 3-5, 5-10 and 10-20 cm or 10-maximum sediment depth), following the standard techniques advised by the Census of Marine Life workshop on the study of "Biodiversity of Deep-sea Sediments". The different layers of the quantitative samples and all the sediment from non-quantitative samples were carefully washed on board with seawater through a sieve column (1, 0.5 and 0.25mm-mesh sieves).The washed sediment samples in the three fractions (1, 0.5 and 0.25mm) were kept in 96% ethanol and labelled for post processing (Castro *et al*. 2013).

Sample sorting and taxonomical work was carried out in LEME (Laboratório de Ecologia Marinha e Estuarina, Universidade de Aveiro) and the specimens were identified whenever possible to Family taxonomic level (Annex 1) and stored in 96% ethanol.

Figure 2.2.Sampling gears used during the IMPACT cruise for macrofaunal studies. Left: USNEL Box corer (Instituto Português do Mar e da Atmosfera- IPMA), Right: Smaller box-corer (Consejo Superior de Investigaciones Cientificas - CSIC)

Table 2.1. List of samples taken for macrofaunal studies during the IMPACT cruise. Sampler: (L) USNEL Box-corer; (S) box-corer from CSIC.NQ: Non-quantitative sample. * Coordinates unavailable

Station	Sample	Depth (m)	Latitude	Longitude	Date	Sampler	Sampled Area (m^2)
St.1	1B-1	519	36°48.04'N	08°02.40'W	19/09/2012	L	0.125
	1B-2	500	36°48.14'N	08°02.33'W	19/09/2012	L	0.067
	1B-3	628	36°47.70'N	08°02.44'W	19/09/2012	L	0.063
St.2	2B-1	555	36°48.55'N	07°59.02'W	20/09/2012	L	0.063
St.3	3B-1	510	36°50.32'N	07°53.43'W	20/09/2012	L	0.052
	3P-2	447	36°50.66'N	07°53.76'W	21/09/2012	S	NQ
	3P-3	374	36°51.11'N	07°54.49'W	21/09/2012	L	0.017
	3P-5	372	36°51.25'N	07°54.28'W	21/09/2012	S	0.008
St.4	4B-1	525	36°51.42'N	07°51.47'W	20/09/2012	L	0.063
	4P-2	392	36°52.05'N	07°51.93'W	21/09/2012	S	0.017
	4P-4	368	36°52.27'N	07°51.68'W	21/09/2012	S	0.008
	4P-5	375	*	*	23/09/2012	S	0.017
St.5	5B-1	521	36°52.93'N	07°49.05'W	21/09/2012	L	NQ
	5P-2	550	36°52.96'N	07°48.88'W	22/09/2012	S	NQ
	5P-3	557	36°52.99'N	07°48.70'W	22/09/2012	S	NQ
	5P-4	391	36°53.08'N	07°49.22'W	22/09/2012	S	0.017
	5P-5	403	36°53.02'N	07°49.32'W	22/09/2012	S	0.017
	5P-7	400	36°52.97'N	07°49.53'W	22/09/2012	S	0.017
St.6	6P-1	500	36°54.93'N	07°42.28'W	22/09/2012	S	NQ
	6P-2	547	36°54.93'N	07°42.15'W	22/09/2012	S	0.008
	6P-4	387	36°55.13'N	07°42.16'W	22/09/2012	S	0.017
	6P-5	384	36°55.18'N	07°42.10'W	22/09/2012	S	0.017
	6P-7	388	36°55.20'N	07°42.06'W	22/09/2012	S	0.008
St.7	7P-1	483	36°55.28'N	07°40.15'W	23/09/2012	S	0.017
	7P-3	470	36°55.31'N	07°40.19'W	23/09/2012	S	0.008
	7P-5	458	36°55.35'N	07°40.20'W	23/09/2012	S	0.017

2.3 DATA ANALYSIS

Taxa richness and density were assessed for quantitative samples only. Because the taxonomical work is still in progress, biodiversity is herein expressed generally as "number of families" (the lowest taxa possible for this study). Density is expressed as ind.dm^{-2} and estimated according to the different area sampled by each replicate sample/gear in the different stations (Table 2.1) and excluding modular organisms (e.g. Porifera, Cnidaria, Bryozoa). The subdivision in depth layers within the sediment is not used in the analysis although all data were kept separately for further study.

Taxa richness, Shannon-Wiener diversity index (H'), Pielou's evenness index (J'), Hurlbert's Expected Family richness (EF(n)) (Pielou 1969, Hurlbert 1971) were calculated using the community analysis PRIMER v6 software (Clarke and Gorley 2006). This software was also used for multivariate analyses. The abundance data were first organized into a sample vs species matrix and non-metric multidimensional scaling (nMDS) ordination was performed using the Bray and Curtis similarity measure, after square root transformation of the density data. An analysis of similarities by randomization/permutation tests (One-way ANOSIM) was performed on the MDS results to assess for differences in the assemblages putatively related to the fishery impact (Fished vs Non-fished), sampler used (L vs P) and location of the stations (1 to 7).

Biomass was assessed using fresh weight of the specimens: microtubes containing 96% ethanol were previously weighed, specimens were grouped by Family (except for Crustaceans that were grouped by Order) and transferred to the microtubes (avoiding transfer of ethanol but keeping the moisture) which were then weighed again. The difference between values with a correction factor (up to +0.0015 mg, determined from an estimated loss of weight due to the evaporation of ethanol) provided the required biomass value.

For the study of the trophic structure of the community each family was allocated to a trophic guild (Annex 2 and 3) defined by the feeding mode, food type, size and source, and life habit (after MacDonald *et al*. 2010). For each taxon the following information was defined: Food source (EP: Epibenthic; SR: Surface; SS: Subsurface); Diet (Ca: Carnivorous; He: Herbivorous; Om: Omnivorous); Food Type/size (sed: sediment; pom: particular organic matter; mic: microfauna; mei: meiofauna; mac: macrofauna; phy: phytoplankton; zoo: zooplankton); Feeding mode (De: deposit feeder; Dt: detritus feeder; Su: suspension feeder; Pr: predator; Sc: scavenger; Sp: suctorial parasite; Gr: Grazer; Br: Browser). According to this information the final trophic guilds were defined.

In order to characterize the life style spectrum of the assemblages each taxon was ascribed to different categories of mobility (M: motile; D: discretely motile; S: sessile) and habitat (F: free living mode; T: tubiculous; B: burrowers; A: attached; X: parasitic).According to this information (Annex 3) the final life-style categories were defined.

3 RESULTS

From the 26 replicate samples, five were not considered for further analysis as they were not quantitative samples (NQ). Regarding these samples it is noteworthy the presence of specimens of some families such as Sabellaridae (Polychaeta), Podoceridae (Amphipoda), Cirolanidae (Isopoda) and Leucosiidae and Xanthidae (Decapoda) that did not occur in the analysed quantitative samples.

A total of 2212 individuals, ascribed to 114 different taxa (Family level) were examined in the quantitative samples (Annex1).The tanaid family Tanaellidae was the most abundant (D1, Table 3.1), followed by five Polychaeta families (Paraonidae, Spionidae, Cirratulidae, Sabellidae and Ampharetidae). Spionidae, Paraonidae and Cirratulidae were also the most frequent groups occurring in 95%, 90% and 80% of the samples, respectively (Table 3.1).

Table 3.1.Dominant taxa(top 10 taxa are indicated)regarding abundance (Abun, dark green) and biomass (Biom, orange) and taxa frequency of occurrence (Fre%, light green). Only values above 50% are given for frequency of occurrence. Note that since crustaceans were weighted by Order rank and not by Family (as the other groups), they are not included in the ranking for biomass dominances

Phylum	Class	Order	Family	Abun	Biom	Fre %
Annelida	Polychaeta	Phyllodocida	Syllidae	D9		52
Annelida	Polychaeta	Sabellida	Sabellidae	D5		
Annelida	Polychaeta	Spionida	Spionidae	D3	D9	95
Annelida	Polychaeta	Terebellida	Cirratulidae	D4		81
Annelida	Polychaeta	Terebellida	Ampharetidae	D6	D8	71
Annelida	Polychaeta	Terebellida	Terebellidae		D7	
Annelida	Polychaeta		Maldanidae		D10	52
Annelida	Polychaeta		Opheliidae			62
Annelida	Polychaeta		Paraonidae	D2		90
Annelida	Clitellata		Oligochaeta			57
Mollusca	Bivalvia	Veneroida	Kelliellidae	D8	D4	
Mollusca	Bivalvia	Veneroida	Semelidae		D5	
Mollusca	Bivalvia	Arcoida	Arcidae		D3	
Arthropoda	Malacostraca	Amphipoda	Phoxocephalidae	D10		62
Arthropoda	Malacostraca	Cumacea	Nannastacidae	D7		
Arthropoda	Malacostraca	Isopoda	Munnopsidae			57
Arthropoda	Malacostraca	Isopoda	Desmosomatidae			67
Arthropoda	Malacostraca	Tanaidacea	Tanaellidae	D1		67
Echinodermata	Crinozoa		Crinoidea		D1	
Echinodermata	Ophiuroidea	Ophiurida	Amphiuridae		D6	
Cephalorhyncha	Priapulida		Priapulida		D2	

Large specimens of Crinoidea (D1) and Priapulida (D2) collected with the large box-corer accounted for the highest biomasses, followed by Mollusca (Arcidae, Kelliellidae, Semelidae) and then by Polychaeta (Maldanidae, Spionidae and Ampharetidae) (Table 3.1). It is noteworthy that the Polychaeta families Spionidae and Ampharetidae are always ranked among the top positions of all community variables (abundance, biomass and frequency).

3.1 MULTIVARIATE-ANALYSIS

When taking into account all the quantitative replicate samples, the multidimensional scaling analysis (MDS) showed the segregation between Fished and Non-fished areas (Figure 3.1.A,red and green symbols, respectively). The significance of these differences is supported by the ANOSIM results (Table 3.2, Test 1, F vs NF: Global R: 0.390; P: 0.1%).

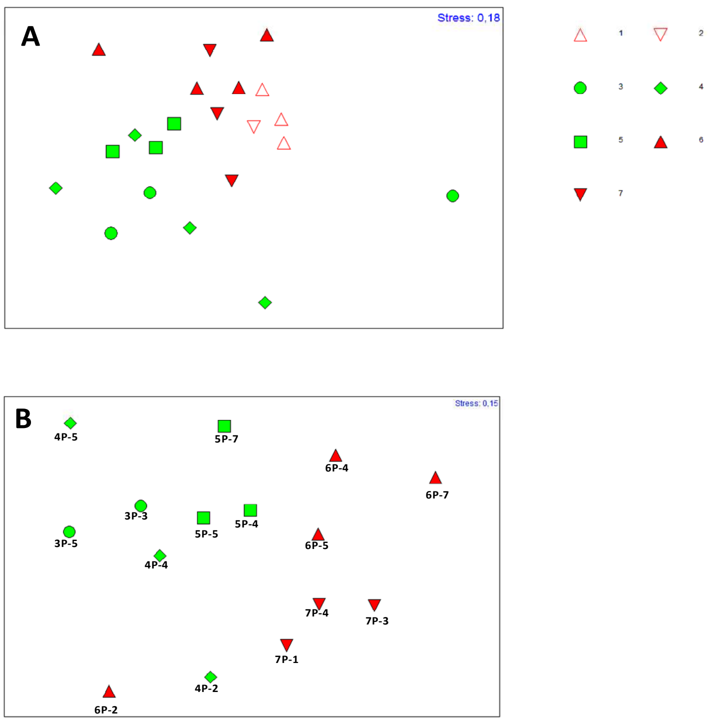

Figure 3.1. Multidimensional scaling (MDS) obtained for biological data (Abundance) for all the samples (A) and only for the samples collected with the small sampler (B). Different symbols indicate different stations and the different colors to the Fished zone (red markers) and Non fished zone (green markers)

When considering all the replicate samples (Figure 3.1.A) a large dispersion of the Non-fished replicate samples is observed due to the distance between replicates 3B-1 and 4B-1 which were taken with the large box-corer (located near the right, bottom corner in Fig 3.1.A) and the remaining replicates. Note that replicates from St.1 and St.2, also taken with the large box-core, are also segregated from the remaining Fished replicates occupying positions towards the right side of the plot. In fact, the ANOSIM results supported the significance of the difference between replicate samples collected with different gear (Table 3.2, Test 2,L vs S: Global R: 0.334; P: 1.0%) which also have different sampled areas of the seafloor (Table2.1).

Subsequently to these results the multivariate analysis was preformed again but using only the replicates taken with the small box-core (the small number of replicates hindered a similar analysis for the large box-cores). In this analysis (Figure 3.1.B) the segregation between Fished and Non-fished becomes more evident and is also supported by the ANOSIM results (Table 3.2, Test 3, F vs NF: Global R: 0.451; P: 0.2%). Globally the differences among stations (only small box-core replicates) were significant (Table 3.2, Test 4: Global R:0.503; P: 0.1%) but, owing to the small number of replicates per station, the statistical power of the pairwise tests was not sufficient to assess further putative differences and their results are inconclusive.

Table3.2. Results of the ANOSIM one-way analysis for global and pairwise tests for factor fished (F) *vs* Non-fished (NF) (ANOSIM test 1), Sampler (L *vs* S) (ANOSIM test 2),Fished (F) vs Non-fished (NF) for samples collected with small box-corer (S) (ANOSIM test 3) and S stations (ANOSIM test 4).*significant (≤5%); ** highly significant (≤1%); ns: not significant

	Sample Statistic	Permutation used	Significant statistic	Significance level	
ANOSIM test 1					
Global Value: F *vs* NF	0.390	999	0	0.1%	**
ANOSIM test 2					
Global Value: L *vs* S	0.334	999	9	1.0%	**
ANOSIM test 3					
Global Value: F *vs* NF	0.451	999	1	0.2%	**
ANOSIM test 4					
Global Value: Station	0.503	999	0	0.1%	**
Parwise tests					
St.3 *vs* St.4	0.333	10	3	30.0%	ns
St.3 *vs* St.5	0.583	10	1	10.0%	ns
St.3 *vs* St.6	0.536	15	2	13.3%	ns
St.3 *vs* St.7	1.000	10	1	10.0%	ns
St.4 *vs* St.5	0.444	10	1	10.0%	ns
St.4 *vs* St.6	0.389	35	4	11.4%	ns
St.4 *vs* St.7	0.630	10	1	10.0%	ns
St.5 vs St.6	0.315	35	5	14.3%	ns
St.5 vs St.7	0.926	10	1	10.0%	ns
St.6 vs St.7	0.444	35	2	5.7%	ns

Due to the significant effect of the sampling gear detected by the ANOSIM test, further analyses and results will be presented separately for different types of sampler: L (large box-corer) and S (small box-corer). Area 1L: Fished zone, 0.318m^2 sampled with the large box-corer (St.1L: 0.255m^2 and St.2L: 0.063m^2). Area 2: Non-fished zone, divided in Area 2L, 0.115m^2 sampled with the large box-corer (St.3L: 0.053m^2 and St.4L: 0.063m^2) and Area 2S, 0.125m^{2}sampled with the small box-core (St.3S: 0.027m^2, St.4S: 0.045 m^2 and St.5S: 0.054 m^2).

Area 3S, Fished zone, 0.098m^2 sampled using the small box-corer (St.6S: 0.054 m^2 and St.7S: 0.045m^2).

3.2 Biodiversity and structure of the macrofaunal assemblages

The specimens collected during this study were organized in major groups: Polychaeta (Aciculata, Canalipalpata, Scolecida, Other Annelids), Mollusca (Heterodonta, Protobranchia, Pteriomorpha, Caenogastropoda, Heterobranchia, Vestigastropoda and Other Molluscs),Crustacea (Amphipoda, Cumacea, Isopoda, Tanaidacea and Other Crustacea) and Others, that include Priapulida, Sipuncula and Nemertea.

Biodiversity

Overall, the highest number of taxa (Figure 3.2, Table 3.3) was found at the replicate sample 1B-3(60 Families; 0.063 m^{2}sampled) whereas the lowest number occurred at replicate sample 3P-5 (8 Families; 0.009 m^2 sampled). When comparing Fished and Non-fished areas separately for the two types of gear the highest number of families was always found in the Fished zone (A1L: 94 and A3S: 62) and the lowest in the Non-fished zone(A2L: 33and A2S: 47) with no obvious differences in the relative contribution of the various taxonomical groups.

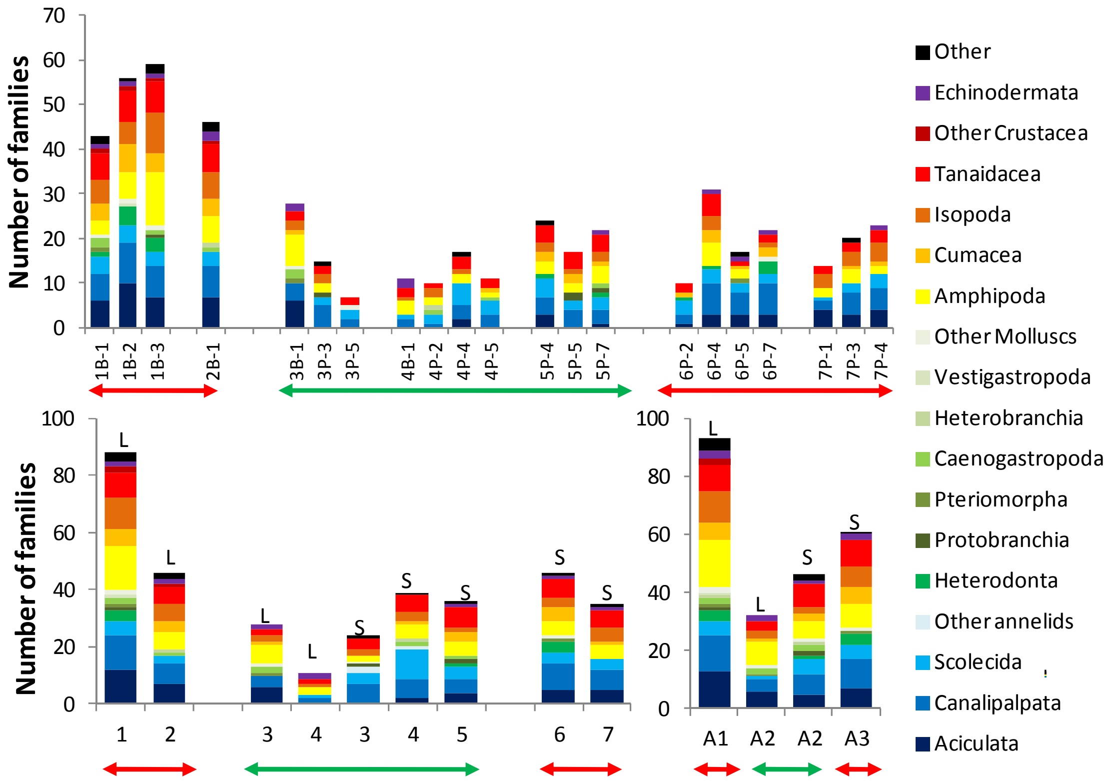

Figure 3.2.Taxa richness (families) of the major faunal groups per replicate sample (above) and pooled by type of sampler in stations(below left) and areas(below right). Note that replicates, stations and areas represent varying sampled seafloor surfaces (see text for details). L: large box-corer, S: small box-corer. Red arrows: Fished zones; Green arrows: Non-fished zones

Table 3.3.Biodiversity data for Families and Trophic Guilds. n: Sample abundance; F: Family richness; H': Shannon-Wiener diversity; J': Pielou's evenness; $EF_{(50)}$ and $EF_{(100)}$: Hurlbert's expected number of families per 50 and 100 individuals, respectively; $ETG_{(50)}$ and $ETG_{(100)}$: Hurlbert's expected number of trophic groups per 50 and 100 individuals, respectively

		Taxonomic groups					Trophic groups				
	n	**F**	**H'**	**J'**	**$EF_{(50)}$**	**$EF_{(100)}$**	**TG**	**H'**	**J'**	**$ETG_{(50)}$**	**$ETG_{(100)}$**
Replicates											
1B-1	195	44	3.23	0.854	23.6	33.4	15	2.06	0.760	10.9	13.3
1B-2	384	57	3.40	0.840	24.0	33.1	15	2.14	0.790	10.4	12.3
1B-3	308	60	3.51	0.857	26.3	37.8	16	2.18	0.786	11.2	13.2
2B-1	245	47	3.23	0.839	22.9	32.2	14	2.06	0.780	10.5	12.2
3B-1	218	29	2.48	0.737	15.1	20.7	11	1.65	0.690	7.8	9.3
3P-3	58	16	1.75	0.629	14.7	---	7	1.19	0.614	6.7	---
3P-5	18	8	1.74	0.834	---	---	4	1.01	0.731	---	---
4B-1	42	11	1.92	0.832	---	---	7	1.35	0.694	---	---
4P-2	20	11	2.11	0.879	---	---	7	1.63	0.840	---	---
4P-4	27	17	2.62	0.924	---	---	7	1.45	0.747	---	---
4P-5	23	11	2.11	0.882	---	---	5	1.42	0.880	---	---
5P-4	110	24	2.49	0.784	16.1	22.8	10	1.50	0.653	7.8	9.7
5P-5	40	17	2.68	0.945	---	---	7	1.55	0.798	---	---
5P-7	192	22	2.03	0.657	13.7	18.2	9	1.24	0.563	6.8	8.2
6P-2	15	11	2.30	0.961	---	---	6	1.67	0.935	---	---
6P-4	111	31	2.97	0.865	21.9	29.8	11	1.89	0.787	9.4	10.9
6P-5	46	18	2.56	0.886	---	---	10	1.60	0.696	---	---
6P-7	51	22	2.80	0.905	21.8	---	9	1.75	0.796	8.9	---
7P-1	33	15	2.38	0.878	---	---	6	1.66	0.924	---	---
7P-3	33	20	2.79	0.930	---	---	11	2.00	0.833	---	---
7P-4	41	24	3.01	0.946	---	---	9	1.90	0.865	---	---
Stations											
St.1L	887	89	3.75	0.836	27.8	39.8	18	2.21	0.763	11.0	12.9
St.2L	245	47	3.23	0.839	22.9	32.2	14	2.06	0.780	10.5	12.2
St.3L	218	29	2.48	0737	15.1	20.7	11	1.65	0.690	7.8	9.3
St.4L	42	11	1.92	0.832	---	---	7	1.35	0.694	---	---
St.3S	76	18	1.87	0.646	14.4	---	7	1.18	0.608	6.3	---
St.4S	70	26	2.78	0.852	21.1	---	11	1.69	0.707	9.6	---
St.5S	342	36	2.47	0.691	16.4	22.5	11	1.45	0.605	7.7	9.4
St.6S	223	47	3.23	0.840	23.1	32.8	12	1.90	0.764	9.5	10.9
St.7S	107	36	3.15	0.878	23.7	34.7	12	1.95	0.786	9.5	11.7
Areas											
A1L	1132	94	3.78	0.832	28.1	41.9	18	2.19	0.759	11.0	12.8
A2L	255	33	2.66	0.760	16.8	23.8	11	1.79	0.746	8.5	9.6
A2S	488	47	2.59	0.673	17.4	25.8	13	1.52	0.591	8.1	10.1
A3L	330	62	3.45	0.836	25.3	38.3	13	2.01	0.783	10.0	11.4

In general, lower diversity and evenness values were found in the Non-fished zone (Table 3.3). Replicate sample 3P-5 yielded the lowest diversity (H': 1.74) and sample 3P-3 the lowest evenness (0.629) while the highest values were found in replicates from the Fished zone (1B-3, H':3.51; 6P-2, J':0.961). The number of individuals collected by the small box-core was usually too low to allow the estimate of $EF_{(100)}$ or even $EF_{(50)}$ (Table 3.3). At station level, H' ranged 1.87-2.74 and 3.15-3.75 in Non-fished and Fished zones, respectively and J' ranged 0.646-0.852 and 0.836-0.878.

Estimates of Hurlbert's expected taxa richness (Table 3.3) are more robust to variability in the area sampled because they are rarefied to a standard number of individuals but they also show consistently higher values in the Fished zone (e.g. A1L, $EF_{(100)}$: 41.9; A3S, $EF_{(100)}$: 38.3) than in the Non-fished zone (A2L, $EF_{(100)}$: 23.8; A2S, $EF_{(100)}$;25.8).The rarefaction curves illustrate very clearly that: i) the biodiversity in the Fished zone is higher than in the Non-fished zone both at Station (Figure 3.3) and Area (Figure 3.4) levels; ii) the variability among stations in the Non-fished area is higher than in the Fished zone (Figure 3.3). Moreover, the proximity of the curves obtained from the samples collected with different samplers (Figure 3.4) confirms that these estimates are not strongly affected by the sample size and/or area sampled but the overall steepness of the curves also indicates that the sampling effort was insufficient to assess the full biodiversity of the different stations and areas (Figures 3.3 and 3.4).

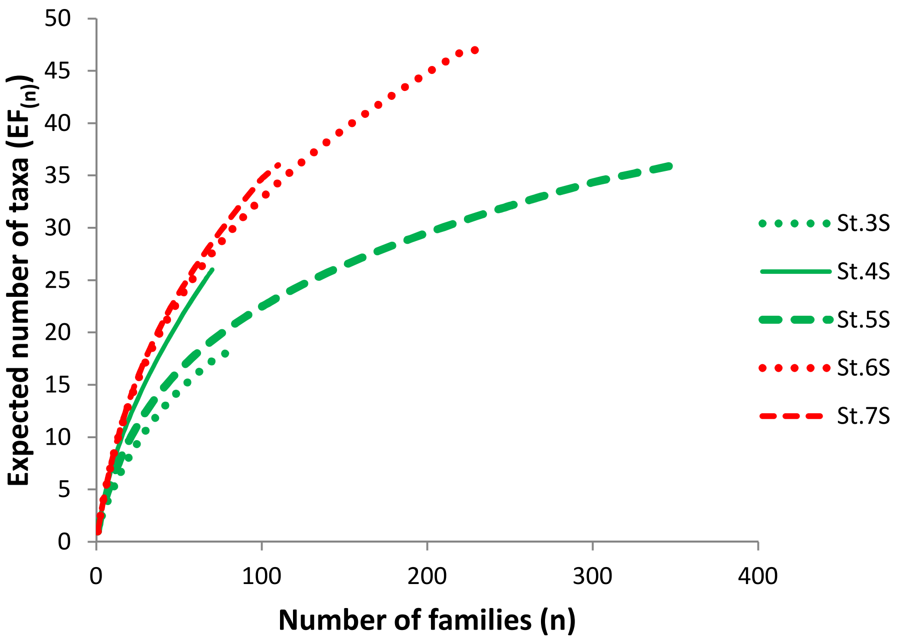

Figure 3.3. Rarefaction curves only for stations sampled with small box-corer. Red: Fished stations (St.6S and St.7S); Green: Non-fished stations (St.3S, St.4S and St.5S)

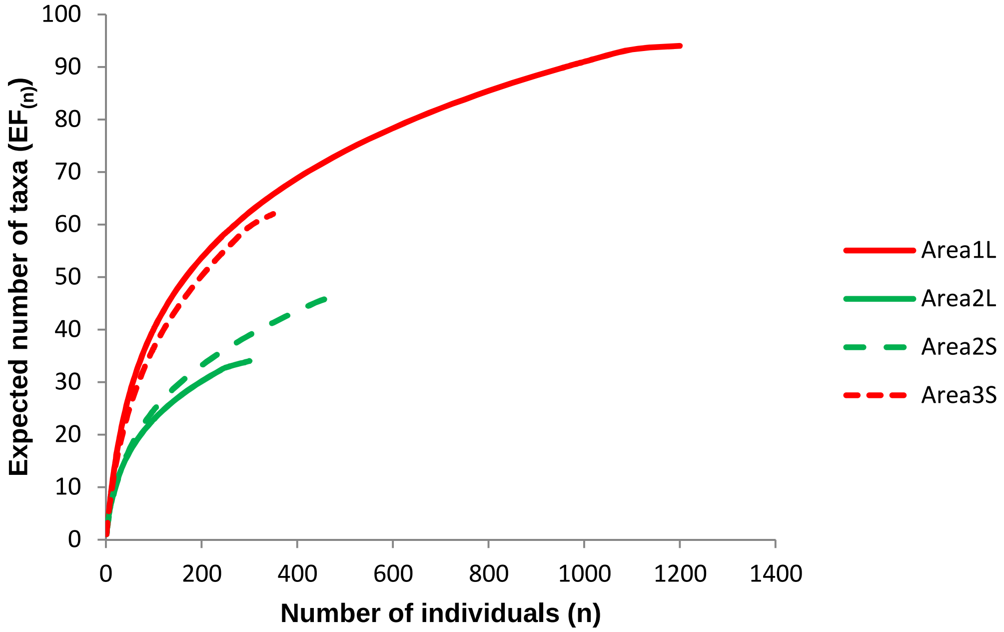

Figure 3.4.Rarefaction curves obtained with the pooled data for different samplers and areas. Red: Fished areas; Green: Non-fished areas; L: large box-core; S: small box-core

Density

Density values varied widely even among replicates of the same station and gear (Figure 3.5). The highest density value (108 ind.dm^{-2}), mainly due to the Tanaidacea occurrence, was estimated for 5P-7, whereas the lowest values occurred in 4B-1 and 4P-2 (8 and 11 ind.dm^{-2}, respectively), all representing the non-fished area. In terms of stations, St.5S showed the highest values of density (64 ind.dm^{-2}) and St.4L the lowest value (8 ind.dm^{-2}). Considering the large box-corer sampler the density was higher in the Fished zone (A1L: 35 ind.dm^{-2}) than in the Non-fished zone (A2L: 22 ind.dm^{-2}), whereas the opposite trend was found in the areas sampled with the small box-corer with higher densities for the Non-fished zone (A2S: 39 ind.dm^{-2}) than in the Fished zone (A3S: 34 ind.dm^{-2}). However, these differences are very small and not significant, owing to the high variability among replicates.

In terms of density the structure of the assemblages showed important variations of the contributions of different taxa (Figure 3.5). Crustaceans, particularly tanaids, were more abundant in the Non-fished zone whereas the polychaetes, particularly the Aciculata, were more abundant in the Fished zones. Noteworthy is the occurrence of Echinodermata (crinoids) in the Non-fished area but only in samples taken with the large box-corer (3B-1 and 4B-1).

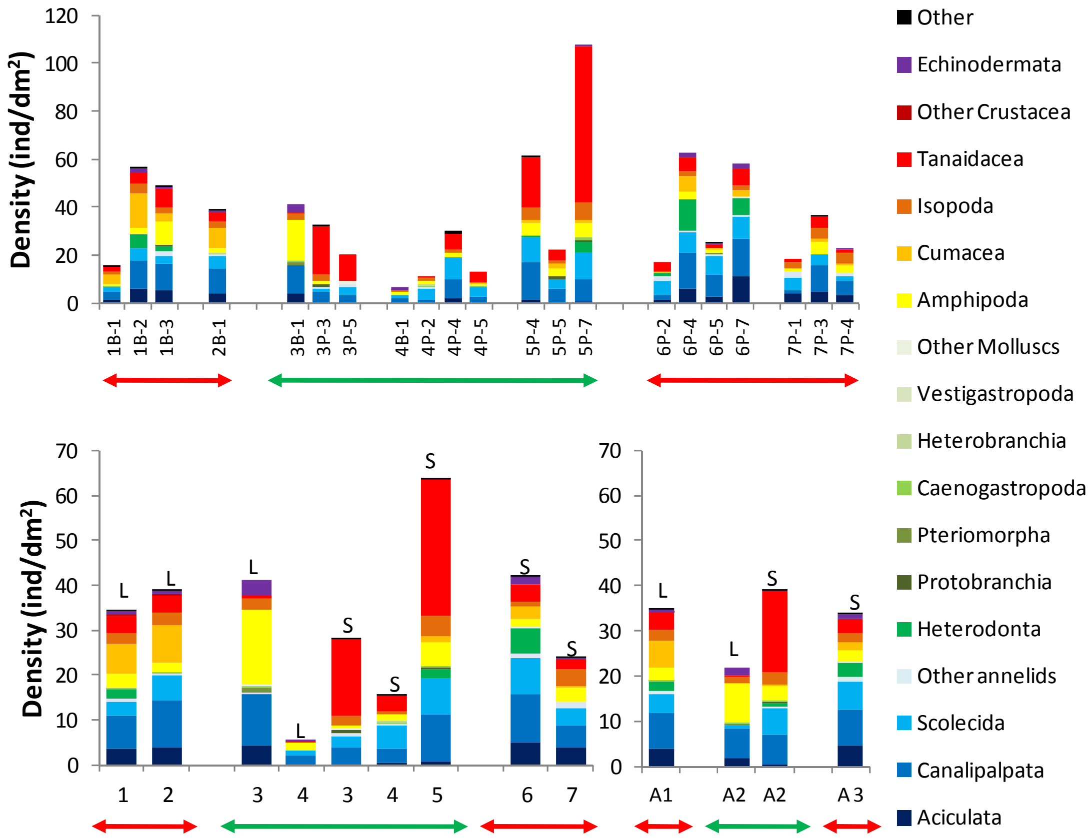

Figure 3.5. Density values (number of individuals per dm^2) of the major faunal groups per replicate sample (above) and pooled by type of sampler in stations(below left) and areas (below right). Note that replicates, stations and areas represent varying sampled seafloor surfaces (see text for details).L: large box-corer, S: small box-corer. Red arrows: Fished zones; Green arrows: Non-fished zones

Biomass

For biomass analysis Cnidaria and Porifera were also considered owing to their meaningful contributions for the total biomass measured at 6P-4, 7P-3 and 7P-4 (Figure 3.6). Replicate samples 3B-1 and 4B-1 sampled with the large box-corer in the Non-fished area showed the highest biomass per surface area (0.4371 and 0.6979 $g_{FW}.dm^{-2}$, respectively), for which crinoids specimens had an overwhelming contribution. Other major contributors to the total biomass were the bivalves (including shell weight) Heterodonta (1B-1, 1B-3 and 6P-4, all from Fished zones) and Pteriomorpha (3B-1, Non-fished zone), and the polychaetes (6P-7 and7P-3, both from Fished zone). Crustaceans had residual contributions for the total biomass. The lowest biomass was measured in 3P-5 (0.0013 $g_{FW}.dm^{-2}$).

The comparison of Fished and Non-fished zones (Figure 3.6 below right) reveals different results according to the gear used: Non-fished areas showed higher biomass than Fished areas when the larger gear was used (A2L: 0.5788 $g_{FW}.dm^{-2}$ *vs* A1L: 0.1033 $g_{FW}.dm^{-2}$), but when the smaller gear was used the Fished area yielded higher biomass than the Non-fished area (A3S: 0.1309 $g_{FW}.dm^{-2}$ *vs* A2S: 0.0231 $g_{FW}.dm^{-2}$).

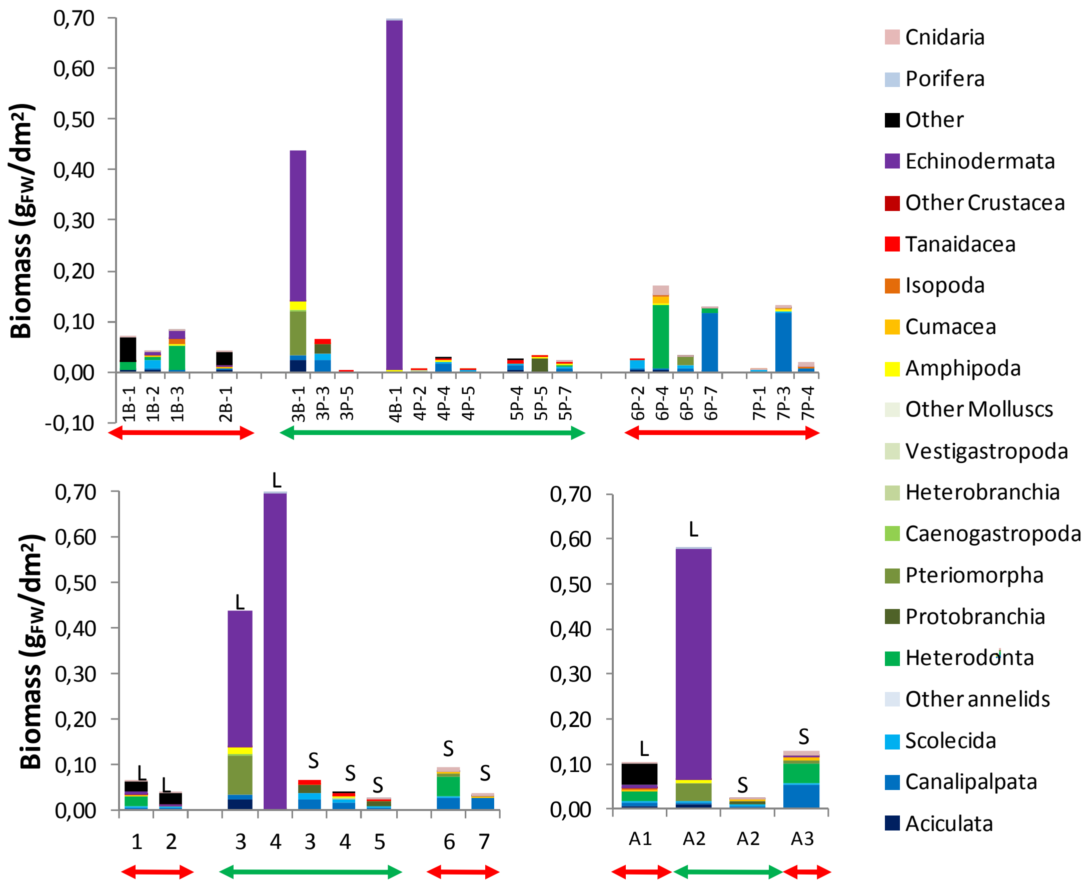

Figure3.6.Biomass values of the major faunal groups per replicate sample (above) and pooled by type of sampler in stations (below left) and areas (below right). Note that replicates, stations and areas represent varying sampled seafloor surfaces (see text for details). L: large box-corer, S: small box-corer. Red arrows: Fished zones; Green arrows: Non-fished zones

Body size spectrum

The body size spectrum of the assemblages was assessed by determining the individual average biomass (IAB) for each family in each replicate sample (dividing the value of the biomass by the number of individuals weighted). The distribution of the estimated body sizes is represented in Figure 3.7. While in the stations sampled with the large box-core the average body size is clearly higher in Non-fished (St.3L, St.4L) than in Fished stations (St.1L, St.2L) such pattern is not obvious in the stations samples with the small box-core.

The largest individuals (higher IAB) were crinoids and occurred in St.3L and St.4L in the Non-fished zone, but were only collected by the large box-core. The station with lower values of mean IAB is St.5S (also in the Non-fished zone) owing to the high dominance of very small tanaids.

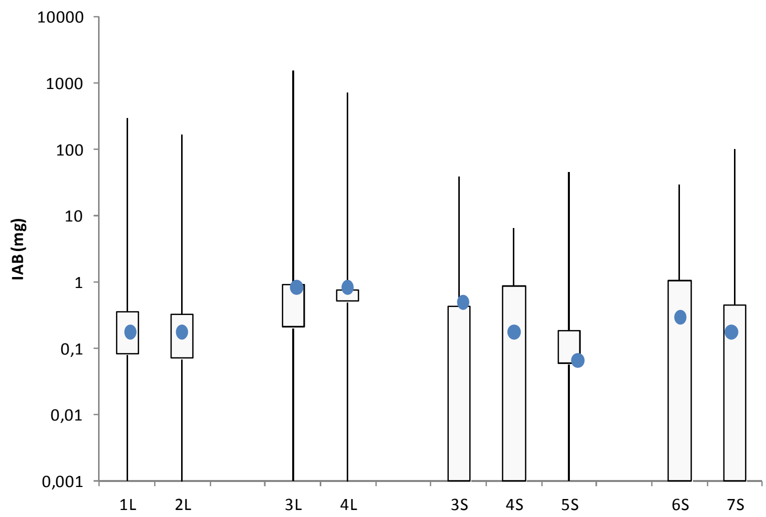

Figure 3.7. Individual Average Biomass (IAB) in mg. the line represents the range (minimum to maximum IAB), the boxes include the 1st to 3rd quartile and the blue markers are the mean value for each station. In several cases the 1st quartile coincides with the minimum and the average coincides with the 3rd (or with the 1st) quartile

3.3 TROPHIC STRUCTURE OF THE MACROFAUNAL ASSEMBLAGES

The taxa found in the study area were ascribed to a total of 18(+1 unknown) different trophic guilds (Annex 2). The main contributions of the different feeding guilds in terms of abundance and biomass are shown in Table 3.4. Overall, surface deposit feeders (SR-De) and surface detritus feeders (SR-Dt) are the greatest contributors to abundance (mainly polychaetes and crustaceans, see Annex 3 for details) while the biomass is dominated by epibenthic suspension feeders (EP-Su) and surface suspension-feeders (SR-Su, mainly crinoids, and some polychaete and bivalve families, see Annex 3 for details).

Table 3.4.Top five dominant trophic guilds in terms of abundance and biomass. Combo code: defined according to four features (Food Source, Diet, Food Type/size and Feeding mode). SR: surface; EP: epibenthic; SS: subsurface; De: deposit feeder; Dt: detritus feeder; Su: suspension feeder; Pr: predator; mei: meiofuna; Mix: mixed groups

Combo code	Abun	Biom
SR-De	D1	D3
SR-Dt	D2	---
EP-Su	D3	D2
SS-Pr-mei	D4	D4
SR-Su	D5	D1
Mix	---	D5

Trophic diversity

Four to 17 trophic guilds(3P-5 and 1B-3, respectively) were present in each replicate samples (Table 3.3) and both surface (SR) and subsurface (SS) feeding animals were present in all replicate samples (Figure 3.8). In terms of abundance, surface deposit feeders were major contributors in all stations except St.3L but surface detritus feeders were the dominant guild in St.3S, St.4S and St.5S (all from Non-fished zone, Figure 3.8below left).Suspension feeders (both epibenthic and surface) were dominant in St.3L and to a lesser extent also in St.4L both from the Non-fished zone, while predators yielded important contributions in St.1L, St.2L, St.6S, St.7S, all from Fished zones(and alsoin St.3L, Non-fished). All together in terms of trophic structure, stations from Fished areas were more homogeneous and showed higher dominance of surface deposit feeders and predators than the ones from Non-fished areas (Figure 3.8below right).

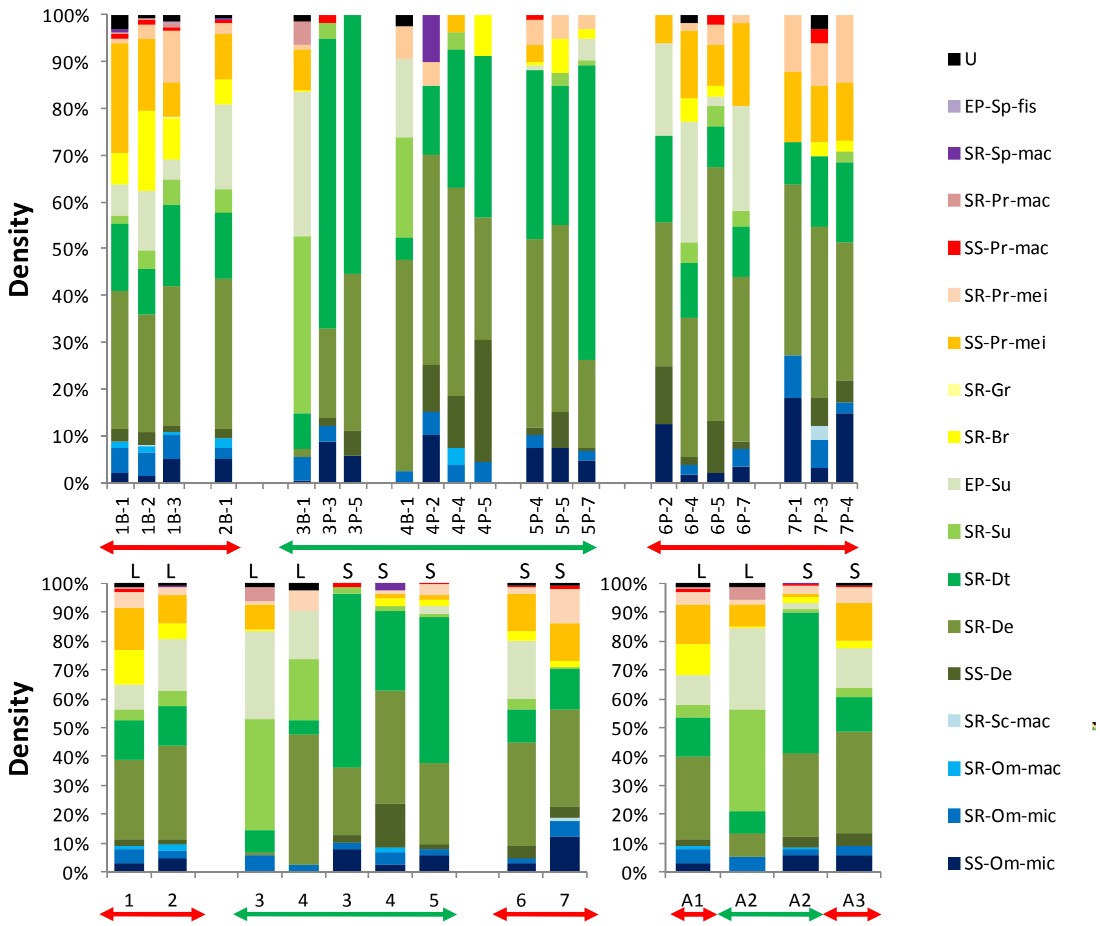

Figure 3.8. Trophic structure of the macrofaunal assemblages in terms of density. Relative contributions (%) of the trophic guilds are shown per replicate sample (above) and pooled by type of sampler in stations (below left) and areas (below right). Note that replicates, stations and areas represent varying sampled seafloor surfaces (see text for details) L: large box-corer, S: small box-corer. Red arrows: Fished zones; Green arrows: Non-fished zones. Combination codes defined as in Annex 2

Trophic diversity and evenness showed the same trends observed for the taxonomical structure of the assemblages: in general, lower diversity and evenness values were found in the Non-fished zone (Table 3.3). Replicate sample 3P-5 yielded the lowest diversity (H': 1.01) and sample 5P-7 the lowest evenness (0.563) while the highest values were found in replicates from the Fished zone (1B-3, H': 2.18; 6P-2, J':0.935). At station level, H' ranged 1.18-1.69 and 1.90-2.21 in Non-fished and Fished zones, respectively and J' ranged 0.605-0.707 and 0.763-0.780.Estimates of Hurlbert's expected trophic guild richness (Table 3.3) also show consistently slightly higher values in the Fished zone (e.g. A1L, $ETG_{(100)}$: 12.8; A3S, $ETG_{(100)}$: 11.4) than in the Non-fished zone (A2L, $ETG_{(100)}$: 9.6; A2S, $ETG_{(100)}$10.1).

Biomass

In terms of biomass (Figure 3.9) the results showed much higher heterogeneity than the ones relative to abundance and there were marked differences between stations sampled with different gear.

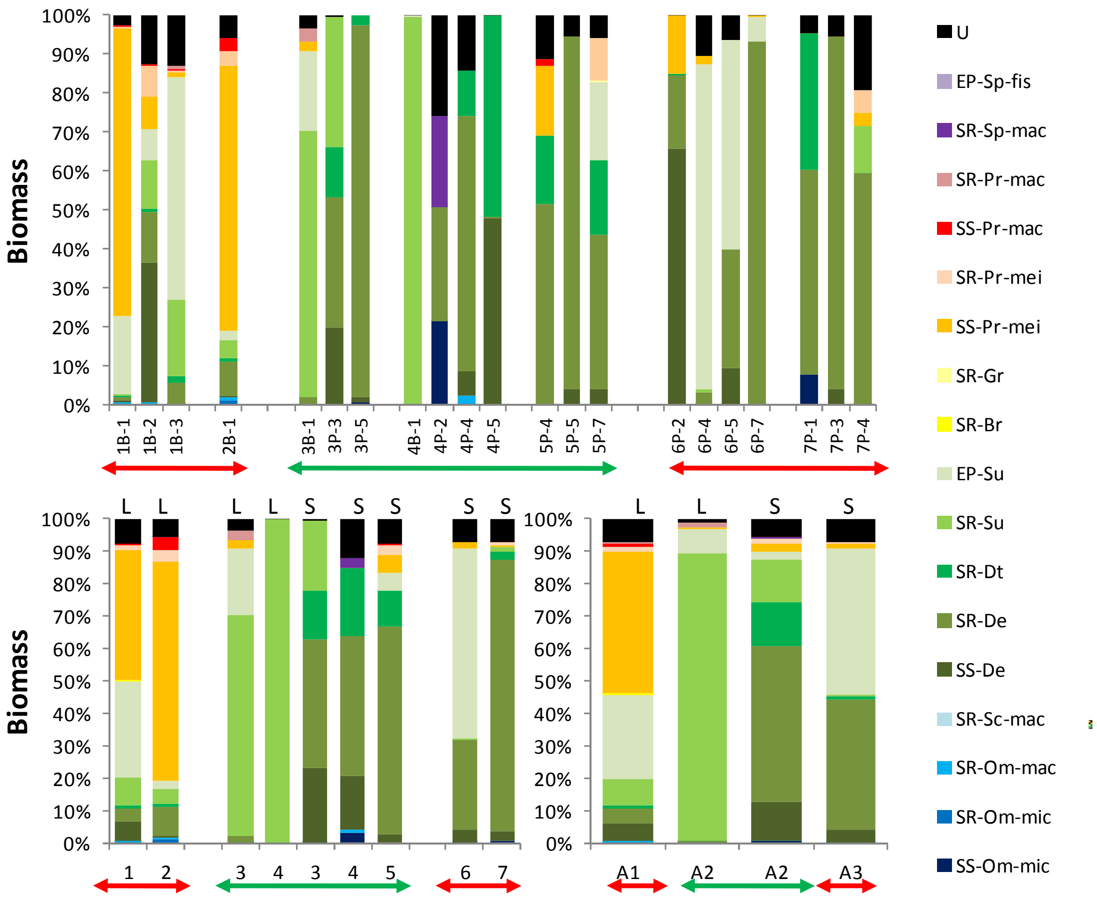

Figure 3.9. Trophic structure of the macrofaunal assemblages in terms of biomass. Relative contributions (%) of the trophic guilds are shownper replicate sample (above) and pooled by type of sampler in stations(below left) and areas (below right). Note that replicates, stations and areas represent varying sampled seafloor surfaces (see text for details). L: large box-corer, S: small box-corer. Red arrows: Fished zones; Green arrows: Non-fished zones. Combination codes defined as in Annex 2

St.3L and St.4L(Non-fished zone, large box-corer) showed a dominance of surface suspension feeders mostly due to the presence of Crinoidea which contributed with more than 70% and 95% for the total biomass of these stations, respectively. Altogether, predators (Pr) were more notorious at St.1L and St.2L (Fished zone, Large box-core). Most of the biomass collected with the small box-core was ascribed to surface deposit feeders but subsurface deposit feeders, surface detritus feeders and surface suspension feeders were also well represented in stations of the Non-fished zone and epibenthic suspension feeders in St.6S (Fished zone).

3.4 Life style spectrum of the macrofaunal assemblages

Taxa were grouped according to their life style totaling eight categories (Figure 3.10). The stations from Fished zones showed higher homogeneity even among stations sampled with different gear.

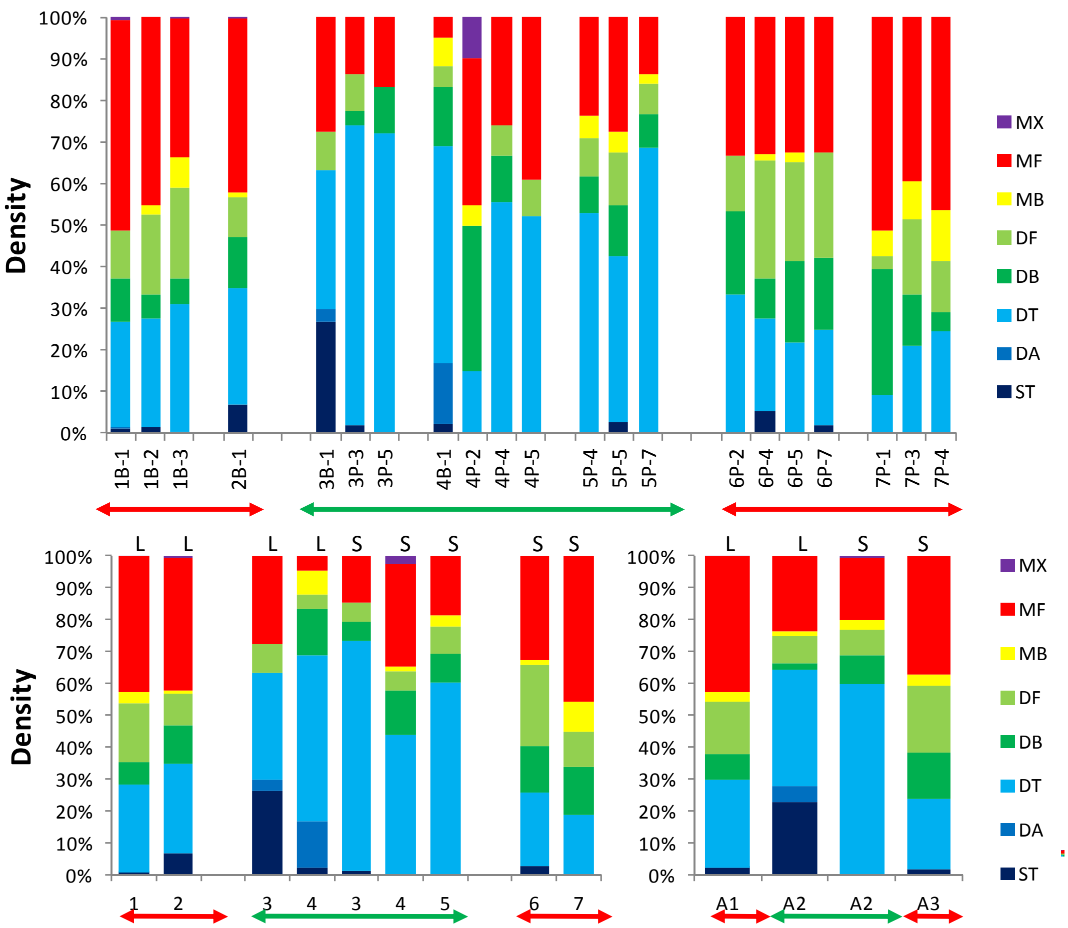

Figure 3.10. Life style spectrum of the macrofaunal assemblages (by density).Relative contributions (%) of the life-style categories per replicate sample (above) and pooled by type of sampler in stations(below left) and areas (below right). Note that replicates, stations and areas represent varying sampled seafloor surfaces (see text for details). L: large box-corer, S: small box-corer. Red arrows: Fished zones; Green arrows: Non-fished zones. Combination codes defined according to Annex 3

A pattern between Fished and Non-fished zones was observed (Figure 3.7 below, right): free living organisms showed higher relative contributions to abundance in Fished areas (MF: 37-42%; DF: 17-21%) than in Non-fished areas (MF: 20-24%; DF: 8-8%), whereas tube-dwellers show an opposite trend (Fished zone DT: 21-28%, ST: ca.2%; Non-fished zone DT: 37-60%, ST: 1-23%).

4 Discussion

Fisheries are a significant source of food for Human populations worldwide but, in order to ensure their sustainability, urgent management measures based on scientific evidence have to be taken. The development of fishing industry during the last century threatens not only the targeted species but also other components of the biological assemblages and the integrity of the habitats (Tyler-Waters *et al*. 2009). Among the various fishing techniques, bottom trawling is one of the most destructive.

Problems that might be associated with intense and prolonged bottom fishing disturbance have only been examined in the last 20 years, however the bottom fishing fleets have been operating for much longer. The biological assemblages that are observed at the present time may be the product of decades of continuous fishing disturbance (Bergman and Hup 1992, Dayton *et al*. 1995). In Portugal some regions, such as the area studied herein, have been impacted for over 60 years and, most probably, they are not maintaining the same biological structure and ecosystem functioning that they had before the fishing disturbance.The traditional and putatively ideal methodological approach to study “before and after impact” is problematical in the case of trawling fisheries. Because all areas that can actually be fished have been continuously impacted for so long, and every time at increasing depths, it has proven extremely difficult to find otherwise reasonably similar control areas not impacted by fishing (Dayton *et al*. 1995). Moreover, there are only few cases where the environmental background is sufficiently studied to support an adequate sampling design.

In the present study, the criteria for the selection of the study area were based on the knowledge of the local experienced skippers and an environmental study was carried out during the macrofaunal benthic sampling. In fact, sediment samples taken during the cruise (E. Salgueiro, unpublished data) revealed that grain size structure varied along the studied transect with coarser sediments in the first stations (St.1-St.4) and an important increase of clay and silt towards the last stations (St.5-St.7). Oceanographic variables (salinity, temperature, oxygen, fluorescence, turbidity, transmittance and PAR/irradiance) were also measured along the transect and a significant anomaly consisting in a water mass with lower values of temperature, salinity, oxygen and turbidity was detected. This anomalous water mass interacts with the seafloor mainly at St.3 and St.4 (Castro *et al.* 2013). A survey conducted later using a Remotely Operated Vehicle (ROV) revealed that the seafloor in this part of the transect (St.3 and St.4) is an enclave of gravely sand covered by a field of crinoids(*Leptometra celtica*) and a rich associated benthic megafauna (Fonseca *et al.* in press).

The environmental characteristics of the study area were fundamental for the results obtained in the present study because: i) they affected the sample strategy – the coarser sediments of the first stations rendered inoperative the large box-core and therefore two types of sampling gear were used and a wider range of depths was covered contrary to the initial plans; ii) they introduced additional sources of variability for the faunal assemblages which were not consistent with the areas previously determined as control (Non-fished) and impact (Fished).

Although the results of the multivariate analysis support a significant difference between Fished and Non-fished zones the interpretation of the observed taxonomic and trophic structure of the assemblages is far more complex and must take into account these sources of variability. The passage of fishing trawlers has effects on benthic communities that are not uniform; they depend on the history of human activities and type of fishing gear used, but they also can vary with specific abiotic properties(e.g. seafloor, water masses) of the habitat and biotic features (e.g. foundation or habitat-forming species) of the benthic assemblages (Løkkeborg 2005).

4.1 IMPACT OF TRAWLING

Habitat disturbance by fishing gear that removes surface dwelling organisms, modifies sediment topography, and occurs over large spatial scale, is expected to reduce the heterogeneity of benthic communities. The expected response of these communities to the stress caused by the physical disturbance of trawling activities is a reduction in taxa richness through elimination of rare and/or sensitive species, and an increase in the dominance of a few relatively tolerant species, as well as the reduction in mean body size of dominant species, and an overall decrease in biomass (Gray 1989, Chicharo *et al*. 2002, Gage *et al*. 2005, Løkkeborg 2005). Although the observed assemblages from Fished zones show less heterogeneity than the ones from Non-fished zones in the study area, the results obtained by comparing the biodiversity (number of families, H', $EF_{(n)}$), density and biomass in Fished and Non-fished zones are inconclusive, inconsistent or even contradict most of the predictions. As mentioned above, there may be confounding effects of the sampling methodology and environmental variability, but in fact there is also a lack of comprehensive literature describing the sensitivity and recoverability of benthic species to physical disturbances such as the one caused by trawling (Tyler-Waters *et al*. 2009). Another fundamental problem is that, owing to the areal extension and duration of trawling fisheries on the Portuguese margin, most of the seafloor and associated benthic assemblages are likely to have suffered some kind of impact and are probably a product of this long-term disturbance (Bergman and Hup 1992, Dayton *et al*. 1995) rendering more difficult any kind of impact assessment.

There are many ways to describe biological assemblages besides comparing their biodiversity. For example, in terms of the information that is exchanged as their components interact, or in terms of size spectra. But according to Pauly *et al*. (2002) "one of the most straightforward ways to describe ecosystems is in terms of the feeding interactions among their component species". Moreover, knowledge on the structural or functional role of benthic species is of utmost importance to assess their sensitivity and recoverability to physical disturbance (Tyler- Walters *et al*. 2009). Biological traits (general biology, feeding habits, habitat preferences, reproduction and life history traits) can be used in the development of combined assessment methods at a community scale (Tyler-Walters *et al*. 2009).

When the trophic structure and life style spectra of the assemblages are compared the decreased heterogeneity of the Fished zones is confirmed but other patterns emerge. The higher relative contribution of free living organisms in Fished zones can be interpreted as a community response to the frequent passage of trawling gear, in contrast with the higher relative contribution of tubiculous animals in Non-fished zones as sessile or less mobile organisms are more intolerant to physical disturbance. The continued sediment mobilization by the frequent passage of trawlers, leading to a more homogeneous distribution of organic matter and grain sizes in Fished zones may determine the dominance of deposit feeders over detritus feeders in Fished areas. On the other hand, the dominance of surface detritus feeders in Non-fished zones is consistent with a patchy distribution of particulate organic matter in less or no disturbed seafloor. Undisturbed conditions are also compatible with the presence of large suspension feeders (e.g. crinoids) in the Non-fished zones, while the higher relative contribution of meiofaunal predators, and to a lesser extent also grazers and browsers, may be interpreted as an opportunistic response of usually highly mobile organisms to higher food availability which may result from the resuspension of surficial sediments.

4.2 SAMPLER EFFECT

Due to technical problems, the large USNEL box-corer became inoperative during the sample collection and sampling strategy was subsequently adapted by using a smaller box-corer. This change of the initial strategy had two different implications: i) the area sampled in stations where the small box-core was used was smaller, because time constraints did not allow increasing sufficiently the number of replicates per station; ii) the operational features of a small box-core may lead to a frequent exclusion of large animals from the sample, as well as to a higher disturbance of the surface sediments and subsequent undersampling of some taxa. A typical example is that in St.3 and St.4, that are characterised by a vast crinoid field (Fonseca *et al*. in press), crinoid specimens were only sampled by the large box-core.

These issues lead to differences in the total biomass and numbers of taxa sampled by the two samplers and have obvious repercussions in biodiversity and body size spectra assessments. The total abundance, number of families, total biomass and maximum body size of the individuals were higher in replicate samples taken with the large box-core and therefore biodiversity, density and body size spectrum assessments were much more satisfactory and representative in the stations sampled with this gear.

More importantly, comparisons of Fished and Non-fished zones yielded different results according to the type of sampler used. Some of the trends illustrated by sampling with the large box-core are more consistent with the prediction that one of the physical disturbance effects of trawling is the reduction in mean body size of dominant species, and a decrease in total biomass (Gage *et al*. 2005). For instance, the total biomass, the size spectrum range and the mean IAB were higher in A2L (Non-fished) than in A1L (Fished). Differences in the functional structure (trophic guild and life style) although notoriously less evident, may also occur but cannot be easily interpreted.

4.3 ENVIRONMENTAL VARIABILITY

Environmental conditions determine species distributions but the habitat preferences of different species are intimately related to their morphology, feeding habits and life styles. On the other hand, both the abiotic and biotic features of an ecosystem are relevant to its recoverability from disturbance (Gage *et al*. 2005,Løkkeborg 2005,Tyler-Walters *et al*. 2009). “The magnitude of changes which can be attributed to fishing often depends upon the nature of the physical environment in which a given habitat is found” (Jennings and Kaiser 1998). This is of utmost importance, especially when an “impact/no-impact” design is adopted instead of a “before/after impact” because the environmental variability between and within the areas compared may overlay, mask or confound the results. This is probably the case in the study area where the most prominent features of environmental variability are the grain size gradient along the sampling transect, and the anomalous water mass that affects two of the three stations of the Non-fished zone.

Grain size as a great influence on the composition and structure of the benthic assemblages and on the fishing impact to these assemblages(Gage *et al*. 2005), and in this respect St.3 and St.4 (Non-fished) are more comparable to St.1 and St.2 (Fished) while sediment properties of St.5 (Non-Fished) are closer to the ones in St.6 and St.7 (Fished). This means that more replicate stations of the same sediment type would clarify some of the observed patterns in biodiversity, abundance and community structure.

Concerning the anomaly in the oceanographic conditions affecting St.3 and St.4, there is an apparent correlation to the presence of the crinoids field (Fonseca *et al*. in press) although this observation requires further in-depth investigation. Nevertheless, it is obvious that this water mass introduces a source of environmental variability and habitat heterogeneity in the Non-fished zone that has no match in the Fished zone. Also, the observed anomalies (low temperature, low salinity, low oxygen) are likely to limit the occurrence and density of some sensitive species and/or alter the composition and structure of the benthic assemblage in relation to the surrounding habitats.

4.4 FINAL REMARKS

This study provides new knowledge on the biodiversity and structure of benthic assemblages from the upper slope of the Portuguese continental margin, with relevance for the understanding and assessment of trawling fishery impacts on marine ecosystems. Some methodological issues arose which can be used as recommendations for future assessments of trawling impacts and monitoring of seafloor integrity:

1. Sampling strategy is of utmost importance: i) selection of adequate control area(s) must consider habitat heterogeneity, and therefore a previous environmental survey is highly recommended; ii) selection of the sampling gear must consider the possible selectivity of smaller samplers, and therefore the use of USNEL type box-cores or other large sampler is advised; iii) the number of replicates per station affects directly the total area sampled and the possibility of performing adequate statistical analyses; it has consequences on the representativeness of biodiversity, abundance and biomass assessments and on the significance of the comparative tests; therefore it is recommended that the number of replicates per stations should be as high as possible although limited by time and other logistic issues.
2. The effects of trawling disturbance are reflected in many different features of the biological assemblages. Besides the more traditional analysis of biodiversity, trophic

structure, life style and body size spectra showed to be good indicators of change and therefore they should become a more common tool on the assessment of trawling impact.

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Annexes

Annex 1

Table 1.All families, or lowest taxa classification, and corresponding values of Abundance (Abund), Frequency (Freq), Minimum value of abundance (Min) and Maximum value of abundance (Max).

Phylum	Subphylum	Class	Subclass	Order	Family	Min	Max	Abund	Freq
Annelida		Polychaeta	Aciculata	Eunicida	Dorvilleidae	1	1	2	2
Annelida		Polychaeta	Aciculata	Eunicida	Eunicidae	1	1	3	3
Annelida		Polychaeta	Aciculata	Eunicida	Lumbrineridae	1	2	7	6
Annelida		Polychaeta	Aciculata	Eunicida	Onuphidae	1	5	16	5
Annelida		Polychaeta	Aciculata	Phyllodocida	Pholoidae	1	12	15	3
Annelida		Polychaeta	Aciculata	Phyllodocida	Polynoidae	1	1	1	1
Annelida		Polychaeta	Aciculata	Phyllodocida	Glyceridae	1	8	28	10
Annelida		Polychaeta	Aciculata	Phyllodocida	Hesionidae	1	8	15	7
Annelida		Polychaeta	Aciculata	Phyllodocida	Nereididae	1	1	1	1
Annelida		Polychaeta	Aciculata	Phyllodocida	Pilargidae	1	5	6	2
Annelida		Polychaeta	Aciculata	Phyllodocida	Syllidae	2	17	69	11
Annelida		Polychaeta	Aciculata	Phyllodocida	Phyllodocidae	1	7	21	9
Annelida		Polychaeta	Aciculata	Phyllodocida	Nephtyidae	1	1	2	2
Annelida		Polychaeta	Aciculata	Phyllodocida	Sphaerodoridae	1	1	1	1
Annelida		Polychaeta	Canalipalpata	Sabellida	Oweniidae	1	2	6	5
Annelida		Polychaeta	Canalipalpata	Sabellida	Sabellidae	1	58	88	8
Annelida		Polychaeta	Canalipalpata	Spionida	Magelonidae	1	3	9	6
Annelida		Polychaeta	Canalipalpata	Spionida	Poecilochaetidae	1	1	1	1
Annelida		Polychaeta	Canalipalpata	Spionida	Spionidae	1	22	147	20
Annelida		Polychaeta	Canalipalpata	Spionida	Chaetopteridae	1	2	5	4
Annelida		Polychaeta	Canalipalpata	Terebellida	Acrocirridae	1	2	3	2
Annelida		Polychaeta	Canalipalpata	Terebellida	Cirratulidae	1	19	93	17
Annelida		Polychaeta	Canalipalpata	Terebellida	Fauveliopsidae	1	3	4	2

Phylum	Subphylum	Class	Subclass	Order	Family	Min	Max	Abund	Freq
Annelida		Polychaeta	Canalipalpata	Terebellida	Flabelligeridae	2	42	44	2
Annelida		Polychaeta	Canalipalpata	Terebellida	Sternaspidae	1	1	1	1
Annelida		Polychaeta	Canalipalpata	Terebellida	Ampharetidae	1	34	79	15
Annelida		Polychaeta	Canalipalpata	Terebellida	Terebellidae	1	1	5	5
Annelida		Polychaeta	Canalipalpata	Terebellida	Trichobranchidae	1	3	7	5
Annelida		Polychaeta	Scolecida		Capitellidae	1	1	2	2
Annelida		Polychaeta	Scolecida		Cossuridae	1	6	16	6
Annelida		Polychaeta	Scolecida		Maldanidae	1	3	15	11
Annelida		Polychaeta	Scolecida		Opheliidae	1	6	33	13
Annelida		Polychaeta	Scolecida		Orbiniidae	1	1	3	3
Annelida		Polychaeta	Scolecida		Paraonidae	1	22	123	19
Annelida		Polychaeta			Undetermined	1	1	2	2
Annelida		Clitellata	Oligochaeta		Undetermined	1	11	29	12
Mollusca		Bivalvia	Heterodonta	Anomalodesmata	Cuspidariidae	1	1	1	1
Mollusca		Bivalvia	Heterodonta	Lucinoida	Thyasiridae	1	2	4	3
Mollusca		Bivalvia	Heterodonta	Veneroida	Cardiidae	2	2	2	1
Mollusca		Bivalvia	Heterodonta	Veneroida	Kelliellidae	1	32	75	7
Mollusca		Bivalvia	Heterodonta	Veneroida	Semelidae	1	7	13	3
Mollusca		Bivalvia	Protobranchia	Nuculanoida	Nuculanidae	1	4	8	4
Mollusca		Bivalvia	Protobranchia	Nuculida	Nuculidae	1	1	1	1
Mollusca		Bivalvia	Pteriomorphia	Arcoida	Arcidae	1	6	7	2
Mollusca		Bivalvia	Pteriomorphia	Pectinoida	Pectinidae	1	1	1	1
Mollusca		Bivalvia			Undetermined	1	2	5	4
Mollusca		Caudofoveata		Chaetodermatida	Chaetodermatidae	1	1	2	2
Mollusca		Gastropoda	Caenogastropoda	Caenogastropoda	Eulimidae	1	1	1	1
Mollusca		Gastropoda	Caenogastropoda	Caenogastropoda	Cerithiopsidae	1	1	1	1
Mollusca		Gastropoda	Caenogastropoda	Littorinimorpha	Rissoidae	1	2	7	6

Phylum	Subphylum	Class	Subclass	Order	Family	Min	Max	Abund	Freq
Mollusca		Gastropoda	Caenogastropoda		Undetermined	1	1	1	1
Mollusca		Gastropoda	Heterobranchia		Pyramidellidae	1	1	2	2
Mollusca		Gastropoda	Vetigastropoda		Undetermined	1	1	1	1
Arthropoda	Chelicerata	Pycnogonida			Undetermined	1	1	1	1
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Cyproideidae	1	4	5	2
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Phoxocephalidae	1	22	55	13
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Oedicerotidae	2	2	6	3
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Ampeliscidae	1	23	32	6
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Aoridae	1	1	2	2
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Lysianassidae	1	1	2	2
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Dulichiidae	8	8	8	1
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Caprellidae	1	1	1	1
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Corophiidae	1	3	6	3
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Talitridae	1	1	1	1
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Amphilochidae	1	3	7	5
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Gammaridae	1	1	1	1
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Pleustidae	2	2	2	1
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Carangoliopsidae	1	3	9	5
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Eriopisidae	1	4	13	7
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Photidae	2	41	55	4
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Ischyroceridae	1	1	1	1
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Stenothoidae	7	7	7	1
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Amphipoda	Undetermined	1	11	19	8
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Cumacea	Bodotriidae	1	2	7	4
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Cumacea	Diastylidae	1	16	53	8
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Cumacea	Lampropidae	2	8	13	3
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Cumacea	Leuconidae	1	2	5	4

Phylum	Subphylum	Class	Subclass	Order	Family	Min	Max	Abund	Freq
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Cumacea	Nannastacidae	1	26	51	8
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Cumacea	Pseudocumatidae	1	29	36	4
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Cumacea	Undetermined	1	7	9	3
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Isopoda	Anthuridae	1	1	2	2
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Isopoda	Desmosomatidae	1	9	56	14
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Isopoda	Paramunnidae	1	4	10	5
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Isopoda	Munnopsidae	1	14	37	12
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Isopoda	Munnidae	1	9	16	4
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Isopoda	Leptanthuridae	1	2	3	2
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Isopoda	Ischnomesidae	1	4	9	4
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Isopoda	Gnathiidae	1	1	1	1
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Isopoda	Janirellidae	1	4	5	2
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Isopoda	Nannoniscidae	1	1	3	3
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Isopoda	Undetermined	1	2	4	3
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Mysida	Mysidae	1	2	5	3
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Tanaidacea	Agathotanaidae	1	18	35	9
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Tanaidacea	Anarthruridae	1	6	15	5
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Tanaidacea	Apseudidae	1	2	3	2
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Tanaidacea	Colletteidae	1	12	42	7
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Tanaidacea	Leptocheliidae	2	2	2	1
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Tanaidacea	Leptognathiidae	1	3	10	6
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Tanaidacea	Nototanaidae	1	9	15	3
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Tanaidacea	Pseudotanaidae	1	4	11	5
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Tanaidacea	Tanaellidae	1	97	210	15
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Tanaidacea	Typhlotanaidae	1	5	18	7
Arthropoda	Crustacea	Malacostraca	Eumalacostraca	Tanaidacea	Undetermined	1	4	18	9
Echinodermata	Echinozoa	Holothuroidea			Undetermined	1	1	1	1

Phylum	Subphylum	Class	Subclass	Order	Family	Min	Max	Abund	Freq
Echinodermata	Crinozoa	Crinoidea			Undetermined	1	6	7	2
Echinodermata	Asterozoa	Ophiuroidea		Ophiurida	Amphiuridae	1	18	43	6
Echinodermata	Asterozoa	Ophiuroidea			Undetermined	1	4	11	5
Cephalorhyncha		Priapulida			Undetermined	1	2	3	2
Echiura					Undetermined	1	1	2	2
Nemertea					Undetermined	1	3	11	7
Sipuncula					Undetermined	1	1	1	1
Cnidaria		Anthozoa	Octocorallia	Pennatulacea	Undetermined	1	1	1	1
Cnidaria		Scyphozoa			Undetermined	1	24	79	11
Porifera					Porifera	1	1	1	1

Annex 2

Table 1.Designation of Combo Codes used in the density and biomass analyses of the trophic structure of the different families.

Combo code	Food Source	Feding mode	Diet	Food type/size	Other Observations
SR-De	Surface	Deposit feeder	-	-	-
SR-Dt	Surface	Detritus feeder	-	-	-
EP-Su	Epibenthic	Suspension feeder	-	-	-
SS-Pr-mei	Subsurface	Predator	-	Benthic meiofauna	-
SR-Su	Surface	Suspension feeder	-	-	-
EP-Sp-fis	Epibenthic	Suctorial parasite	-	Fish	-
SR-Sp-mac	Surface	Suctorial parasite	-	Benthic macrofauna	-
SR-Pr-mac	Surface	Predator	-	Benthic macrofauna	-
SS-Pr-mac	Subsurface	Predator	-	Benthic macrofauna	-
SR-Pr-mei	Surface	Predator	-	Benthic meiofauna	-
SS-Pr-mei	Subsurface	Predator	-	Benthic meiofauna	-
SR-Gr	Surface	Grazer	-	-	-
SR-Br	Surface	Browsing	-	-	-
SS-De	Subsurface	Deposit feeder	-	-	-
SR-Sc-mac	Surface	Scavenger	-	Benthic macrofauna	-
SR-Om-mac	Surface	-	Omnivorous	Benthic macrofauna	-
SR-Om-mic	Surface	-	Omnivorous	Benthic microfauna	-
SS-Om-mic	Subsurface	-	Omnivorous	Benthic microfauna	-
Mix	-	-	-	-	Mixed Groups
U	-	-	-	-	Unknown

Annex 3

Table 1.All families, or lowest taxa classification, and its trophic and mobility characteristics: Food Source (EP: epibenthic SR: Surface SS: subsurface); Diet (Ca: carnivorous; He: herbivorous; Om: omnivorous); Food type/size (sed: sediment; pom: particular organic matter; mic: benthic microfauna; mei: benthic meiofauna; mac: benthic macrofauna; phy: phytoplankton; zoo: zooplankton; fis: fish); Feeding mode (De: deposit feeder; Dt: detritus feeder; Su: suspension feeder; Pr: predator; Sc: scavenger; Sp: suctorial parasite; Ch: chemosynthetic; Li: lignivorous; Gr: Grazer; Br: Browsing); Mobility (M: motile; D: discretely motile; S: sessile); Habitat (F: free living mode; T: tubiculous; B: borrow dwelling; A: attached; X: parasitic) ; and Combo code (Combination code).

Phylum	Lower taxa classification	Food Source	Diet	Food type/size	Feeding Mode	Mobility	Habitat	Combo code
Annelida	Dorvilleidae	SR	Om	pom/mic/dia/mei	Sc/Gr	M	F	SR-Om-mic
Annelida	Eunicidae	SR	Ca	mac	Pr	M	F	SR-Pr-mac
Annelida	Lumbrineridae	SS	Ca	mei/mac	Pr	M	F	SS-Pr-mei
Annelida	Onuphidae	SR	Om	pom/mac/alg	Dt/Br/Pr/Sc	D	T	SR-Om-mac
Annelida	Pholoidae	SS	Ca	mei	Pr	M	F	SS-Pr-mei
Annelida	Polynoidae	SS	Ca	mac	Pr	M	F	SS-Pr-mac
Annelida	Glyceridae	SS	Ca	mei	Pr	M	F	SS-Pr-mei
Annelida	Hesionidae	SS	Ca	mac	Pr	M	F	SS-Pr-mei
Annelida	Nereididae	SR	Om	pom/mic/dia	Dt/Pr	D	T	SR-Om-mic
Annelida	Pilargidae	SR	Ca	mac/mei	Pr	M	F	SR-Pr-mei
Annelida	Syllidae	SS	Ca	mei	Pr	M	F	SS-Pr-mei
Annelida	Phyllodocidae	SR	Ca	mei	Pr	M	F	SR-Pr-mei
Annelida	Nephtyidae	SS	Ca	mac	Pr	M	F	SS-Pr-mac
Annelida	Sphaerodoridae	SR	Om	pom/mic/dia	Dt	M	F	SR-Dt
Annelida	Oweniidae	SR	Om	sed/pom/mic/dia	De	D	T	SR-De
Annelida	Sabellidae	EP	Om	pom/phy	Su	S	T	EP-Su
Annelida	Magelonidae	SR	Om	sed/pom/mic/dia	De	D	F	SR-De
Annelida	Poecilochaetidae	SS	Om	pom/mic/mei	Pr/Sc/Dt/Gr	D	F	SS-Om-mic
Annelida	Spionidae	SR	Om	sed/pom/mic/dia/phy	De/Su	D	T	SR-De

Phylum	Lower taxa classification	Food Source	Diet	Food type/size	Feeding Mode	Mobility	Habitat	Combo code
Annelida	Chaetopteridae	SR	Om	pom/mic/dia/phy/zoo	Su/Dt	S	T	SR-Su
Annelida	Acrocirridae	SR	Om	sed/pom/mic/dia	De	M	F	SR-De
Annelida	Cirratulidae	SR	Om	sed/pom/mic/dia	De	D	F	SR-De
Annelida	Fauveliopsidae	SR	Om	sed/pom/mic/dia	De	D	F	SR-De
Annelida	Flabelligeridae	SR	Om	sed/pom/mic/dia	De	D	F	SR-De
Annelida	Sternaspidae	SS	Om	sed/pom/mic	De	D	B	SS-De
Annelida	Ampharetidae	SR	Om	sed/pom/mic/dia	De	D	T	SR-De
Annelida	Terebellidae	SR	Om	sed/pom/mic/dia	De	D	T	SR-De
Annelida	Trichobranchidae	SR	Om	sed/pom/mic/dia	De	D	T	SR-De
Annelida	Capitellidae	SS	Om	sed/pom/mic	De	D	F	SS-De
Annelida	Cossuridae	SR	Om	sed/pom/mic/dia	De	M	F	SR-De
Annelida	Maldanidae	SS	Om	sed/pom/mic	De	D	T	SS-De
Annelida	Opheliidae	SS	Om	sed/pom/mic	De	M	F	SS-De
Annelida	Orbiniidae	SS	Om	sed/pom/mic	De	M	F	SS-De
Annelida	Paraonidae	SR	Om	sed/pom/mic/dia	De	D	B	SR-De
Annelida	Polychaeta	SR	Om	mic/dia	Br/Gr	M	F	SR-Om-mic
Annelida	Oligochaeta	SS	Om	pom/mic/dia	Dt	M	F	SS-Om-mic
Mollusca	Cuspidariidae	SR	Ca	mei/zoo	Pr	D	F	SR-Pr-mei
Mollusca	Thyasiridae	SR	Om	pom/phy	Su/Ch	D	F	SR-Ch-Om
Mollusca	Cardiidae	EP	Om	pom/phy	Su	D	B	EP-Su
Mollusca	Kelliellidae	EP	Om	pom/phy/zoo	Su	D	F	EP-Su
Mollusca	Semelidae	EP	Om	pom/phy/zoo	Su	D	F	EP-Su
Mollusca	Nuculanidae	SR	Om	sed/pom/mic	De	D	F	SR-De
Mollusca	Nuculidae	SS	Om	sed/pom/mic	De	M	F	SS-De
Mollusca	Arcidae	EP	Om	pom/phy	Su	D	A	EP-Su
Mollusca	Pectinidae	EP	Om	pom/phy	Su	D	F	EP-Su
Mollusca	Bivalvia	EP	Om	pom/phy	Su	D	F	EP-Su

Phylum	Lower taxa classification	Food Source	Diet	Food type/size	Feeding Mode	Mobility	Habitat	Combo code
Mollusca	Chaetodermatidae	SS	Om	sed/pom/mic	De	M	F	SS-De
Mollusca	Eulimidae	SR	Ca	mac	Sp	M	X	SR-Sp-mac
Mollusca	Cerithiopsidae	SR	Ca	mac	Pr	M	F	SR-Pr-mac
Mollusca	Rissoidae	SR	He	dia	Gr	M	F	SR-He-mic
Mollusca	Caenogastropoda	SR	Ca	mac	Sp	M	X	SR-Sp-mac
Mollusca	Pyramidellidae	SR	Ca	mac	Sp	M	X	SR-Sp-mac
Mollusca	Vetigastropoda	SR	U	U	U	M	F	U
Arthropoda	Pycogonida	SR	Ca	mac	Pr	M	F	SR-Pr-mac
Arthropoda	Cyproideidae	SR	u	u	u	M	F	u
Arthropoda	Phoxocephalidae	SR	Ca	mei	Pr	M	B	SR-Pr-mei
Arthropoda	Oedicerotidae	SS	Ca	mei	Pr	M	F	SS-Pr-mei
Arthropoda	Ampeliscidae	SR	Om	pom/mic/dia/phy	Su	D	T	SR-Su
Arthropoda	Aoridae	SR	Om	pom/mic/dia/phy	Su	D	T	SR-Su
Arthropoda	Lysianassidae	SR	Ca	mac	Sc	M	F	SR-Sc-mac
Arthropoda	Dulichiidae	SR	He	dia	Gr	D	T	SR-He-mic
Arthropoda	Caprellidae	SR	He	dia	Gr	M	F	SR-He-mic
Arthropoda	Corophiidae	SR	Om	pom/mic/dia/phy	Su	D	T	SR-Su
Arthropoda	Talitridae	SR	u	u	u	M	F	u
Arthropoda	Amphilochidae	SR	u	u	u	M	F	u
Arthropoda	Gammaridae	SR	Om	pom/mic/dia/phy	Su	D	T	SR-Su
Arthropoda	Pleustidae	SR	Ca	mac	Pr	M	F	SR-Pr-mac
Arthropoda	Carangoliopsidae	SR	Om	pom	Dt	M	F	SR-Dt
Arthropoda	Eriopisidae	SR	Om	pom	Dt	M	F	SR-Dt
Arthropoda	Photidae	SR	Om	pom/mic/dia/phy	Su	D	T	SR-Su
Arthropoda	Ischyroceridae	EP	Om	pom/phy/mic/zoo	Su	M	T	EP-Su
Arthropoda	Stenothoidae	SR	Ca	mac	Pr	M	F	SR-Pr-mac
Arthropoda	Amphipoda	SR	Om	mic/dia	Br/Gr	M	F	SR-Om-mic

Phylum	Lower taxa classification	Food Source	Diet	Food type/size	Feeding Mode	Mobility	Habitat	Combo code
Arthropoda	Bodotriidae	SR	He	dia/alg	Gr/Dt	M	F	SR-He-mic
Arthropoda	Diastylidae	SR	He	dia/alg	Gr/Dt	M	F	SR-He-mic
Arthropoda	Lampropidae	SR	He	dia/alg	Gr/Dt	M	F	SR-He-mic
Arthropoda	Leuconidae	SR	He	dia/alg	Gr/Dt	M	F	SR-He-mic
Arthropoda	Nannastacidae	SS	Ca	mei	Pr	M	F	SS-Pr-mei
Arthropoda	Pseudocumatidae	EP	Om	pom/phy	Su	M	F	EP-Su
Arthropoda	Cumacea	EP	Om	pom/phy	Su	M	F	EP-Su
Arthropoda	Anthuridae	SR	Ca	mac	Pr	M	F	SR-Pr-mac
Arthropoda	Desmosomatidae	SS	Om	pom/mic	Dt	M	F	SS-Om-mic
Arthropoda	Paramunnidae	SR	Om	pom/mic/dia	Dt/Gr	M	F	SR-Om-mic
Arthropoda	Munnopsidae	SR	Om	pom/mic/dia	Dt/Gr	M	F	SR-Om-mic
Arthropoda	Munnidae	SR	Om	pom	Dt	M	F	SR-Dt
Arthropoda	Leptanthuridae	SR	u	u	u	M	F	u
Arthropoda	Ischnomesidae	SR	Om	pom/mic/dia	Dt	M	F	SR-Dt
Arthropoda	Gnathiidae	EP	Ca	fis	Sp	M	X	EP-Sp-fis
Arthropoda	Janirellidae	SR	Om	pom/mic/dia	Dt	M	F	SR-Dt
Arthropoda	Nannoniscidae	SR	Om	pom/mic/dia	Dt	M	F	SR-Dt
Arthropoda	Isopoda	SR	Om	pom	Dt	M	F	SR-Dt
Arthropoda	Mysidae	EP	u	u	u	M	F	u
Arthropoda	Agathotanaidae	SR	Om	pom	Dt	D	T	SR-Dt
Arthropoda	Anarthruridae	SR	Om	pom	Dt	D	T	SR-Dt
Arthropoda	Apseudidae	SR	Om	pom	Dt	D	T	SR-Dt
Arthropoda	Colletteidae	SR	Om	pom	Dt	D	T	SR-Dt
Arthropoda	Leptocheliidae	SR	Om	pom	Dt	D	T	SR-Dt
Arthropoda	Leptognathiidae	SR	Om	pom	Dt	D	T	SR-Dt
Arthropoda	Nototanaidae	SR	Om	pom	Dt	D	T	SR-Dt
Arthropoda	Pseudotanaidae	SR	Om	pom	Dt	D	T	SR-Dt

Phylum	Lower taxa classification	Food Source	Diet	Food type/size	Feeding Mode	Mobility	Habitat	Combo code
Arthropoda	Tanaellidae	SR	Om	pom	Dt	D	T	SR-Dt
Arthropoda	Typhlotanaidae	SR	Om	pom	Dt	D	T	SR-Dt
Arthropoda	Tanaidacea	SR	Om	pom	Dt	D	T	SR-Dt
Echinodermata	Holothuroidea	SR	Om	mic/dia	Br/Gr	M	F	SR-Om-mic
Echinodermata	Crinoidea	SR	Om	pom/phy/zoo	Su	D	A	SR-Su
Echinodermata	Amphiuridae	SR	Om	pom/mic/dia	Su/De/Dt	D	F	SR-Su
Echinodermata	Ophiuroidea	SR	Om	zoo	Su/De/Dt	D	F	SR-Su
Cephalorhyncha	Priapulida	SS	Ca	mei	Pr	M	B	SS-Pr-mei
Echiura	Echiura	SR	Om	pom/mic/dia/alg	Dt	D	F	SR-Dt
Nemertea	Nemertea	SS	Ca	mac	Pr	M	F	SS-Pr-mac
Sipuncula	Sipuncula	SR	He	pom/alg	Dt/Br	D	F	SR-He-mac
Cnidaria	Pennatilacea	EP	Om	pom/phy	Su	S	F	EP-Su
Cnidaria	Scyphozoa	EP	u	u	u	S	A	u
Porifera	Porifera	EP	Om	pom	Su	S	R	EP-Su